Strategic Management Journal
Strat. Mgmt. J., **33**: 965–985 (2012)
Published online EarlyView in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/smj.1950
Received 16 October 2009; Final revision received 15 December 2011

LICENSING-IN FOSTERS RAPID INVENTION! THE EFFECT OF THE GRANT-BACK CLAUSE AND TECHNOLOGICAL UNFAMILIARITY

MARIA ISABELLA LEONE[1] and TOKE REICHSTEIN[2]*
[1] *LUMSA University, Faculty of Law, Rome, Italy*
[2] *Copenhagen Business School, Department of Innovation and Organizational Economics, Frederiksberg, Denmark*

Drawing on contractual economics and innovation management, licensing-in is hypothesized to accelerate licensees' invention process. Studying a matched dataset of licensees and non-licensees, licensees are shown to be faster at inventing, but the effect is negated if the license includes a grant-back clause, shifting incentives from licensee to licensor. Also, the effect is significantly reduced if the licensee is unfamiliar with the licensed technology. The effect of the grant-back clause is offset if the licensee is unfamiliar with the licensed technology, suggesting that the licensee retains the incentives to invent under these circumstances.

INTRODUCTION

It is crucial for firms to have the ability to introduce innovations at a rapid pace. Accelerating the invention process increases the probability that a firm will achieve first-mover advantages in terms of higher returns from innovation, achievement or continuation of technology leadership in the industry, and greater market share (Ahuja and Lampert, 2001; Kessler and Chakrabarti, 1996; Merges and Nelson, 1990). Rapid invention helps firms to overtake rivals and to capture new and unexplored opportunities in the innovation landscape (Markman *et al*., 2005), which, in turn, is a unique market competence (Eisenhardt and Martin, 2000; Kessler and Chakrabarti, 1996; Markman *et al*., 2005). Prior work has identified the external drivers affecting a recipient firm's likelihood of introducing an invention/innovation (e.g., Fleming and Sorenson, 2004), the share of sales that can be attributed to innovation (e.g., Laursen and Salter, 2006), and the number of inventions/innovations introduced (e.g., Ahuja, 2000; Katila and Ahuja, 2002). However, little research has been done on what drives and affects the speed at which firms introduce new technological advances.

According to Markman *et al*. (2005: 1060) '[t]he need for new sources of technology to accelerate product development [is the main reason why] organizations are increasingly turning to licensing.' Technology in-licensing feeds the inventive capacity of licensees (Rigby and Zook, 2002), and its importance is growing among firms that are using it as a mechanism to absorb externally developed technologies and integrate them into their internal knowledge (see, e.g., Anand and Khanna, 2000; Arora and Fosfuri, 2003; Kim and Vonortas, 2006). This precipitates new and novel combinations of knowledge, thereby fostering innovation (Choi, 2002; Fleming and Sorenson, 2004).

Keywords: technology in-licensing; invention speed; incentives; grant-back; technological unfamiliarity
* Correspondence to: Toke Reichstein, Copenhagen Business School, Department of Innovation and Organizational Economics, Kilevej 14A, 2000 Frederiksberg, Denmark.
E-mail: tr.ino@cbs.dk

Major corporations have recognized that licensing-in accelerates invention speed. Du Pont's chief technology officer stated that sourcing external technologies 'will change [our] business model. We will use this access to the world of available technologies to bring new products to market' (Yet2.com, 2008). IBM also announced 'a new licensing program with the venture capital community to help startup companies accelerate the development of innovative solutions in the marketplace' (IBM, 2005), while Microsoft has affirmed that '[t]he central goal of ... [its] ... intensified patenting work is to create opportunities to work with companies of all sizes to promote innovation and technological progress' (Microsoft, 2008: 7). Licensing is thus seen as a tool for boosting firms' innovation performance (Atuahene-Gima, 1993; Chatterji, 1996; Roberts and Berry, 1984).

This paper develops the idea that licensing-in augments the recipient firm's product development process by reducing invention time. Exploiting already developed solutions to resolve technological problems accelerates the rate at which firms can identify a technology trajectory that leads to the introduction of a new invention. This is captured in the assessment made by the senior patent counsel of the Coca-Cola Company, that '[i]t does not make much sense for us to try to "re-invent the wheel". This strategy [licensing-in] allows us to truly focus on the development of breakthrough technology for the beverage industry' (Yet2.com, 2008). In addition, we argue that the effect of licensing-in on invention speed is circumstantial. We propose that two contingencies spur the licensing-in effect. First, building on the seminal work of Grossman and Hart (1986), we posit that the benefit from licensing-in in terms of shortening the time to invention is contingent on the contractual specification of intellectual property rights. The allocation of intellectual property rights plays a decisive role in *ex post* commitment by shifting incentives. The grant-back clause that obliges the licensee to hand over the rights to future advances or improvements in the licensed technology to the original licensor, is asserted to shift the incentive to invest time and resources in the further development of the technology away from the licensee, which will prolong the time to invention. Second, unfamiliar technologies are more difficult to assimilate and to recombine with in-house technology, thereby extending the time to invention compared to licensing a technology that is within the licensee's existing technological domain. At the same time, the paper argues that lack of familiarity with the licensed technology leaves the licensee reliant on the licensor in terms of the learning required to assimilate it. The licensee, therefore, retains incentives to cooperate with the licensor even if the license agreement contains a grant-back clause. This shift in the incentive for commitment to the licensor moderates the effect of the grant-back, rendering the effect of such a clause trivial at best.

The hypotheses of the paper build on contractual economics and innovation management. To our knowledge, no previous work has investigated the effect of property rights specifications in a technology licensing context looking at the performance of the licensee in terms of time to invention, let alone technology contingencies affecting this relationship. Results suggest that licensing-in shortens the time to invention. The evidence also shows that the acceleration effect fundamentally relies on the incentives specified by property rights and the overlap between the licensed technology and licensees past technological achievements.

The remainder of the paper is organized as follows. We present theoretical arguments and hypotheses for how and under what circumstances licensing-in allows licensees to accelerate their invention process. We follow with an outline of the data used for testing, which describes the approach used to obtain comparable samples of licensees and non-licensees, and the econometric technique employed. We then present the results and conclude the article with a discussion.

BACKGROUND AND HYPOTHESES

Licensing-in and speed of invention

Firms' innovation strategies increasingly involve technology in-licensing, leading to firms becoming active in the markets for technology where licensing accounts for the lion's share of technology exchanges and also plays a lead role in the diffusion of technology (Anand and Khanna, 2000; Arora and Fosfuri, 2003). Research in this area tends to focus on what has been termed the 'licensing dilemma' (Fosfuri, 2006)—the licensor's decision about whether to license-out technologies or commercialize them in-house. However, in order to understand the nature and effect of licensing, the demand side of the market for technology is equally important (see Arora and Gambardella [2010] and Ceccagnoli *et al.* [2010]). We attempt to accommodate this trend, providing further insights into the markets for technology from the licensee's perspective.

There are numerous reasons why firms choose to license-in technologies. The conventional literature on licensing suggests that licensing-in allows firms to keep up with technological advances and remain at the technological frontier, thereby keeping competitors at bay. It provides licensees with already developed and proven technologies (Atuahene-Gima, 1993; Roberts and Berry, 1984) and may be a tactical reaction to a perceived technological shortfall (Lowe and Taylor, 1998). Similarly, the market for technology allows firms to pursue diversification strategies because licensing-in increases the licensee's likelihood of introducing new product designs (Caves, Crookell, and Killing, 1983). This effect increases as the size of the market for technology grows larger, making transaction costs lower, and adding to the incentive to substitute internal technology development with external technology acquisition (Cesaroni, 2004). Thus, licensing-in can be seen as a technology outsourcing strategy and an alternative to in-house research and development (R&D) (Arora, Fosfuri, and Gambardella, 2001; Fosfuri, 2006; Silverman, 1999).

However, licensing-in is not confined only to firms unable to produce novel inventions in-house; it can also be part of an integrated invention strategy aimed at producing dynamic benefits. Technology in-licensing can foster learning (Johnson, 2002) by extending the licensee's technology search space and facilitating the transfer of otherwise undisclosed knowledge. Furthermore, licensing-in may entail 'a higher potential for more distant exploration than exploration through internal search' (Laursen, Leone, and Torrisi, 2010: 877). From this perspective, licensing-in allows licensees to search more widely for technologies that can be exploited for in-house invention activity, increasing the possibilities of new, potentially lucrative combinations of existing bodies of knowledge. Also, licensing-in may generate complementarities between the licensed technology and in-house R&D (Cassiman and Veugelers, 2006) and act as a catalyst for complementary relationships between the parties involved, similar to the arguments put forward for strategic alliances (Lane and Lubatkin, 1998; Mowery, Oxley, and Silverman, 1996).[1]

Reduction of time between inventions and leapfrogging competitors are incentives for strategic technology partnering (Hagedoorn, 1993). Exploiting ready-made solutions developed by an external source accelerates firms' identification of appropriate, functional solutions to their technological challenges, and saves time since the receiving firm is in a position to learn from the mistakes of others (Gomory, 1989). In a technology in-licensing context, therefore, licensees can save time in relation to R&D activities by avoiding repetitions of stages or tasks. Reducing the number of tasks required for the development of a new invention means the licensee has to concentrate on fewer problems and is able to dedicate more resources to the few remaining: licensing-in allows licensees to 'shortcut the process of discovery, reduce technology risk and compress innovation time' (Markman *et al.*, 2005: 1061). Indeed, Markman and colleagues suggest that the pressure for faster product development may explain firms' increasing use of technology in-licensing.

