Licensing Exchange—
Insights from the Biopharmaceutical Industry

Stefan Wuyts and Shantanu Dutta[1]

[1] Stefan Wuyts is an Associate Professor of Marketing, Faculty of Economics and Business Administration, Tilburg University, The Netherlands (Warandelaan 2, P.O. Box 90153, 5000 LE Tilburg; tel.+31(13)4668775; fax.+31(13)4668354; email s.h.k.wuyts@uvt.nl). Shantanu Dutta is the Dave and Jeanne Tappan Chair of Marketing, Marshall School of Business, University of Southern California (3660 Trousdale Parkway, ACC 306E, Los Angeles, CA 90089-0443; tel. 213-740-5038; fax. 213-740-7828; email sdutta@marshall.usc.edu). The first author extends his appreciation to the Netherlands Organization for Scientific Research for financial assistance.

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Abstract

Licensing out technologies is a main source of revenue for dedicated technology firms. While licensing exchange has received very little attention in prior marketing literature, it is economically important and poses particular challenges. One major obstacle for obtaining new licensing deals is the information asymmetry between licensors and licensees. The main premise of this study is that the variation among dedicated technology firms of the number of new licensing deals that they obtain can be explained by their voluntary disclosure of strategic information and their position in the industry's licensing and social networks. An empirical study of the biopharmaceutical industry shows that, while voluntarily disclosing strategic information enables dedicated biotechnology firms to sign more new licensing deals, firms should be careful not to disclose too much information. As to network structure, dedicated biotechnology firms with more central positions in the licensing exchange network obtain more new licensing deals, but again, the effect has an inverted-U shape, indicating a dark side of network centrality. Finally, the study provides evidence that licensing exchange is socially embedded. A central position in the social network of board interlocks leads to more new licensing deals. Dedicated technology firms can use these insights to address practical questions, such as how much strategic information they should reveal, as well as to set long-term directions regarding network position.

Introduction

Licensing technologies is an important economic activity with an estimated value of more than $100 billion worldwide (Economist, 2005). For many firms, especially those referred to as dedicated technology firms, licensing technologies is in fact *the* essential form of exchange. Dedicated technology firms focus on R&D related activities along the value chain while other firms perform more downstream activities related to product development and commercialization, a division of activities that is very prominent in the biopharmaceutical industry (Stuart, Ozdemir, & Ding, 2007). In 2000, more than half of the drugs in the pipelines of pharmaceutical firms such as Schering-Plough, Johnson & Johnson, and American Home Products resulted from licensing agreements (Simonet, 2002). Technology licensing is a complex form of exchange. In technology-intensive industries, licensees are confronted with a plethora of technological opportunities that can hardly be overseen by a single firm, leading to a substantial information asymmetry between the individual licensor and potential licensees. This problem is exacerbated by uncertainty ex ante about the value of the technology being offered by a dedicated technology firm. Such uncertainty in technology-intensive industries puts a burden on inter-firm exchange relationships (e.g., Kauffman, 2001; Wuyts, 2007), posing a challenge to dedicated technology firms as they attempt to license-out their technologies.

Prior research has considered the licensing of intellectual property as an essential element of competition (Gans & Stern, 2003; Grindley & Teece, 1997) and has drawn attention to the importance of the information asymmetry problem (e.g., Anton & Yao, 2004). However, whereas previous research has focused on technology licensing as an additional source of revenue for large established firms, often in the context of (international) expansion (Fosfuri, 2006; Kotabe, Sahay, & Aulakh, 1996), there has been no systematic study of the specific challenges of

dedicated technology firms that often have not integrated their technologies into products. Furthermore, the growing literature on inter-firm interaction in the pharmaceutical industry has mainly devoted attention to either large pharmaceutical firms (e.g., Wuyts, Dutta, & Stremersch, 2004) or start-up firms that face very specific challenges related to Stinchcombe's (1965) liability of newness hypothesis (e.g., Higgins & Gulati, 2006). In sum, a study of dedicated technology firms and their ability to license out their technologies would help bridge a void in prior literature.

To explain differences between dedicated technology firms in terms of the number of their new licensing deals, we draw on both theory of agency and theory of structure (following Sewell, 1992). While theory of structure emphasizes that firms' behaviors and outcomes are driven by (network) structures in which economic actors are embedded, theory of agency emphasizes firms' voluntary actions and intentions. Regarding voluntary action, we focus on the firm's voluntary disclosure of strategic information (e.g., Ackert & Church, 2006; Eccles & Mavrinac, 1995). Regarding network structure, we focus on the firm's centrality in the industry's licensing exchange network, which has been associated with multiple benefits including status (e.g., Ahuja, 2000; Gulati & Gargiulo, 1999; Podolny, 1993; Wasserman & Faust, 1994). In addition, we examine the firm's centrality in the industry's network of social ties formed by individuals. Such ties have been accredited to influence the behavior and performance of economic actors through their function as information conduits (Braudel, 1985; Granovetter, 1985; Macaulay, 1963).