Hence, there are good reasons to believe that licensing-in not only allows firms to catch-up through market exploitation of the licensed technology but also puts the licensee in a favorable position with regard to producing new inventions through possible recombinations of knowledge, increased efficiency in internal R&D activities, and synergy effects. Licensing-in may also precipitate learning mechanisms and should not be seen as a way of avoiding legal battles but as a means for recipient firms to boost the rate of invention, an aspect that is acknowledged in studies of technology transfer from developed to developing countries (see, e.g., Prahalad and Hamel, 1990). On the basis of these considerations, we hypothesize that:

Hypothesis 1: Time to the introduction of a new invention is shorter for licensees than for comparable non-licensees

Grant-back clause and speed of invention

Technology license agreements imply the licensor signs over to the licensee the intellectual property

[1] IBM, which is actively involved in technology licensing, emphasizes this aspect stating that: 'Licensing is undertaken with the aim of forming a complementary relationship between IBM and the licensee' (IBM, 2010).

DOI: 10.1002/smj

rights on technology. In addition, the licensor needs to disclose additional knowledge to allow the licensee to fully exploit the licensed technology. By doing so, the licensor may be furthering the attempts of the licensee to develop the licensed technology to produce an improved version, which, in time, will undermine the licensor's competitive advantage (Davies, 1977). This fear of creating competitors reduces the willingness to license-out a technology and creates what has been described as the *boomerang effect* of licensing (Choi, 2002). To manage this risk, license agreements often include a grant-back clause, which obliges licensees to grant the licensor the rights on future advances or improvements to the licensed technology developed during the term of the agreement (Choi, 2002; Shapiro, 1985). However, as highlighted by Van Dijk (2000: 1433), '[f]uture exchange clauses obviously weaken (licensee's) incentives to improve current technology.' For licensees, the potential competitive advantages of technology improvements are reduced because any advance is instantly transferred to the licensor.[2]

In line with Grossman and Hart (1986) and Aghion and Tirole (1994), we consider license agreements to be incomplete contracts in the sense that they fail to account for all eventualities. First, no contract can specify the whole of the knowledge to be transferred: information elicited via the contract represents only a portion of the underlying knowledge necessary for exploitation of the licensed technology. Second, 'the exact nature of the innovation is ill-defined ex ante and the two parties cannot contract for delivery of a specific innovation' (Aghion and Tirole, 1994: 1186). Under these circumstances, conflicts between the parties may emerge unless the contract is designed to be incentive compatible (Choi, 2002). A grant-back clause secures for the licensor the rights to all subsequent technological advances or improvements introduced by the licensee, based on the licensed technology. From an incomplete contract perspective, a grant-back clause removes some of the residual-right-of-control and shifts the property rights of the potential future asset toward the licensor, providing it with an incentive to assist the licensee in developing the technology further and forging a collaborative arrangement. However, the grant-back clause takes away from the licensee any potential competitive advantage from its developments of the technology. Thus, a grant-back clause provides a shift in the incentives toward the licensor and away from the licensee. The licensee will, accordingly, invest less time and fewer resources in developing the technology further and will rely on the licensor to continue to invest, portraying a free rider behavior. A grant-back clause may create misalignments in the licensee's and licensor's incentives, which will induce failure in the realization of complementarities and synergies and hamper the exchange of knowledge that might help the licensee to short-cut the invention process. Similarly to Hart and Moore (2008), we would suggest that the agent (licensee) will not perform as well if less is to be gained from its investment, resulting in a holdup situation and underinvestment.[3] Accordingly, we hypothesize that:

> *Hypothesis 2: Time to invention is longer for licensees that sign license agreements that contain a grant-back clause compared to licensees that sign license agreements with no grant-back clause*

Unfamiliar technologies and speed of invention

Our first hypothesis argues that licensing-in speeds up the licensee's invention process. However, this effect may be contingent on the licensed technology and the capabilities of the licensee to absorb it. The literature on search processes shows that enriching the knowledge assets through the addition of previously unknown variations increases the number of potential solutions to a given technological problem (March, 1991) and increases the number of possible combinations that might generate new inventions (Fleming and Sorenson, 2001). Obtaining previously inaccessible knowledge may thereby enhance inventiveness in terms of the number of inventions produced by the firm. This is the argument proposed by Katila and Ahuja (2002), who find a positive relationship between search scope and the number of new products introduced by the firm. However, the extensive literature on interfirm technology transfer shows that possession of related knowledge tends to be an enabling factor in the absorption of external knowledge

[2] Leiponen (2008) examined the link between innovativeness and the control of intellectual outputs and found a positive impact among business to business service providers.

[3] See Ziedonis (2004) for a discussion of the role of holdups in the markets for technology.

(see, e.g., Arora and Gambardella, 1990; Cassiman and Veugelers, 2006; Cohen and Levinthal, 1989). Indeed, prior knowledge about a technology may be essential for the ability to recombine it with in-house knowledge. Relatedness between the existing and the external knowledge increases the utility of the latter and enhances firm performance (Teece and Pisano, 1994).

In the context of licensing, knowledge relatedness tends to refer to 'familiarity' with a technology and to be defined by 'the degree to which knowledge of the technology exists within the company, not necessarily embodied in [its] products' (Roberts and Berry, 1984: 3). In-house knowledge about the licensed technology enables the firm to adopt the embodied knowledge quickly, and to exploit it successfully. Licensing-in as an intermediate entry strategy involving a medium level of corporate commitment should be reserved to new businesses with similar technological characteristics (Roberts and Berry, 1984). Similarly, Choi (2002: 809) suggests 'that the transfer of the core technology endows the licensee with the ability to win in the future competition with probability $\theta \ldots$ [interpreted] as a parameter for the licensee's ability to absorb the technology.' Licensing-in an unfamiliar technology may present difficulties related to the integration and assimilation of the acquired knowledge. It will require the licensee to devote more time to understanding the new knowledge before the knowledge can be assimilated and eventually developed into new inventive outcomes. Also, expansion of the knowledge base to encompass an unfamiliar technology will increase rather than reduce the number of problems that will need to be resolved in invention activity, and may result in despecialization on the part of the licensee. While acquisition of an unfamiliar technology eventually may produce a larger number of inventions, the above arguments lead to the hypothesis that:

Hypothesis 3: The time to invention for licensees that license unfamiliar technologies will be longer than the time to invention for licensees that license familiar technologies

Grant-back clause, unfamiliar technology, and speed of invention

Incomplete contract theory asserts that the agent's (licensee's) performance relies on the allocation of entitlements (Hart and Moore, 2008). Technology in-licensing may potentially lead to improvements in the licensed technology or development of a completely new technology. The intellectual property rights of these assets are allocated between the licensee and licensor. The licensee is, however, relatively less incentivized to invest time and resources in the technology when a grant-back clause is included in the contract since it does not receive full benefits (Hypothesis 2). Irrespectively of a grant-back clause, the licensee, however, also benefits from the establishment of a channel of information and knowledge with the licensor, thereby enhancing receptive capacity. This benefit is stronger when the licensed technology is unfamiliar since the licensee relies more heavily on the licensor's help for understanding, absorbing, and integrating it. The licensee receives more benefits from the contractual relationship than those derived from an uncertain invention process. The licensee retains an incentive to engage with and commit to the licensor, and to invest time and resources in activities related to the licensed technology when the technology is unfamiliar even when a grant-back clause is negotiated. At the same time, the licensee knows that the licensor is 'willing to invest some time with the licensee, since [it can] foresee some future benefits from grant-backs' (Smith and Parr, 2005: 451). This interpretation resolves the potential holdup that a grant-back clause might produce since the licensee generally feels it has received its entitlement. From the licensor's perspective, contracting with a licensee who is unfamiliar with the licensed technology provides the latter with some flexibility in negotiating the contract, and allows some degree of circumvention of the grant-back clause effect. We hypothesize that:

Hypothesis 4: The grant-back clause extends the licensee's time to invention less if the licensee is unfamiliar with the licensed technology compared with if the licensee is familiar with the licensed technology.

DATA AND METHOD

This section presents the empirical setting and data, the matching procedure, the variables and measures used in the analysis, and the econometric technique employed.

DOI: 10.1002/smj

Empirical setting and data

Empirically, we only consider patent license agreements because they function as channels for knowledge dissemination (Shapiro, 1985), thereby ensuring a minimum transfer and dissemination of knowledge from licensor to licensee. Apart from facilitating technology licensing (Gallini and Winter, 1985), patents are characterized by high levels of knowledge codification, which makes technology transfer easier and faster (David and Olsen, 1992), and makes the knowledge potentially more accessible to the recipient firms (Arora and Ceccagnoli, 2006; Gans, Hsu, and Stern, 2008; Hall and Ziedonis, 2001). Furthermore, the licensee can expect a certain level of disclosure of knowledge beyond that formally described in the patent document, which will increase the success of the knowledge transfer and assimilation and exploitation of the technology (Arora, 1996).

The empirical analysis is based on a sample of patent license agreements taken from an extensive database, the Financial Valuation Group Intellectual Property (FVGIP), which is compiled and maintained by the Financial Valuation Group. Several alternative datasets are exploited in studies in the intellectual property rights literature. We consider the FVGIP dataset appropriate to test the hypotheses in this paper for several reasons. First, it contains detailed information on both transactions and parties, allowing cross-checking and verification, thereby improving reliability, not to mention enabling us to couple the information with data from several other sources. This provides a high number of combinations, which extends the opportunities for further research and allows us to identify key characteristics of the firms' invention activities, capabilities, strategies, and behavior. Second, the data are compiled from publicly available records of intellectual property transactions that can be checked and scrutinized. Third, this dataset has been employed less frequently in the literature, which means our results can be seen as strengthening previous findings on the role of licensing in shaping technological achievements and property rights relations. The dataset was also used by Laursen *et al*. (2010), who studied the amplifier effect of licensing-in as a mechanism for the firm to search the technology space.

We started with a set of 600 patent licenses. In order to obtain the detailed information required for our analysis, we worked on retrieving original documents or excerpts contained in other company filings (e.g., S1, 8K, 10K), referred to in the FVGIP data. In many cases, confidentiality clauses in the license agreements meant we were unable to trace the original documents: these records were dropped from our sample. Wherever possible, we extracted exact information on licensed patents (identification number), licensing parties (names), and the industries involved (Standard Industry Classification [SIC] code). Even though contracts were downloadable, it proved impossible (for confidentiality reasons) to obtain the identification numbers of a subset of them, making it impossible for us to collect the data required for our analysis. We proceeded as follows to minimize any bias contributable to missing values. We searched for the patents in the U.S. Patent and Trademark Office (USPTO) dataset on the basis either of the information encapsulated in the text of the license agreement (application number or title of the licensed patent) or the name of the assignee in the year of the license, coupled with the keywords provided in the FVGIP dataset. This produced a sample of 227 licenses and 884 USPTO patents.

We combined the 227 licenses with data from the USPTO drawn from the National Bureau of Economic Research (NBER) patent database to obtain the patent statistics used for the construction of our variables. We used patents to measure invention following the general convention (Davies, 1977). Since the 227 licenses included agreements signed up to 2002, we manually updated the NBER database to May 2008 for all the firms in our sample, adding application dates to all additional patents granted to these firms subsequent to the signing of the license agreement of reference. The additional records were identified using the USPTO search engine (http://patft.uspto.gov/).

From the 227 observations, we removed 94 records, leaving us with a final subset of 133 for our analysis. Three factors led to certain files being excluded. First, given the features of our analysis, we can only consider licensee firms that filed USPTO patents prior to the license agreement of reference (see also Laursen *et al*., 2010). This meant disregarding 76 licensees who were not in the NBER dataset. Second, we dropped seven observations referring to large companies with immeasurable patent histories (Microsoft, Abbott Laboratories, Siemens, IBM, Proctor and Gamble, Ericsson, Hitachi), for which it was impossible

DOI: 10.1002/smj

to find a suitable non-licensing match. Third, we omitted 11 observations because of missing information for key patent-based variables (generality index, claims) employed in the analysis. Investigating potential attrition, we considered time of signing of the license agreement, number of patents included, and contractual specifications for the agreements included compared to those not included. The results gave no cause for concern.

Matching procedure

We created a control sample of comparable non-licensees in order to investigate whether our sample of licensees would have introduced new inventions at a slower pace had they not licensed-in the patents. We applied propensity score matching and exact matching procedures to obtain this comparable matched sample. The propensity score matching technique is based on the likelihood that an observation would be a licensee conditional on observables (Rosenbaum and Rubin, 1983, 1984). We used logistic regression specification to estimate the conditional probabilities of being a licensee and allowed non-licensees to be matched with multiple licensees, running the procedure with replacements.

The propensity score matching method relies heavily on the use of appropriate inputs to obtain propensity scores (Heckman, Ichimura, and Todd, 1997). Coherence in the definitions and measures across the treatment and control samples reduces the likelihood of bias in the main analysis. Furthermore, matching procedures tend to be invalidated if there are too many regressors (Dehejia and Wahba, 2002). We employed a limited number of variables to measure invention activities and invention rates of firms prior to a license agreement. We, hence, aimed to obtain a control sample of non-licensees with invention strategies comparable to the licensees. Specifically, we employed five technology related variables—patent stock, average number of cites, average time between patents, technological diversity, and technology collaboration.

In addition to the propensity score matching procedure, we applied two exact matching criteria. First, we considered a matched firm to be suitable only if its patents are primarily in the same technology class as the licensee. This ensured that the compared firms faced similar technological barriers and opportunities. Second, we ensured that the values of the variables used in the propensity score matching procedure were observed simultaneously. This enabled a 'twin-like' snapshot of the non-licensee at the point in time when the licensee signed the contract (t=0), making the control and the treated samples chronologically comparable.

Using USPTO data as an input for the matching procedure means that we consider only firms that patented with the USPTO prior to the license agreement of reference. USPTO data are extremely useful and represent perhaps the most comprehensive single source of potential matching firms. The USPTO database also contains key information that allows us to generate exemplary instruments to indicate firms' invention activities, invention behavior, and invention intensity.

The matching procedure identified a substantial number of potential matches for each licensee. We checked each of them manually, starting with the most likely to have signed a license agreement at the same time as our registered licensee, conditional on the matching variables. Using the Thomson Research Database, we searched the potential matched firms' filings for indications that they had been involved in licensing-in activities. Firms report licensing activities in their S1, 10K, and/or 8K filings. Subsequently, we browsed Google on 'license agreement' and company name. This type of Google search should reveal a firm's involvement in licensing, since it searches all publicly available files recording the daily activities of firms (e.g., press releases). It also searches publicly available Securities and Exchange Commission filings of licensees and licensors, which increases the chances of finding information on license agreements involving the target firms. Using these two search methods, we categorized the matched firm as a non-licensee only if we found no indications of licensing-in activity in the two years before and after the point of reference.

We checked that the matched non-licensee had survived for at least five years after the matched license agreement. Most firms were still in existence. This may cause bias in the estimates since we do not guarantee this for licensees. However, since this potential bias would go against our hypotheses, we can consider findings that support them to be conservative estimates. Since we use past technology related variables as inputs, the procedure provides matching firms that are comparable to the licensees in terms of technological achievements.

DOI: 10.1002/smj

Variables

Dependent variable

Time to invention (transition) measured in months is extracted by considering license date as the onset of risk, and date of application for first patent filed after the signing of the license agreement as the transition time. The onset of risk for the matched non-licensee is the time when the matched licensee signed the license agreement (t=0). We allow this assumption since the matching procedure also ensures that the matched pairs are comparable at that point in time. By using dates of patent applications rather than patent grants, we ensure that our results will not be biased by differences in patent office procedures, across patents and patent categories. Patent grant is our measure of invention since the USPTO database only includes patent applications that effectively were approved. Patents are an incomplete measure in the sense that firms are less likely to patent process inventions and lower value inventions (Fleming and Sorenson, 2001; Levin *et al*., 1987). However, we have no reason to suspect that this pattern will differ between licensees and non-licensees, since the matched sample is based on prior patenting behavior and invention activity.

Explanatory variables

Licensee: The matching procedure generates a dummy allowing us to distinguish between licensees and non-licensees, which we employ to test Hypothesis 1. Using prior technological and invention achievements in the matching procedure increases the likelihood that significance of it can be attributable to the effect of signing the license agreement rather than differences in the patenting behavior of licensees and non-licensees.

Grant-back: Going through the license agreements one by one, allowed us to create a dummy variable indicating inclusion of a grant-back clause. We attribute a value of 0 to the grant-back dummy for non-licensees, since, by definition, there is no grant-back clause because there is no licensing contract.

Unfamiliarity: We regard a technology to be unfamiliar to the licensee if the licensee's prior patent history (previous six years) did not include any patent grants in the International Patent Classification (IPC) code listed in the patent(s) included in the license agreement. The variable is a dummy for unfamiliarity. Since unfamiliarity is related to the patents included in the license agreements, we calculate this variable only for licensees. Therefore, to test Hypotheses 3 and 4, we consider only licensees.

Matching variables

The variables used in the matching procedure are included as explanatory variables in the *time-to-invention* regressions. Any significance with respect to these variables can be attributed primarily to variations within the treatment categories.

Similar to Ahuja and Lampert (2001), we use measures of prior invention performance to pick up some of the unobserved heterogeneity among firms in terms of patenting strategy and ability. We compute *patent stock* as the logarithm of the number of patents granted before the signing (potential signing in the case of a non-licensee) of a license agreement. *Average number of cites* received by the firm to already granted patents is used as a measure of the firm's ability to generate high value inventions. Past success may be a strong incentive for the firm to invest more in invention activities. General invention speed is measured as the average time between granted patent applications, prior to signing the license agreement (*average time between patents*). A firm's *technological diversity* is measured as the number of different primary IPC codes in which the firm has patented. A more diverse patenting history may be advantageous in the sense that a diversified skills base opens up a larger area of the invention landscape for a firm's search. We also account for whether the firm is a *technology collaborator,* measured by a firm's co-patenting activity prior to the license agreement. We acquired this information from a recent addition to the NBER patent dataset (http://www.nber.org/∼jbessen/). Finally, since invention speed and invention strategy can differ substantially across technology classes, we include five dummies for *computers and communications, drugs and medical, electrical and electronics, mechanical*, and *other* technologies. The benchmark category is *chemical technologies*. The technology classifications are taken from Hall, Jaffe, and Trajtenberg (2001).