Our study thus provides an examination of the phenomenon of licensing exchange[2] and first insight into why some firms obtain more new licensing deals than other firms. The study of the benefits and drawbacks of voluntary information disclosure in the context of licensing exchange

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[2] With licensing exchange, we refer to the licensing of technologies by dedicated technology firms. This focus sets the study apart from other studies that have examined alternative types of licensing, such as the licensing of brands in the context of brand extensions (Colucci, Montaguti, & Lago, 2008).

contributes to the stream of research in information economics that is concerned with information asymmetry problems (e.g., Ackert & Church, 2006; Eccles & Mavrinac, 1995; Stiglitz 2002). Our findings regarding the embeddedness of licensing exchange in the licensing exchange network as well as the industry's social network are useful extensions to the network literature, where exchange has received relatively little attention.

For testing the developed framework, we gather data on information disclosure, licensing deals, social ties, and other relevant firm characteristics for 130 public biotechnology firms from 1994 to 2000. The estimation results show that (1) voluntarily disclosing strategic information to the public domain aids dedicated technology firms in obtaining more new licensing deals but that too much information disclosure can be harmful, (2) a dedicated technology firm's centrality in the licensing exchange network has a curvilinear effect on the number of new licensing deals, with firms that are very isolated or very central obtaining fewer licensing deals than firms in-between, and (3) licensing exchange is socially embedded and the degree centrality of a dedicated technology firm's position in the industry's social network of board interlocks[3] has a positive effect on licensing success.

These findings improve the understanding of licensing exchange and have implications for managing dedicated technology firms.

Theory and Hypotheses

Technology licensing is a phenomenon observed in highly complex business environments that are characterized by a fast pace of technological change and where large numbers of new technologies are developed over time. The biopharmaceutical industry is a case in point. Since the commercialization of new biotechnology in the early eighties, the biopharmaceutical industry

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[3] Board interlocks refer to the phenomenon that a firm's board members also sit on the boards of other firms, an important representation of social ties in industry networks (Dooley, 1969; Ornstein, 1980; Zajac & Westphal, 1996) with informational benefits (Davis, 1991; Haunschild, 1993).

has witnessed a strong growth in terms of technologies and in terms of dedicated biotechnology firms ("licensors"). At the same time, many firms ("licensees") are on the lookout for new and promising technologies that can aid in the identification of drug leads or in the development of new drugs. The characteristics of technology-intensive environments pose specific challenges to licensing exchange. One important challenge that arises is the information asymmetry between licensors and potential licensees. No licensee firm can be aware of all technological opportunities, let alone process all of the available information about new technological opportunities. And, even if it is aware of a certain technological opportunity, the licensee faces a great deal of uncertainty regarding its value and applicability (Jensen & Thursby, 2001). In this study, it is argued that dedicated technology firms can engage in deliberate disclosure of information to reduce the information asymmetry and that also their position in the industry's network structures is instrumental in this regard. In sum, we will employ both arguments of voluntary action and arguments of structure to explain the variation in the number of new licensing deals into which dedicated technology firms enter.

From a theory point of view, we follow Sewell (1992), who reformulated earlier works by Giddens (1979) and Bourdieu (1977) and discussed the complementarities of two fundamental perspectives of economic action—the theory of agency and the theory of structure. The theory of agency offers a first perspective on economic behavior involving the recognition that actors engage in voluntary and deliberate actions to achieve their goals. In the context of information asymmetry, the prior literature has pointed to the important role of information disclosure as a way to reduce information asymmetry and stimulate exchange (e.g., Ackert & Church, 2006). On the other hand, the theory of structure emphasizes that economic action is guided by the structures in which economic actors are embedded, and it has been actively developed in the network literature. We consider inter-firm exchange networks as well as social networks. A

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firm's position in the industry's licensing exchange network conveys possible benefits such as status (Podolny, 1993). A firm's position in the industry's social network (shaped by individual employees' ties to other firms) influences the dissemination of information with social ties serving as conduits of information (Braudel, 1985; Granovetter, 1985). In what follows, we will elaborate on voluntary information disclosure, centrality in the inter-firm (licensing) exchange network, and centrality in the industry's social network, and we will theorize on their likely impact on the number of new licensing deals for the firm.