Control variables

Differences in search strategies produce diversified innovation advantages. Following Katila and

DOI: 10.1002/smj

Ahuja (2002), we control for *search depth* and *search scope* being the degree to which firms reuse knowledge and the degree to which firms use new and previously unexplored knowledge in invention activities, respectively.

We control for the firm's ability to handle *technological complexity,* following Lanjouw and Schankerman (1999), using average number of claims on prior-to-license-agreement patent grants. Technologies characterized by complexity often involve more convoluted learning processes (Lin, 2003). Technological complexity hampers both knowledge transfer and the licensee's ability to assimilate the intellectual property embodied in the license agreement. Experience with complexity and the articulation of complex bodies of knowledge helps the firm to organize and integrate the licensed technology and the knowledge it embodies, into its own knowledge base.

We control for *technological specialization* by including the Herfindahl index based on the share of patents in each IPC code. Firms that are technologically specialized may exhibit differences in time to invention because of a simplistic attitude toward invention that steers them to concentrate on what they do best (Miller and Chen, 1996).

A firm's technological achievements are heavily influenced by past experience in developing new technologies (Henderson and Cockburn, 1994; Katila and Ahuja, 2002). Firms develop critical knowledge in their innovation activities, which benefits them in future ventures in new areas of the innovation landscape (Nerkar and Roberts, 2004). We control for *technological experience* with a variable measuring the time between the first patent granted to the firm and the signing of the license agreement. We control for the firm's ability to introduce globally applicable inventions by including a *technological generality* index, calculated as the share of cites received by a patent from different technological classes (Hall *et al*., 2001). We use the maximum generality score for the firm's previous patents.

We control for *technology furnishing* expressed by a dummy for whether the license agreement includes a technology furnishing clause (non-licensees scored 0 for having no technology furnishing agreement) obliging the licensor to assist the licensee in understanding and integrating the licensed technology.

We include two dummy variables for firm size: *medium sized firms* (100–500 employees) and *large firms* (more than 500 employees), with small firms (less than 100 employees) as the benchmark. We use a discontinuous firm size measure because the employment statistics obtained were often approximate values.

We use a dummy to control for a *North American firm*. Firms outside North America may experience a distance barrier to patenting with the USPTO. These firms (European or Japanese in the dataset) may choose to patent first with their local patent office and then apply to the USPTO, which will affect time to patent.

Finally, there are substantial differences across industries in terms of patenting propensity (Levin *et al*., 1987). In some industries, patents represent major value. In industries such as pharmaceuticals and chemicals, imitation costs are substantially lower than invention costs. Therefore, the ability to protect an invention is more important in these and similar industries, creating cross-industry differences in patenting propensities. We control for this by including industry dummies representing: a) *primary, construction, and electricity;* b) *chemicals, petroleum refining, rubber, and plastics;* c) *measuring, analyzing, and controlling instruments;* d) *other manufacturing;* e) *services*. We ignore these dummies in regressions considering only licensees since the number of observations is too small to distinguish between industry and technology dummies.

Econometric technique

The hypotheses refer to time to invent. Accordingly, we transform the data into event history data and consider several potential duration model candidates. We ruled out the Cox Proportional Hazard Model specification because the time periods investigated are not completely overlapping. Our choice from among remaining models was based on the mechanisms that may drive the hazard to invention. Theoretically, we identified two competing effects. First, an initial dominating learning effect causing the hazard to invention to be augmented as time elapses. Firms become exposed to new inputs and ideas that, when accumulated, increase their invention propensity. Second, a negative effect on the hazard to invention emerges as the most inventive firms exit the sample, leaving a group of less inventive and less learning-oriented firms. This selection effect becomes increasingly dominant over time, as more invention active firms make the transition to invention, lowering the average inventiveness among the remaining sample. The effect eventually overtakes the learning effect causing the hazard function to decline. Thus, we expect a nonmonotonic hazard function, which displays an initial convex increasing shape, then a concave increasing shape, eventually becoming a decreasing function as the selection effect overtakes the learning function. We expect the function to exhibit a peak after a finite period. Based on this expectation, we employ a log-logistic model specification that allows for this particular transition pattern (Bennett, 1983).[4] Thus, the model specification is an accelerated failure time setup ($\ln(t_i) = -x_i\beta_x + \ln(\tau_i)$). This model specification makes no assumptions about the proportionality of the hazards.

Substantial frailty (unobserved heterogeneity) effects may emerge because of omitted variables, which intrinsically are unobserved and in which our sample may be biased. Such endogeneity issues may produce heterogeneity in the firm's hazard functions and potential bias in estimates. We model this unobserved heterogeneity using a random effects approach (frailty model) and apply a likelihood ratio test to compare the restricted and unrestricted model specifications. The unobserved heterogeneity is, however, firm specific. The sample includes license agreements that involve the same licensees, and we have a non-licensee that is matched with two separate licensees. Thus, we apply a shared frailty model specification assuming unobserved heterogeneity common between observations representing the same firm (see Gutierrez [2002] for a discussion of shared frailty modeling).

RESULTS

Validating the matching procedure

Before starting the analysis, we confirmed that our matching procedure provided comparable licensees and non-licensees. We ran t-tests across all variables and a probit regression to explain the likelihood of having signed a license agreement given the conditional variables used in the matching procedure. Table 1 reports the results. The t-tests exhibit some discrepancies between the two samples considering variables not used in the matching procedure, yet not across all of them and not necessarily in favor of the licensees. Only the dummy variables for technology collaboration exhibit weak significance at the 10 percent level considering the probit matching model. The overall validity and explanatory power of the model is shown to be very poor as expressed by the insignificant Wald chi-square. Also, the model explains only 1.1 percent of the total variation related to being a licensee or not. Given that the matching variables are considered appropriate, we can conclude that the matching procedure is successful in terms of providing comparable non-licensees for the analysis of time to invention. These results, however, also indicate the need to include these as controls in the analysis.

Descriptive statistics

Among the 266 firms studied, the longest time to introduce a new invention is 300 months. The firms in our sample are subject to May 2008 censoring, which indicates that the license agreement in this case was May 1983 and coincides with the date of the earliest license agreement in the sample. In this case, the firm is a non-licensee matched with a licensee that patented after 191 months (April 1999). We have a total of 90 transitions to invention (61 licensees and 29 non-licensees). The total number of at risk months in the sample is 32,351 (14,507 months for licensees and 17,844 for non-licensees).[5] On average, licensees patent 109 months after signing a license, while matched non-licensees take an average of 134 months to patent. Transition time to patenting in the licensed technology is similar. Only 34 of the 133 licensees make the transition, and are at risk for a total of 17,137 months. Thus, the average number of at risk months is 129 for these firms.

An univariate Kaplan-Meier survival analysis provided preliminary support for Hypothesis 1—licensees introduce new patents more quickly than their non-licensee counterparts. The analysis also

[4] A log-normal model produces a similar transition pattern. To check robustness, we compared the results of the two model specifications. Overall, we found no differences in the estimates or conclusions. The results of the log-normal specification are available upon request.

[5] We considered whether our results could be attributed to the arbitrary choice of monthly spell lengths by running the analysis registering the transitions yearly instead. The results were virtually the same indicating that our findings are not a by-product of the arbitrary choice of spell length.

DOI: 10.1002/smj

Table 1. Comparison of licensee and non-licensee across variables using t-tests and probit regression on matching model

	t-test of mean values		Matching model	
	Non-licensee	Licensee	estimate	std. err.
Patent stock	1.12	1.29	0.019	0.099
Average number of cites	9.53	9.85	0.001	0.006
Average time between patents	21.96	21.21	−0.000	0.002
Technological diversity	1.91	4.18	0.006	0.007
Technological collaborator	0.04	0.09*	0.485*	0.355
Computers and communications	0.98	0.98	0.035	0.306
Drugs and medical	0.36	0.36	−0.004	0.202
Electrical and electronics	0.09	0.09	−0.020	0.303
Mechanical	0.05	0.05	0.014	0.405
Others	0.15	0.15	0.007	0.253
Grant-back	0.00	0.16***		
Search scope	0.16	0.69**		
Search depth	0.31	0.33		
Technological complexity	1.07	0.54*		
Technological specialization	0.65	0.42***		
Technological experience	46.36	71.76***		
Technological generality	0.59	0.50*		
Technological furnishing	0.00	0.20***		
Medium sized firm	0.25	0.31		
Large firm	0.17	0.14		
North American firm	0.77	0.94***		
Constant			−0.068	0.189
Number of observations			266	
Log-likelihood			−182.323	
χ^2			7.174	
Pseudo R^2			0.011	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ at a one sided test, Standard errors in parentheses.

indicates the hazard function to be nonmonotonic exhibiting the expected pattern supporting our econometric choice to use a log-logistic specification. Finally, the analysis revealed the hazards of licensees and non-licensees not to be parallel shifted, justifying our choice to use an accelerated failure time specification.