Voluntary Information Disclosure

In information economics, information disclosure has been presented as a way to overcome information asymmetry and stimulate exchange (e.g., Ackert & Church, 2006; Eccles & Mavrinac, 1995; Stiglitz, 2000, 2002). Eccles and Mavrinac (1995) conclude that, especially in technology-intensive industries, firms should voluntarily disclose non-financial information, as this will make potential investors more receptive. By disclosing strategic information into the public domain, dedicated technology firms can proactively address the information asymmetry with potential exchange partners. Interestingly, prior marketing literature has focused on mandatory information disclosure (e.g., Moorman, Du, & Mela, 2005), with little to no attention to information disclosure as a strategic tool. In the context of licensing, firms can strategically disclose information about their strategic market position and technologies in development, so that the potential licensee is better informed about the firm. Because some of the potential licensees are not known to the firm, information disclosure in this context is typically general in nature, directed to the public domain such as through press releases or by voluntarily elaborating on strategic issues in public filings such as those required by the U.S. Securities and Exchange Commission (SEC). If voluntary information disclosure is effective in reducing information

asymmetry, a naive view of information disclosure would thus predict that voluntary information disclosure increases the number of a firm's new licensing deals.

However, the disclosure of firm-specific information has a drawback that has not received much attention in the prior literature but that is especially relevant in the context of licensing exchange (where confidentiality is particularly important, see Anton & Yao, 2004). Licensees may perceive technology firms that disclose very detailed strategic information into the public domain as less careful about confidentiality since the publicly disclosed information is accessible to all potential licensees, including competitors. Being more selective in terms of the information that is disclosed into the public domain may serve as a quality signal. We therefore argue that there is a curvilinear effect. Disclosing strategic information reduces the information gap with potential licensees. This disclosure may initially stimulate licensing exchange, but very high levels of information disclosure may conflict with the need for confidentiality in licensing exchange and thus hinder rather than stimulate licensing exchange. If there were a curvilinear effect, the optimum would be at an intermediate level of voluntary information disclosure:

H_1 The degree of a dedicated technology firm's voluntary information disclosure has
            an inverted U effect on the number of new licensing deals.

Centrality In Licensing Exchange Network

Prior research has shown that uncertainty in decision environments increases the importance of signals, such as signals associated with network positions in business settings (e.g., see Sacks, 2002, for a study on the importance of such signals for venture capitalists). An important information signal for potential licensees is the dedicated technology firm's degree centrality in the licensing exchange network (i.e., the number of licensing deals with different partner firms). First, higher levels of degree centrality are associated with higher visibility (e.g., Gulati &

Gargiulo, 1999; Powell, White, Koput, & Owen-Smith, 2005; Wasserman & Faust, 1994).

Second, degree centrality also signals status and quality, particularly in contexts characterized by quality uncertainty (Ahuja, 2000; Podolny, 1993; Tsai, 2000; Van den Bulte & Wuyts, 2007). In different technology-intensive industries, Shrum and Wuthnow (1988) found that reputational status is indeed a function of the firm's total number of ties to other firms. Status in turn has a positive effect on exchange: actors with higher status are more preferred exchange partners (Thye, 2000).[4]

In view of these different benefits, the prior literature would thus suggest a linear and positive effect of degree centrality in the licensing exchange network on the number of new licensing deals. However, a very central position in the licensing exchange network bears a risk that is particular to the context of technology licensing. When licensors have signed many licensing deals in the past, potential licensees may question the uniqueness of the licensor's know-how (controlling for the number of technological domains covered by past licensing deals). Scarcity and uniqueness of know-how heighten its perceived value (e.g., Menon & Pfeffer, 2003). Hence, potential licensees may be less attracted to dedicated technology firms that are very centrally located. This dark side of network centrality has not received much attention in prior literature, but it is expected to be particularly strong in the context of licensing exchange. In sum, firms with a very low degree centrality in the licensing exchange network face low visibility and status (sometimes referred to as the liability of disconnectedness, see Powell, Koput, & Smith-Doerr, 1996), whereas very centrally located firms are associated with low uniqueness. Firms at intermediate levels of degree centrality enjoy the benefits of visibility and status while avoiding

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[4] Besides better status, degree centrality in the inter-firm network also conveys other benefits, such as increased power (Beckman & Haunschild, 2002). While it is not clear how power advantages can be instrumental in the search for new licensing deals, it is impossible on the basis of the information on degree centrality to unequivocally determine whether its effect on obtaining new licensing deals is driven by status or by other advantages that are conveyed by such a central network position.

the drawback of low perceived uniqueness and may thus obtain the most new licensing deals, suggesting an inverted U-shape effect:

H_2 A dedicated technology firm's degree centrality in the licensing exchange network has an inverted U effect on the number of new licensing deals.