Table 2 presents the descriptive statistics for the explanatory, matching, and control variables, and the associated Pearson correlation coefficients. Some 36 percent of observations are firms patenting primarily in drugs and medical technologies, and 10 percent and nine percent, respectively, patent primarily in computers and communications technologies, and electrical and electronics technologies. The benchmark category, and therefore the class excluded from our model and the tables, is chemical technologies, which accounts for about 25 percent of observations. The correlation coefficients do not suggest major multicolinearity problems.

Regression results

Table 3 presents the results of the accelerated failure time regressions. Models I–III investigate the time to invention of licensees and non-licensees, considering the control variables only (Model I), including the licensee dummy (Model II), and including the grant-back clause variable (Model III). Models IV–VII indicate the role of familiarity, grant-back clause, and the combined effect for licensees only. Models IV and V consider time to invention in general, Models VI and VII present the results for time to invention in the licensed IPC code(s).

All the models are specified as shared frailty regressions and exhibit significant chi-square values, which suggests validity. The likelihood ratio comparison statistics are all significant and suggest that the random effects estimation approach is more appropriate than a standard accelerated failure time model specification. The negative ln

Table 2. Descriptive Statistics and Correlations Coefficients (N = 266)

	Variable	Mean	S.D.	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
[1]	Licensee	0.50	0.50														
[2]	Unfamiliarity	0.55	0.50														
[3]	Grant-back	0.08	0.27	0.29	0.02												
[4]	Patent stock	1.20	1.12	0.07	−0.24	0.29											
[5]	Average number of cites	9.69	14.96	0.01	−0.07	0.13	0.11										
[6]	Average time between patents	21.58	34.04	−0.01	0.14	−0.09	−0.10	0.08									
[7]	Technological diversity	3.05	15.00	0.08	−0.12	0.30	0.65	−0.02	−0.07								
[8]	Technological collaborator	0.06	0.25	0.11	−0.08	0.15	0.33	−0.01	0.03	0.33							
[9]	Computers and communication	0.10	0.30	0.00	−0.06	0.14	−0.11	0.28	−0.03	−0.05	−0.09						
[10]	Drugs and medical	0.36	0.48	0.00	−0.11	−0.16	−0.09	0.06	−0.13	−0.09	0.06	−0.25					
[11]	Electrical and electronics	0.09	0.29	0.00	0.13	0.10	0.16	−0.02	0.01	0.10	−0.03	−0.10	−0.24				
[12]	Mechanical	0.05	0.21	0.00	−0.09	0.00	0.01	−0.05	0.27	−0.02	0.02	−0.07	−0.16	−0.07			
[13]	Others	0.15	0.36	0.00	0.09	0.03	0.10	−0.12	0.04	0.01	−0.02	−0.14	−0.32	−0.13	−0.09		
[14]	Search depth	0.42	1.46	0.18	−0.27	−0.01	0.20	0.04	−0.06	0.13	0.11	−0.07	0.18	−0.04	−0.02	−0.04	
[15]	Search scope	0.32	0.42	0.02	−0.33	0.01	0.15	−0.03	−0.21	0.06	0.05	−0.07	0.10	−0.05	0.08	0.10	0.24
[16]	Technological complexity	0.80	2.43	−0.11	−0.20	0.05	−0.09	0.34	−0.12	−0.04	−0.07	0.15	0.02	−0.07	−0.03	−0.01	−0.04
[17]	Technological specialization	0.54	0.39	−0.29	−0.24	−0.14	−0.34	0.11	−0.03	−0.14	−0.09	0.10	0.15	−0.10	−0.08	−0.04	0.08
[18]	Technological experience	59.06	75.71	0.17	0.02	0.23	0.70	0.06	0.42	0.39	0.25	−0.15	−0.18	0.22	0.08	0.15	0.04
[19]	Technological generality	0.55	0.39	−0.11	−0.17	0.18	0.57	0.31	0.02	0.18	0.12	0.09	−0.08	0.05	−0.01	−0.03	0.13
[20]	Technological furninshing	0.10	0.30	0.34	0.01	0.46	0.21	0.26	−0.02	0.21	0.17	0.18	−0.10	−0.06	0.05	−0.04	−0.01
[21]	Medium sized firm	0.28	0.45	0.07	−0.11	0.10	0.10	0.08	0.01	−0.02	0.04	0.05	−0.01	−0.17	0.07	0.09	0.10
[22]	Large firm	0.16	0.37	−0.04	−0.02	0.10	0.26	−0.04	0.09	0.23	0.10	−0.14	−0.11	0.12	0.20	0.08	0.00
[23]	North American firm	0.86	0.35	0.24	−0.10	0.00	0.01	0.12	0.02	−0.01	−0.24	0.10	−0.03	0.09	0.04	−0.16	0.07

	Variable	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]
[16]	Technological complexity	0.17							
[17]	Technological specialization	0.03	0.21						
[18]	Technological experience	0.02	−0.19	−0.34					
[19]	Technological generality	0.02	0.07	−0.20	0.39				
[20]	Technological furninshing	0.10	0.03	−0.06	0.20	0.13			
[21]	Medium sized firm	0.12	0.04	−0.06	0.07	0.06	0.07		
[22]	Large firm	0.15	0.00	−0.09	0.27	0.05	0.13	−0.27	
[23]	North American firm	−0.04	0.05	−0.10	0.00	0.03	0.07	−0.01	−0.09

Correlation coefficients above 0.11 are significant at a 5% level.
Statistics involving unfamiliarity is only based on 133 observations.

Table 3. Determinants of time to invention: results of accelerated failure time models

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
Grant-back × Unfamiliarity					−0.218		−2.726***
					[0.523]		[0.813]
Unfamiliarity				0.042	0.102	0.854***	0.827***
				[0.256]	[0.296]	[0.228]	[0.190]
Grant-back			0.617**	1.260***	1.412***	0.795**	2.788***
			[0.368]	[0.280]	[0.449]	[0.405]	[0.690]
Licensee		−0.619***	−0.496**				
		[0.263]	[0.268]				
Matching variables							
Patent stock	−0.290*	−0.455**	−0.511***	−0.385**	−0.389**	0.199*	0.184*
	[0.209]	[0.226]	[0.216]	[0.181]	[0.180]	[0.126]	[0.137]
Average number of cites	0.011	0.003	0.008	0.027***	0.027***	0.004	−0.001
	[0.010]	[0.011]	[0.011]	[0.008]	[0.008]	[0.008]	[0.009]
Average time between patents	0.000	−0.002	−0.000	−0.003	−0.003	0.027***	0.028***
	[0.003]	[0.003]	[0.004]	[0.003]	[0.003]	[0.005]	[0.004]
Technological diversity	0.002	0.007	0.012	0.019***	0.019***	−0.030***	−0.017***
	[0.011]	[0.012]	[0.012]	[0.007]	[0.007]	[0.010]	[0.006]
Technological collaborator	−0.676**	−0.602*	−0.364	0.300	0.344	−0.826***	−0.782***
	[0.405]	[0.395]	[0.427]	[0.366]	[0.374]	[0.300]	[0.325]
Computers and communications	−0.098	0.181	0.046	−0.184	−0.210	−1.261***	−1.526***
	[0.507]	[0.459]	[0.460]	[0.363]	[0.358]	[0.319]	[0.302]
Drugs and medical	−0.416*	−0.350*	−0.308	0.015	0.034	−1.683***	−1.427***
	[0.261]	[0.265]	[0.248]	[0.271]	[0.273]	[0.299]	[0.267]
Electrical and electronics	−0.290	−0.543*	−0.806**	−1.547***	−1.495***	−2.124***	−2.139***
	[0.376]	[0.358]	[0.385]	[0.366]	[0.380]	[0.323]	[0.288]
Mechanical	−0.400	−0.343	−0.749	1.087***	1.190***	−2.629**	−2.242**
	[0.428]	[0.451]	[0.586]	[0.411]	[0.471]	[1.231]	[1.239]
Others	−0.510**	−0.464*	−0.513**	0.425*	0.447*	−1.252***	−1.065***
	[0.297]	[0.301]	[0.287]	[0.299]	[0.299]	[0.291]	[0.308]
Controls variables							
Search Depth	−0.343***	−0.304***	−0.348***	−0.396***	−0.407***	0.088***	0.071***
	[0.082]	[0.084]	[0.089]	[0.073]	[0.077]	[0.024]	[0.024]
Search Scope	−0.165	−0.212	−0.085	−0.073	−0.055	−0.908***	−0.791***
	[0.232]	[0.225]	[0.232]	[0.196]	[0.200]	[0.243]	[0.231]

Table 3. (*Continued*)

	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
Technological complexity	−0.118**	−0.067	−0.112*	−0.188***	−0.196***	−0.024	−0.087*
	[0.063]	[0.067]	[0.072]	[0.058]	[0.059]	[0.058]	[0.065]
Technological specialization	0.063	−0.100	0.113	−0.559*	−0.488	−0.302	−0.568*
	[0.309]	[0.309]	[0.330]	[0.409]	[0.424]	[0.402]	[0.410]
Technological experience	0.002	0.005**	0.005**	0.003**	0.003**	−0.001	−0.002
	[0.002]	[0.003]	[0.003]	[0.002]	[0.002]	[0.002]	[0.002]
Technological generality	0.587**	0.433*	0.499**	0.306	0.372	−0.260	0.068
	[0.309]	[0.296]	[0.280]	[0.340]	[0.369]	[0.269]	[0.301]
Technological furnishing	−0.372*	−0.049	−0.338	−0.656**	−0.721**	−0.270	0.038
	[0.267]	[0.285]	[0.327]	[0.300]	[0.332]	[0.276]	[0.291]
Medium sized firm	−0.407**	−0.365**	−0.459**	−1.292***	−1.299***	−0.842***	−0.955***
	[0.238]	[0.218]	[0.221]	[0.269]	[0.266]	[0.244]	[0.245]
Large firm	−0.220	−0.448*	−0.396*	−0.837***	−0.850***	1.039***	0.612*
	[0.259]	[0.277]	[0.269]	[0.296]	[0.296]	[0.380]	[0.415]
North American firm	0.091	0.305	0.317	1.716***	1.734***	−0.592	−0.528
	[0.260]	[0.266]	[0.260]	[0.496]	[0.490]	[1.088]	[1.070]
Constant	4.912***	5.232***	4.991***	3.262***	3.143***	6.114***	6.016***
	[0.391]	[0.422]	[0.428]	[0.634]	[0.693]	[1.075]	[1.040]
log(Γ) constant	−1.085***	−1.127***	−1.158***	−1.454***	−1.465***	−2.049***	−2.063***
	[0.147]	[0.147]	[0.146]	[0.168]	[0.170]	[0.249]	[0.245]
log (Θ) constant	1.792***	1.772***	1.768***	1.514***	1.513***	1.914***	1.896***
	[0.242]	[0.231]	[0.219]	[0.229]	[0.229]	[0.256]	[0.251]
Industry dummies	Yes	Yes	Yes	No	No	No	No
Number of observations	266	266	266	133	133	133	133
Groups	250	250	250	118	118	118	118
Transitions	90	90	90	61	61	34	34
Total months at risk	32351	32351	32351	14507	14507	17137	17137
Log-likelihood	−226.431	−223.745	−222.394	−124.676	−124.592	−77.391	−77.012
χ^2	46.226***	51.599***	54.302***	52.444***	52.612***	68.200***	68.957***
Likelihood ratio comparison	32.871***	34.155***	35.426***	30.780***	29.577***	25.270***	20.708***

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ at a one sided test, Standard errors in parentheses.

DOI: 10.1002/smj

(Gamma) coefficients suggest a log-logistic hazard function that first increases and then decreases, consistent with the argument that there are two opposing effects—namely an initial dominant learning effect, which is gradually overtaken by a selection effect.

Models II and III indicate that licensing-in does shorten the time to invent, which supports Hypothesis 1. The licensee variable exhibits negative estimates significant at the one percent and five percent level, respectively, suggesting technology in-licensing acts as a propeller that allows the licensee to shortcut the invention process. The grant-back clause variable introduced in Model III is found significantly positive at a five percent level. This supports Hypothesis 2 that *time to invention is longer for licensees that sign license agreements that contain a grant-back clause compared with licensees that sign license agreements with no grant-back clause.*

However, comparing the coefficient of the grant-back clause and the licensee variable using a Wald test indicates that we cannot consider their absolute values to be different. Licensees whose contracts include a grant-back clause are on a par with non-licensees. These findings are consistent with the notion that a grant-back clause shifts the incentive to invest time and resources in further development of the technology away from the licensee. Figure 1 depicts the hazard functions for licensees with a grant-back clause, licensees without grant-back clauses, and non-licensees based on Model III estimates. The higher peak of the hazard function for licensees without the grant-back clause indicates an increased likelihood of transition to patenting in the period after signing the license agreement, resulting in a shorter time to patent. It also clearly illustrates the similarity in hazard functions between non-licensees and licensees with grant-back clauses in their contracts.

Hypothesis 2 also finds support in Models IV–VIII looking only among licensees. Hypothesis 3, *time to invention for licensees that license unfamiliar technologies will be longer than the time to invention for licensees that license familiar technologies*, does not find support when considering time to invention in general (Models IV and V), but does find support when investigating time to invention in technological classes in which the licensed technologies are classified (Models VI and VII). This is congruent with the findings of Roberts and Berry (1984) advocating that licensing-in is more suited for new business with familiar technological characteristics. Accordingly, the acceleration effect of licensing-in on time to invention seems to be more pronounced when it involves familiar technologies or invention in familiar domains.

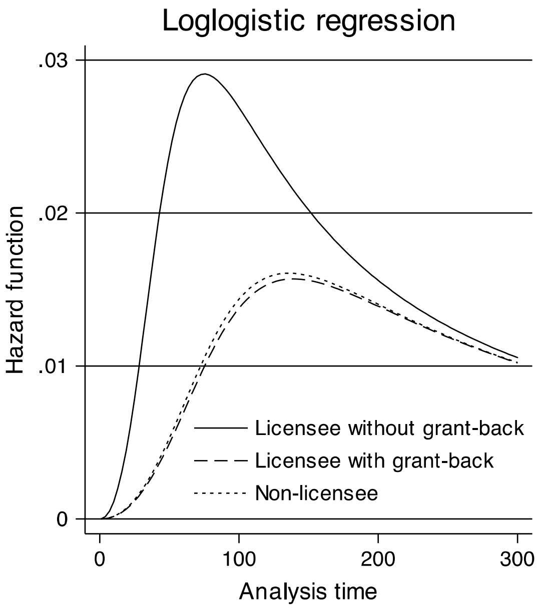

Figure 1. Estimated hazard functions of licensees (with and without grant-back clause) and non-licensees

Hypothesis 4, *the grant-back clause extends the licensee's time to invention less if the licensee is unfamiliar with the licensed technology compared with if the licensee is familiar with the technology*, finds support only in Model VII with a significant negative estimate associated with the interaction between grant-back and unfamiliarity. What is more, comparison of the combined effect of the interaction term and the grant-back clause ($2.788+(-2.726)= 0$) using the Wald test revealed the absolute values of the two parameter estimate cannot be considered different. This indicates that the grant-back, in fact, is overturned when the licensed technology is unfamiliar. Firms that license an unfamiliar technology become reliant on the licensor, which in turn creates a situation where even a grant-back clause does not shift the incentive away from the licensee.

Among control variables, we find a search depth strategy tends to shorten the time to invention, while a search scope strategy shortens the time to invention in the licensed technological class(es) only. Medium sized firms generally display a shorter time to invention than small and large firms. But firms that introduce more generally applicable inventions exhibit a longer time to invention. Finally, if we look at licensees only, we find that firms familiar with complex technologies show shorter times to invention in general.

Likelihood ratio tests were used to investigate whether the stepwise introduction of variables provide significant higher likelihood statistics. The likelihood improved significantly when introducing the licensee variable in Model II. Introducing the grant-back clause in Model III, however, did not improve the likelihood significantly. Two potential reasons may account for this. First, the grant-back clause and the technology furnishing clause tend to co-occur. A grant-back clause incentivizes the licensor to fully commit to assisting the licensee. Licensees seek to gain from the committed licensors through a technology furnishing clause. Much in line with the arguments of the paper, these clauses may separately hamper the invention process, but in conjunction promote it. The grant-back clause effect may, in accordance, partially be captured in the technological furnishing variable in Model II, which in turn leads to low likelihood improvements going from Model II to III. The co-occurrence hypothesis receives support in the data's basic statistics. Second, firms working with rapidly changing technologies need to accelerate own invention speed. Exploiting competences, invention activities and investments of an external source, like a licensee, may allow firms to do just that. A grant-back clause will, accordingly, often be seen when the licensed asset is in a rapidly changing technological class. An overrepresentation of the use of the grant-back clause is observed in the electrical and electronics technologies. Results also suggest invention speed to be higher for this type of technology. Low improvement in likelihoods from Model II to III may, hence, partially be attributed to the contribution of the electrical and electronics dummy to the likelihood of Model II. Finally, we find no significant improvement in the likelihood when introducing the significant interaction term in Model VII. This can mainly be attributed to the number of observations. Relatively few contracts have a grant-back clause when the licensee is unfamiliar with the technology. Under these conditions, the licensor may expect the potential gain from the grant-back to be limited, and therefore put less weight on securing a grant-back agreement than on other more desirable terms. This suggests we take a cautious attitude toward the findings. However, it is equally important to remember that 'goodness of fit is not as important as statistical and economic significance of the explanatory variables' (Wooldridge, 2002: 465).

Supplementary analysis

Patent quality

There may be trade-offs between pace of innovation and the cost and quality of output since it may take more resources to accelerate the process (e.g., Kessler and Bierly, 2002). However, in some circumstances *slow innovation* (Cheshire, 2007) is desirable since it allows firms to seek alternatives, to examine new ideas, and to learn and to choose superior strategies (Norling, 2009) that may produce inventions of a higher quality. As a supplement to the above, we consider the quality of the patents filed by licensees and non-licensees. Table 4 reports the results of t-tests comparing the mean of the number of forward citations received, the number of claims made, and the number of IPC codes under which the patents are recorded. These three measures are used frequently as measures of technology quality, value, or promise. Observed differences in mean values are negligible. Only number of forward citations exhibits a weak tendency for non-licensees to produce higher quality patents. We also investigated if there were any correlation between time to invention and the three measures of quality and found no indications of this. The weak indication of high quality of non-licensee patents is hence not attributable to rate of patenting.