Centrality In Board Interlock Network

Another structural trait of dedicated technology firms that may influence licensing exchange is their position in the industry's social network. Much research in the social network literature has argued that firm action is socially embedded in that the social network that pervades industry structures has an important bearing on individual firm action (e.g., Braudel, 1985; Granovetter, 1985; Macaulay, 1963). One explicit manifestation of such social ties between firms has received ample attention in the organizational behavior, network, and economics literature (e.g., Dooley, 1969; Ornstein, 1980; Pfeffer & Salancik, 1978; Zajac & Westphal, 1996): interlocked directory boards. The interlocked boards phenomenon, which dates back at least to the beginning of the 20th century (Dooley, 1969), refers to the practice of individuals' serving on the boards of multiple firms. While prior research has examined both drivers of board interlocks such as personal career motives versus coordination motives (e.g., Zajac, 1988) and diverse consequences such as increased inter-firm coordination and control (e.g., Ornstein, 1980), our interest primarily goes to the informational benefits of board interlocks. More precisely, a firm's degree centrality in the board interlock network (i.e., the number of board interlock ties to different other firms) is a form of social capital that provides access to information that flows through the network (Beckman & Haunschild, 2002; Davis, 1991). A central position in this social network allows for a better dissemination of information on the motives, capabilities, and developments of the firm (Gulati & Westphal, 1999). Several studies have confirmed that board interlocks serve as

important conduits of information (e.g., Haunschild, 1993; Useem, 1984) and play an important role in the diffusion of information (e.g., Davis, 1991). If board members of a dedicated technology firm serve on the directory boards of other industry participants, information on new promising technologies in development can more easily find its way to other actors, which is likely to reduce the information asymmetry with other industry participants—such as potential licensees.

In sum, if board interlocks aid in reducing the information asymmetry between a licensor and its potential licensees, we should expect a positive effect of degree centrality in the board interlock network on obtaining new licensing deals:

H$_3$ A dedicated technology firm's degree centrality in the board interlock network has
               a positive effect on the number of new licensing deals.

Note that we do not expect an inverted-U effect of degree centrality in the board interlock network on the number of new licensing deals, which may seem at odds with H$_1$ and H$_2$. However, an essential difference is that a firm's position in the social network of board interlocks is much less visible to other industry participants than are the voluntary disclosure of information in the public domain and a firm's past licensing deals with industry participants. Hence, a firm's degree centrality in the board interlock network will less likely cause concerns about uniqueness and confidentiality.

Control Variables

We control for the following firm descriptors that are likely to influence the number of new licensing deals. First, we control for firm age as firms may pursue revenue growth through other means than new licensing deals as they get older. Second, we control for the fact that some of the firms in our sample may have developed drugs in their lifetime, which reflects an interest in

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alternative sources of revenue beyond licensing. Third, we control for (the log of) R&D investment as firms' emphasis on R&D determines how well they can cope with technological change and be more innovative (Gao, Zhou, & Yim, 2007; Nijssen, Hillebrand, Vermeulen, & Kemp, 2006). Fourth, we control for technological breadth, i.e., the number of different technological domains in which the firm has signed licensing deals in the past. Fifth, we control for the quality of the firm's internal knowledge base (quality-weighted patents) as well as for the firm's reliance on its own proprietary knowledge as opposed to external knowledge for developing new knowledge (which has been associated with lower innovativeness, Sørensen & Stuart, 2000). Sixth, we control for (the log of) firm size as larger firms may be more likely to integrate some of the downstream activities along the value chain providing them with strategic alternatives to licensing out their technologies. Seventh, we control for time, to account for the possibility that licensing has increased or decreased in importance over time at the industry level.

Table 1 provides a summary of the different constructs, their hypothesized/expected effects, and the actual effects found in the empirical study described below.

< Insert Table 1 about here >

Empirical Test

The developed theory is tested in the biopharmaceutical industry where dedicated biotechnology firms have occupied an important position since the early eighties (Wuyts et al., 2004). With their focus on upstream activities along the value chain (Stuart et al., 2007), dedicated biotechnology firms' primarily develop new technologies (Powell, White, Koput, & Owen-Smith, 2005). They license out their technologies to industry partners, and such licensing represents their main, and often only, source of revenue (e.g., Simonet, 2002). Even though some

biotechnology firms have started developing drugs of their own in later years, licensing remains an essential form of exchange.

Data Sources and Measures

Several data sources were used to create a new database. Below, the different measures are discussed and are ordered by database.

RECAP. The Recombinant Capital databases provide information on licensing deals, board interlocks, and technology domains.

New licensing deals (*#LIC DEAL$_{i,t}$*): the number of licensing deals that a dedicated biotechnology firm *i* enters into in year *t* is the dependent variable in this study.

Centrality in the licensing exchange network (*LICCENTR$_{i,t}$*): We measure a firm's degree centrality in the licensing exchange network by counting the number of licensing deals that firm *i* has entered into from its inception until year *t*, correcting for redundancies in partners. Similar local assessments of centrality have been used in previous research (e.g., Powell et al., 1996). Alternative centrality measures are less visible and thus less likely to serve as effective signals (Brass & Burkhardt, 1993). In view of the signaling logic developed in H1 and in order to arrive at an accurate measure of centrality as proxy for status and quality signal, the measure needs to reflect that a more recent licensing deal has stronger signaling value than an early licensing deal as knowledge depreciates over time. Prior research has suggested a 20% depreciation rate in the biopharmaceutical industry (Henderson & Cockburn, 1996). We adopt the same 20%

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depreciation rate, but we will investigate the sensitivity of our findings to the choice of depreciation rate.[5]

Centrality in the board interlock network ($BICENTR_{i,t}$): Recombinant Capital also provides information on board composition, including board members who have left the firm in prior years, as well as personal bios per individual board member. The bios provide information on external boards on which the board members serve or have served in the past. On the basis of this combined information, we derive the board composition for firm i in year t. Subsequently, we count the number of links to external boards (restricted to the biopharmaceutical industry) over all the firm's board members, which is an index of firm i's degree centrality in the board interlock network in year t (corrected for redundancies). Mariolis and Jones (1982) show that this measure, also used in recent studies on board interlocks (e.g., Fiss & Zajac, 2004; Uzzi & Lancaster, 2004), is more stable and reliable than other measures of centrality, such as the ones proposed by Bonacich (1972).

Technology breadth ($TBREADTH_{i,t}$): the technological breadth of a firm's licensing deals is measured by counting the number of technological domains in which biotechnology firm i has obtained licensing deals from its inception until year t.

SEC: The U.S. Securities and Exchange Commission publishes filings of firms on the stock market as part of a strategy to secure fair trading and protect investors, obliging firms to reveal certain information about themselves. Much information reported in the SEC filings is thus mandatory. From these filings, we collected information on firm size and R&D expenditures (we model the log of both variables, $logRD_{i,t}$, $logSIZE_{i,t}$).

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[5] The measure for licensing centrality where φ represents a 20% depreciation rate and $T = 0$ corresponds with the inception of firm i thus becomes: $LC_{it} = \sum_{T=0}^{T=t} L_{i,t-T}(1-\varphi)^T$

Voluntary information disclosure ($DISCL_{i,t}$): Certain sections in the SEC filings, however, are voluntary, meaning that it is at the individual firm's discretion whether or not to disclose specific strategic information. These sections (identified by the SEC and detailed in Regulation S-K) serve as the input for the voluntary information disclosure scale. In a first step, based on a detailed content analysis of SEC filings, we identified 14 information items that are non-mandatory and related to the firm's customers, competitors, pipeline, and legal issues.[6] In a second step, two independent coders coded all the SEC filings for the firm/year combinations in our sample along these 14 aspects (1 if the firm provided the information item and 0 otherwise). The coders converged in over 90% of these allocation decisions. For each firm in each year, a proxy of voluntary information disclosure was calculated as the sum across these 14 aspects. We investigated the sensitivity of this measure to the different individual information items by re-estimating the model reported below, omitting subsequent (groups of) individual information items from this scale. The reported results are not sensitive to such changes.

NBER. The National Bureau of Economic Research provides information on patents as well as qualifiers of patents, such as citations received and self-citations. Examining each firm's patent portfolio up to year *t*, we constructed a measure of citation-weighted patents to control for the quality of the firm's internal knowledge base ($PATQUAL_{i,t}$). We also derived the degree of self-citations from this database. Each patent contains a reference list of citations to prior patents on which the new patent is based. NBER's self-citation index reflects the proportion of these patents that refer to the firm's own prior patents. This variable is averaged over the firm's patent portfolio to arrive at a self-citations index for firm *i* in year *t* ($PATSELF_{i,t}$).

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[6] (1) general description of the competitive environment; (2) strength of competition; (3) names of competitors; (4) other details about competition; (5) general description of the pipeline; (6) specific therapeutic domains in the pipeline; (7) stage of development in the pipeline; (8) other details about the pipeline; (9) general description of the customers; (10) share of most important customers; (11) other details about customers; (12) general information about legal issues; (13) names of opponents in litigation; (14) other details about litigation.

Websites. We consulted the websites of all firms in our sample to register the year of founding and calculated the age of biotechnology firm i in year t ($AGE_{i,t}$).

FDA Orange Book. To account for firms' search for alternative sources of revenue, we identify those firms that have developed drugs of their own at any point in their lifetime and create a dummy variable (1 if this firm had at least one drug approved and 0 otherwise) ($DRUGS_i$).