Table 4. Comparison of patent characteristics: results of t-tests on mean values

	Licensee	Non-licensee	Difference
Number of cites	9.332	12.815	−3.483*
Number of claims	24.378	20.276	4.102
Number of IPC codes	1.383	1.448	−0.065

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Cooperation-competition

The results can be argued to be consistent with the tensions between cooperation and competition identified by Hamel (1991) and Agarwal, Croson, and Mahoney (2010). Licensees and licensors seek to benefit from each other's time and resource investments but are hesitant to cooperate unconditionally since the presence of a partner might partially eliminate advantages. The grant-back clause could be considered evidence of this tension. The licensor seeks to cooperate but defends its competitive position by contractually securing any improvements to the technology. We sought the tension between cooperation and competition in the technology licensing by investigating whether the use of a grant-back clause was more prominent in cases where licensee and licensor were in the same two-digit industry. We found that 80 percent of the grant-back clause contracts were between firms in the same industry, and only 46 percent of contracts with no grant-back clause were between firms in the same industry. This regularity proved significant at the one percent level ($\chi^2 = 8.44$), suggesting this tension is present in technology licensing. Overall, our analysis suggests that a shift toward competition rather than cooperation leads to the use of contractual clauses that inhibit the positive invention gains that could be realized from technology licensing.

CONCLUSIONS

This paper addresses licensing from the licensee's viewpoint, investigating whether licensing-in of technologies enables the licensee to introduce new inventions more rapidly. This acceleration effect is argued to be moderated by a contractual grant-back clause and unfamiliarity with the licensed technology. Based on a model that includes matched samples of licensees and non-licensees, we find strong support for the hypothesis that licensees generally invent more rapidly than their non-licensee counterparts. The results suggest that licensing-in involves much more than the transfer of intellectual property rights. We conjecture that the licensee is able to tap into the licensor's knowledge and invention capabilities beyond what is included in a patent document. This allows the licensee to shortcut the invention process, thus avoiding unfruitful and time-consuming invention efforts. License agreements thereby act as the catalysts for a licensee's invention activities, allowing a speedier invention process.

The results are consistent with contract theory that suggests a grant-back clause shifts the incentive to further develop the technology away from the licensee. The licensee will choose to dedicate fewer resources and less time to assisting the licensor in generating new inventions based on the licensed technology and may even choose to free ride by relying solely on the inputs and activities of the licensor. Our results also suggest that licensing-in of an unfamiliar technology may prolong the invention process. Moving to an unfamiliar technology involves difficulties related to integrating and assimilating it to in-house invention activities. Furthermore, the literature argues that external search among unfamiliar technologies increases the number of possible combinations and generates a higher number of possible solutions to technological challenges, thereby increasing the number of potential new products introduced by the firm. However, licensing in an unfamiliar technology may increase the number of tasks required for the firm to be able to exploit it for its own invention activities. Licensing-in an unfamiliar technology generally leads to a longer time to invention; however, it also renders the licensee more reliant on the goodwill and assistance of the licensor to assimilate and integrate it and obliges the licensee to invest time and resources in the technology for the licensor to be content to continue the partnership. We provide evidence that a grant-back clause has no effect on the time to invention dynamics if the licensee is unfamiliar with the licensed technology. The incentive to invest does not shift from the licensee since there are other and stronger incentives that also involve investing in the technology.

Limitations and future research

The paper has limitations related mainly to the nature of licensing agreements and patents. First, observations may be affected by selection bias caused by firms' disclosure policies. Firms may choose not to disclose either licensing agreements or patent information, since both reveal information useful for competitors. A Heckman (1979) selection model, in theory, would mediate this potential bias. However, this solution would be, at best, a partial imperfect correction since we do not

DOI: 10.1002/smj

know whether our original sample is representative of the population. Furthermore, we believe this potential selection effect is likely to reduce the support for our hypotheses since nondisclosure often is used for secrecy in relation to invention activities. Our estimates are, therefore, likely to be conservative. The drop in observations due to missing values in the non-contractual variables may lead to selection bias in the form of overrepresentation of larger firms. However, we consider this potential source of bias to be of limited relevance since the sample does not exhibit substantial differences in the key technology related variables—including patent stock, which is also a size measure.

We acknowledge the presence of a time lag between the license date and the 'real' point in time (presumably before) when firms began thinking about exploiting the technology. However, given that we match licensees with non-licensees based on technology related characteristics, we can assume that non-licensees were investigating other technologies and simply decided against licensing. The study may also be subject to endogeneity bias in that firms signing a license agreement containing a grant-back clause are those firms with non-invention related motives. However, the grant-back clause becomes insignificant when the licensed technology is unfamiliar to the licensee, which we would not expect if the analysis was vulnerable to this potential source of bias.

The analysis cannot be considered a natural experiment since the treatment variable is subject to potential endogeneity. Licensees are chosen by licensors, who may have more perfect information for selecting the very best licensees compared to the information we used to select matched non-licensees. However, it is somewhat perplexing that the licensor cannot predict the free rider nature of the licensee when including a grant-back clause if it is able to foresee an otherwise unpredictable performance like invention.

The analysis could be challenged in terms of whether the inventions generated are attributable only to the licensed technology and not a shift in technology strategies among licensees compared to non-licensees. To investigate this, we conducted the analysis investigating time to first invention that cites the licensed patent(s). Results were consistent with those presented in the paper, suggesting this reservation to be negligible.

Finally, there are circumstances where firms intentionally slow their invention and patenting processes. For instance, the relevance of disclosure as a reason not to patent has been established in a number of studies (see, e.g., Arundel and Kabla, 1998; Cohen, Nelson, and Walsh, 1998). Secrecy over technology advances can be a competitive advantage in the sense that competitors are kept in the dark about the area of the technological landscape in which the firm is active, and about the advances it has achieved. However, such patterns are often industry or technology specific. We control for industry and use the primary IPC code of the firms in the exact matching procedure. Also, we use average time between patents in the propensity score matching procedure. This variable matches the treatment and control sample with respect to patent timing characteristics, assuming the two groups introduce an equal number of inventions, which is dictated by other matching variables. Therefore, we consider this possible concern to be of minor importance.

Managerial implications

The paper has managerial implications for both licensees and licensors. There are several reasons why firms may choose to license-in proven technology. Among these are intellectual property rights motives, technological diversification purposes, and learning benefits leading to higher likelihood of becoming innovative. This paper indicates that firms should also consider advantages in terms of shortcutting the invention process when deciding whether to enter the demand side of the market for technology. Technology in-licensing is shown to function as a strategic tool that allows licensee technologically to overtake competitors. This may, in turn, allow them to free up resources for other purposes in the long run. The paper also has implications for firms seeking to gain advantages as licensors by outsourcing further development of the technology to an external partner through licensing. The licensor should consider the overlap in technological capabilities of the licensee and the licensed technology when negotiating contractual specifications. Licensors enjoy lower synergies through a grant-back clause when the licensed technology is familiar to the licensee, suggesting licensors should identify other means through which they can capture the technological advances made by the licensee.

ACKNOWLEDGMENTS

We thank Andrea Fosfuri, Marco Giarratana, Keld Laursen, Thomas Rønde, two anonymous referees and Editor Will Mitchell for valuable comments. The paper benefited from suggestions made at the 2009 AOM Conference, Carlos III University, European School of Management and Technology, the 2009 DRUID-DIME Academy Winter PhD Conference, and the 2008 SMS Conference. Thanks go to the Financial Valuation Group of Florida, Inc. for allowing us access to their Intellectual Property Transaction Database, and for providing preliminary information on the license agreements employed in this study. Maria Isabella Leone is grateful for financial support from the EVPAT project funded by the European Investment Bank. Both authors acknowledge the contribution of the Danish Council for Independent Research in Social Sciences. The usual disclaimers apply.

REFERENCES

Agarwal R, Croson R, Mahoney JT. 2010. The role of incentives and communication in strategic alliances: an experimental investigation. *Strategic Management Journal* **31**(4): 413–437.

Aghion P, Tirole J. 1994. The management of innovation. *Quarterly Journal of Economics* **109**(4): 1185–1209.

Ahuja G. 2000. Collaboration networks, structural holes, and innovation: a longitudinal study. *Administrative Science Quarterly* **45**(3): 425–455.

Ahuja G, Lampert CM. 2001. Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal*, June–July Special Issue **22**: 521–543.

Anand BN, Khanna T. 2000. The structure of licensing contracts. *Journal of Industrial Economics* **48**(1): 103–135.

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

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

Arora A, Fosfuri A. 2003. Licensing the markets for technology. *Journal of Economic Behavior and Organization* **52**(2): 272–295.

Arora A, Fosfuri A, Gambardella A. 2001. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. MIT Press: Cambridge, MA.

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

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

Arundel A, Kabla I. 1998. What percentage of innovations are patented? Empirical estimates for European firms. *Research Policy* **27**(2): 127–141.