Finally, we include a time trend ($YEAR_t$).

Sample and Model

We collected all the above information for 130 dedicated biotechnology firms. This sample resulted from a random selection of 172 public biotechnology firms from the Recap database—one of the most comprehensive databases covering the biopharmaceutical industry—and a further reduction based on data availability. Taking into account the lag structure, we have, on average, 3.5 observations per firm in the time period 1994-2000. Note, however, that the calculation of the licensing centrality measure, which should reflect all prior licensing deals, is based on all licensing deals from the inception of the biotechnology firm on (i.e., also from before 1994). The number of licensing deals firms enter into in a given year ranges from 0 to 15. More than 80% of the 130 biotechnology firms never had any drug approved in their lifetime (also beyond the sampling time frame). One restriction of the study sample is that all firms are public. This restriction allows us to derive firm-relevant information from SEC filings, but it inhibits the generalization of the study results to new ventures or start-up biotechnology firms (consistent with our positioning and conceptualization). To detect any other possible biases, we further compared the 130 firms in the sample with the other 42 randomly selected biotechnology firms for which we had gathered (incomplete) information. This comparison reveals no significant

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differences in terms of patent productivity, profitability, number of employees, or number of licensing deals. However, the firms in the sample are somewhat more R&D-intensive as their average R&D expenditures are higher than the average expenditures of the firms that were not included in the final sample. Tables 2 and 3 provide sample descriptors and correlations.

< Insert Tables 2 and 3 about here >

As for the model specification, recall that the dependent variable is a count variable—the number of biotechnology firm i's new licensing deals in year t. Because we observe overdispersion in the data (violating the equality of mean and variance assumption in Poisson estimation), we specify a negative binomial model (e.g., Hausman, Hall, & Griliches, 1984). All independent variables are lagged with one period (except for firm age and year and the time-invariant drugs dummy variable). We mean-center the licensing centrality and information disclosure variables. The mean variance inflation factor is 2.09, with a maximum of 5.22, well below the threshold value of 10, suggesting that our results are not harmed by multicollinearity (Mason & Perreault, 1991). We adopt the most common negative binomial model used in econometric applications with mean function λ_i and variance function $\lambda_i + \alpha\lambda_i^2$ (Cameron & Trivedi, 1986):

$$f\left(y_{it}|\lambda_{it},\alpha\right) = \frac{\Gamma\left(y_{it}+\alpha^{-1}\right)}{\Gamma(y_{it}+1)\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\lambda_{it}}\right)^{\alpha^{-1}}\left(\frac{\lambda_{it}}{\alpha^{-1}+\lambda_{it}}\right)^{y_{it}}, \qquad (1)$$

with $\lambda_{it} = \exp\left(x_{it}'\beta\right)$, where x_{it}' denotes a matrix of explanatory variables (including $DISCL_{i,t-1}$, $DISCL^2_{i,t-1}$, $LICCENTR_{i,t-1}$, $LICCENTR^2_{i,t-1}$, $BICENTR_{i,t-1}$, $logRD_{i,t-1}$, $logSIZE_{i,t-1}$, $TBREADTH_{i,t-1}$, $PATQUAL_{i,t-1}$, $PATSELF_{i,t-1}$, $AGE_{i,t}$, $DRUGS_i$, $YEAR_t$) and β denotes a vector of unknown parameters.

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Furthermore, as the panel character of our data with multiple observations per firm violates the standard assumption of independence between observations, we specify a maximum likelihood random effects negative binomial model in which the dispersion parameter is randomized such that $\frac{1}{1+\alpha_i} \sim Beta(r,s)$.

< Insert Table 4 about here >

Results and Discussion

Table 4 summarizes the estimation results. First, we find support for H_1 as the degree of a firm's voluntary information disclosure exerts an inverted U-effect on the number of new licensing deals (with a main term $\beta = 0.038$, $p = 0.211$ and a quadratic term $\beta = -0.020$, $p < 0.05$). Figure 1 illustrates this quadratic effect within the boundaries of the data (recall that voluntary information disclosure is mean-centered). Firms are worse off in terms of obtaining new licensing deals by disclosing either very little information or an abundant amount of information compared to firms that disclose information at moderate levels. In other words, there are two pitfalls of which firms should be aware as they disclose strategic information into the public domain in order to obtain new licensing deals. While voluntary information disclosure can reduce information asymmetry with potential licensees, giving away a large amount of strategic information into the public domain is again associated with fewer new licensing deals, arguably because it signals a lack of concern for confidentiality.

< Insert Figure 1 about here >

Second, we also find support for an inverted U effect of licensing centrality on the number of new licensing deals (with a main term $\beta = 0.136$, $p < 0.01$ and a quadratic term $\beta = -0.004$, $p < 0.01$), in support of H_2. Figure 2 illustrates this effect within the boundaries of the data: the inverted U is less pronounced, and the effect on the number of new licenses decreases only as

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licensor firms occupy very central positions in the licensing exchange network.[7] This corresponds to a firm's central position in the licensing exchange network signaling value in that the number of previous licensing deals signals the quality of a firm's knowledge base. However (given technological breadth of prior licensing deals, investments in R&D, and firm size), firms that are very centrally positioned in the licensing exchange network with a large number of past licensing deals obtain fewer new licensing deals than firms with moderate levels of licensing network centrality. This is consistent with the argument developed in H_2 that very central positions in the licensing exchange network raise doubts regarding uniqueness, which, in turn, hinders obtaining new licensing deals. However, we cannot exclude alternative explanations. For example, a resource-based perspective (e.g., Leonard-Barton, 1992) on this phenomenon might suggest that, as firms learn from past licensing deals, they develop procedures that enhance their licensing exchange capability. As experience becomes very high, these procedures may become so ingrained that they reduce flexibility and make the firm more rigid. We elaborate on such shortcomings of the present study in the limitations and conclusions section.

< Insert Figure 2 about here >

Third, we find support for H_3 that a firm's degree centrality in the board interlock network leads to more new licensing deals ($\beta = 0.025$, $p < 0.05$). As board members of a biotechnology firm serve on external boards of other firms in the biopharmaceutical industry, the biotechnology firm is more strongly embedded in the industry's social network, which ensures better information dissemination, reducing the information asymmetry with potential new licensees.

The coefficients of the control variables also provide some interesting insights. Firms that have signed previous licensing deals across a broader range of technological domains obtain

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[7] Note that, while Table 1 reports that the number of prior licensing deals ranges from 0 to 52, the licensing centrality variable used in the estimations ranges between -4.95 and 26.2 due to the 80% depreciation correction and mean-centering.

more new licensing deals ($\beta = 0.025$; $p < 0.10$). Furthermore, firms that invest more in R&D obtain more new licensing deals ($\beta = 0.192$; $p < 0.05$). Older firms sign fewer licensing deals ($\beta = -0.019$; $p < 0.10$). A compare means test shows that the few firms that have developed drugs in their lifetime are, on average, older than the other firms, which may point to a possible explanation for this effect.

< Insert Table 4 about here >

Robustness Tests

We estimate alternative models to verify the robustness of the reported results. First, to better understand the implications of some of the firms developing drugs of their own, we estimate models in which we interact the theoretical variables with the drug dummy variable. None of these interaction effects are significant. Second, we re-estimate the model using different knowledge depreciation parameters in reasonable ranges around 20%, but this also does not affect the results. Third, we explore the presence of interaction effects between several of the variables included in the model, such as between technological breadth and licensing centrality, but these interaction effects do not increase the explanatory power of the model and do not affect the substance of the conclusions derived above. Fourth, we include year dummy variables to account for industry shocks, but none were significant, and other results are not affected.

Theoretical and Managerial Implications

Theoretical Implications

The combined findings help understand why some dedicated technology firms obtain more licensing deals than others. Below, we categorize the main theoretical insights.

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1. Importance of both action and structure. Licensing exchange differs from other types of exchange because of the technological complexity, large numbers of technological opportunities in fast-moving fields, and uncertainty regarding the value of the licensed technology, which can cause substantial information asymmetry between licensors and licensees that can stand in the way of obtaining new licensing deals. On the one hand, licensors can deliberately disclose firm-specific strategic information into the public domain. The findings show that engaging in such purposeful action has consequences for signing new licensing deals. On the other hand, the network structures in which licensors are embedded also influence the number of new licensing deals they obtain, as the firm's network position has informational value to licensees. The network literature has pointed to the importance of firms' network positions in this regard. More precisely, the findings indicate that firms' positions in the licensing exchange network as well as the social network of board interlocks influence how many new licensing deals they obtain. The combined findings thus support the complementarities of the theories of agency and theories of structure in explaining economic action (Sewell, 1992).

2. Dark side of voluntary information disclosure. While the prior literature on information asymmetry and information disclosure has argued that disclosing strategic information is beneficial, a dark side has been overlooked. In the context of licensing exchange, the voluntary disclosure of strategic information conflicts with the concept of confidentiality. As licensors disclose too much information about their strategic position and pipeline, they make themselves less attractive because confidentiality and selective information disclosure are highly valued in the market of intellectual property. This line of reasoning may apply to any context where a desire for information can conflict with confidentiality concerns.