Atuahene-Gima K. 1993. Determinants of inward technology licensing intentions: an empirical analysis of Australian engineering firms. *Journal of Product Innovation Management* **10**: 230–240.

Bennett S. 1983. Log-logistic regression models for survival data. *Applied Statistics* **32**(2): 165–171.

Cassiman B, Veugelers R. 2006. In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition. *Management Science* **51**(1): 68–82.

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

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

Cesaroni F. 2004. Technological outsourcing and product diversification: do markets for technology affect firms' strategies? *Research Policy* **33**(10): 1547–1564.

Chatterji D. 1996. Accessing external sources of technology. *Research Technology Management* **39**(2): 569–596.

Cheshire D. 2007. Slow innovation: a savour-y way to success. *Change This* **40**(6): 1–9.

Choi JP. 2002. A dynamic analysis of licensing: the 'boomerang' effect and grant-back clauses. *International Economic Review* **43**(3): 803–829.

Cohen WM, Levinthal DA. 1989. Innovation and learning: the two faces of R&D. *Economic Journal* **99**(397): 569–596.

Cohen WM, Nelson RR, Walsh J. 1998. Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not). NBER Working paper no. 7552. National Bureau of Economic Research: Cambridge, MA.

David PA, Olsen TE. 1992. Technology adoption, learning spillovers, and the optimal duration of patent-based monopolies. *International Journal of Industrial Organization* **10**(4): 517–543.

Davies H. 1977. Technology transfer through commercial transactions. *Journal of Industrial Economics* **26**(2): 161–175.

Dehejia RH, Wahba S. 2002. Propensity score-matching methods for nonexperimental causal studies. *Review of Economics and Statistics* **84**(1): 151–161.

Eisenhardt KM, Martin JA. 2000. Dynamic capabilities: what are they? *Strategic Management Journal*, October–November Special Issue **21**: 1105–1121.

Fleming L, Sorenson O. 2001. Technology as a complex adaptive system: evidence from patent data. *Research Policy* **30**(7): 1019–1039.

Fleming L, Sorenson O. 2004. Science as a map in technological search. *Strategic Management Journal*, August–September Special Issue **25**: 909–928.

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

Gallini NT, Winter RA. 1985. Licensing in the theory of innovation. *RAND Journal of Economics* **16**(2): 237–252.

Gans JS, Hsu DH, Stern S. 2008. The impact of uncertain intellectual property rights on the market for ideas: evidence from patent grant delays. *Management Science* **54**(5): 982–997.

Gomory RE. 1989. From the ladder of science to the product development cycle. *Harvard Business Review* **67**(6): 99–105.

Grossman SJ, Hart OD. 1986. The cost and benefits of ownership: a theory of vertical and lateral integration. *Journal of Political Economy* **94**(4): 691–719.

Gutierrez RG. 2002. Parametric frailty and shared frailty survival models. *STATA Journal* **2**(1): 22–44.

Hagedoorn J. 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. *Strategic Management Journal* **14**(5): 371–385.

Hall B, Jaffe A, Trajtenberg M. 2001. The NBER patent citations data file: lessons, insights, and methodological tools. NBER Working paper no. 8498. National Bureau of Economic Research: Cambridge, MA.

Hall BH, Ziedonis RH. 2001. The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry. *RAND Journal of Economics* **32**(1): 101–128.

Hamel G. 1991. Competition for competence and inter-partner learning within international strategic alliances. *Strategic Management Journal*, Summer Special Issue **12**: 83–103.

Hart O, Moore J. 2008. Contracts as reference points. *Quarterly Journal of Economics* **123**(1): 1–48.

Heckman JJ. 1979. Sample selection bias as a specification error. *Econometrica* **47**(1): 153–161.

Heckman JJ, Ichimura H, Todd P. 1997. Matching as an econometric evaluation estimator: evidence from evaluating a job training program. *Review of Economic Studies* **64**(4): 605–654.

Henderson R, Cockburn I. 1994. Measuring competence? Exploring firm effects in pharmaceutical research. *Strategic Management Journal*, Winter Special Issue **15**: 63–84.

IBM. 2005. IBM announces new licensing program to prompt collaborative innovation with VCs & startups. IBM. Available at: http://www-03.ibm.com/press/us/en/pressrelease/19042.wss (April 2010).

IBM. 2010. Technology. IBM. Available at: http://www.ibm.com/ibm/licensing/technology/. (April 2010).

Johnson D. 2002. 'Learning-by-licensing': R&D and technology licensing in Brazilian invention. *Economics of Innovation and New Technology* **11**(3): 163–177.

Katila R, Ahuja G. 2002. Something old, something new: a longitudinal study of search behavior and new product introduction. *Academy of Management Journal* **45**(8): 1183–1194.

Kessler EH, Bierly PE. 2002. Is faster really better? An empirical test of the implications of innovation speed. *IEEE Transactions on Engineering Management* **49**(1): 2–12.

Kessler EH, Chakrabarti AK. 1996. Innovation speed: a conceptual model of context, antecedents, and outcomes. *Academy of Management Review* **21**(4): 1143–1193.

Kim YJ, Vonortas NS. 2006. Technology licensing partners. *Journal of Economics and Business* **58**(4): 273–289.

Lane PJ, Lubatkin M. 1998. Relative absorptive capacity and interorganizational learning. *Strategic Management Journal* **19**(5): 461–477.

Lanjouw JO, Schankerman M. 1999. The quality of ideas: measuring innovation with multiple indicators. NBER Working paper no. 7345.National Bureau of Economic Research: Cambridge, MA.

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

Laursen K, Salter AJ. 2006. Open for innovation: the role of openness in explaining innovative performance among U.K. manufacturing firms. *Strategic Management Journal* **27**(2): 131–150.

Leiponen A. 2008. Control of intellectual assets in client relationships: implications for innovation. *Strategic Management Journal* **29**(13): 1371–1394.

Levin RC, Klevorick AK, Nelson RR, Winter SG. 1987. Appropriating the returns from industrial research and development. *Brookings Papers on Economic Activity* **3**: 783–831.

Lin B-W. 2003. Technology transfer as technological learning: a source of competitive advantage for firms with limited R&D sources. *R&D Management* **33**(3): 327–341.

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

March J. 1991. Exploration and exploitation in organizational learning. *Organization Science* **2**(1): 71–87.

Markman GD, Gianiodis PT, Phan PH, Balkin DB. 2005. Innovation speed: transferring university technology to market. *Research Policy* **34**(7): 1058–1075.

Merges RP, Nelson RR. 1990. On the complex economics of patent scope. *Columbia Law Review* **90**(4): 839–916.

Microsoft. 2008. Open innovation: the evolution of the Microsoft approach to intellectual property. *Microsoft Announcements* **2008** (August): 1–15.

Miller D, Chen M-J. 1996. The simplicity of competitive repertoires: an empirical analysis. *Strategic Management Journal* **17**(6): 419–439.

Mowery DC, Oxley JE, Silverman BS. 1996. Strategic alliances and interfirm knowledge transfers. *Strategic Management Journal*, Winter Special Issue **17**: 77–91.

Nerkar A, Roberts PW. 2004. Technological and product-market experience and the success of new product introductions in the pharmaceutical industry. *Strategic*

Management Journal, August–September Special Issue **25**: 779–799.

Norling P. 2009. In innovation, is patience a virtue? *Research-Technology Management* **52**(3): 18–23.

Prahalad CK, Hamel G. 1990. The core competence of the corporation. *Havard Business Review* **68**(3): 79–91.

Rigby D, Zook C. 2002. Open market innovation. *Harvard Business Review* **80**: 80–89.

Roberts EB, Berry CA. 1984. Entering new businesses: selecting strategies for success. Working paper 1492-3-84 Sloan School of Management, MIT: Cambridge, MA.

Rosenbaum PR, Rubin DB. 1983. The central role of propensity score in observational studies for causal effects. *Biometrika* **70**(1): 41–55.

Rosenbaum PR, Rubin DB. 1984. Reducing bias in observational studies using subclassification on the propensity score. *Journal of American Statistical Association* **79**(387): 516–524.

Shapiro C. 1985. Patent licensing and R&D rivalry. *American Economic Review* **75**(2): 25–30.

Silverman BS. 1999. Technological resources and the direction of corporate diversification: toward an integration of the resource-based view and transaction cost economics. *Management Science* **45**(8): 1109–1124.

Smith GV, Parr RL. 2005. *Intellectual Property: Valuation, Exploitation, and Infringement Damages.* Wiley: Hoboken, NJ.

Teece DT, Pisano G. 1994. The dynamic capabilities of firms: an introduction. *Industrial and Corporate Change* **3**(3): 537–555.

Van Dijk T. 2000. License contracts, future exchange clauses and technological competition. *European Economic Review* **44**(8): 1431–1448.

Wooldridge JM. 2002. *Econometric Analysis of Cross Section and Panel Data*. MIT Press: Cambridge, MA.

Yet2.com. 2008. Licensing and intellectual property tip*s*. Yet2.com. Available at: http://www.yet2.com/app/insight/insight/20010429_compendium (April 2010).

Ziedonis RH. 2004. Don't fence me in: fragmented markets for technology and the patent acquisition strategies of firms. *Management Science* **50**(6): 804–820.

DOI: 10.1002/smj