3. Licensing exchange is socially embedded. The 1980s witnessed a revival of economic sociology that urged a revised view on exchange in-between the classical/neoclassical economics

tradition and the sociological tradition that have developed independently since the beginning of the 20th century (Granovetter & Swedberg, 1992). The essential assertion of this "new economic sociology" is that, at all times, exchange is in some way both economic and social (Braudel, 1985; Granovetter, 1985; Macaulay, 1963). Scholars in diverse disciplines have subsequently examined the nature of social embeddedness in exchange and its consequences for firm performance, acknowledging that the social layer that pervades industry structures influences the attitudes and behaviors of economic actors. One important manifestation of this social layer is board interlocks. To the best of our knowledge, marketing scholars have ignored the board interlock phenomenon in the study of their principal subject matter—exchange. We provide empirical evidence that board interlocks have consequences for exchange. This also contributes to the board interlock literature where researchers have associated board interlocks with firm behavior such as adoption but rarely in the context of exchange. In addition, the contrasting arguments and empirical findings regarding the implications of board interlocks for firm performance have sharpened the distinction between opponents and proponents of this phenomenon. The finding that firms that are more centrally located in the board interlock network obtain more new licensing deals indicates that board interlocks are an expression of social capital that stimulates exchange; i.e., licensing exchange is socially embedded.

Implications for Managerial Practice

While the previous literature has mainly focused on the benefits of central network positions, centrality is no panacea. A too central position in the licensing exchange network leads to fewer new licensing deals, arguably because it reduces the (perceived) uniqueness. Managers of very centrally located dedicated technology firms should therefore advertise their investments in technological renewal and the novelty of the technology paths that the firm has recently followed.

The quadratic effect of information disclosure points to a paradox in technology markets. Disclosing strategic information can be useful in terms of bridging the information asymmetry with potential licensees, but it can also signal a lack of concern for confidentiality. In licensing exchange, firms thus ought to strike a balance between informing the market and assuring confidentiality. Dedicated technology firms should consider voluntary information disclosure as a tool in their communication strategies, while not employing it excessively because the deliberate choice not to reveal certain information items may signal quality and concern for confidentiality.

Finally, the analyses also provide some insights specifically of interest to dedicated biotechnology firms. For example, dedicated biotechnology firms obtain more new licensing deals if their previous licensing deals cover more technological domains. Even though the effect is weak, it suggests that dedicated biotechnology firms that 'dedicate' themselves to only one or a few technological domains have difficulty sustaining licensing success over time.

Limitations and Conclusions

Hopefully the findings related to board interlocks will inspire marketing scholars to single out this phenomenon and investigate its consequences for inter-firm exchange. More direct measures of information flows through board interlocks would advance this field. As to voluntary information disclosure, our study did not provide insight into licensee perceptions of licensor firms disclosing little or much information, nor did we examine the exact contents of the different information items. We only considered the public disclosure of information as opposed to information disclosure that is specifically targeted at selected industry participants. Furthermore, our interpretation of the curvilinear effect of licensing centrality on licensing success relies on arguments of status and uniqueness, neither of which was directly measured. Ahuja (2000) found a similar curvilinear effect of degree centrality on the formation of new inter-firm alliances

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among competitors, suggesting a saturation effect in that the required resources and coordination costs associated with many past alliances may at some point in time make firms reluctant to form any new alliances. While this line of logic is very specific to the context of strategic co-optation alliances and is unlikely to apply to the context of licensing exchange, measuring these unobservable factors more explicitly would allow for ruling out such alternative explanations.

Another limitation of this study is the restriction to degree centrality as the measure of an actor's position in a network. First, a firm's status may be a function not only of the number of its ties to partner firms but also of the status of these partner firms (e.g., Bonacich, 1972). A biotechnology firm that has signed five licensing deals with highly reputed pharmaceutical firms may send a stronger signal of status and quality than another that has signed five licensing deals with low-status pharmaceutical firms. We did not have accurate data to construct this centrality measure. Second, it would be useful to validate Mariolis and Jones' (1982) finding that degree centrality is the optimal operationalization in the context of information dissemination in the board interlock network. Other measures such as 'betweenness centrality' (Freeman, 1977) and 'closeness centrality' (Freeman, 1979) account for the firm's being on the shortest path distance between other actors and the firm's distance to all other actors, respectively. More comprehensive network data than those available for this study are required to construct these alternative centrality measures. Note that an advantage of examining degree centrality is that, even if it is less controllable than voluntary information disclosure, it can be influenced by the firm in the long run (as opposed to most of the more complex centrality measures).

To conclude, marketing studies on health industries and the biopharmaceutical industry in particular have focused on specific sets of industry actors, such as large pharmaceutical firms or physicians, while overlooking other players. This study draws attention to dedicated biotechnology firms, firms that are often accredited to be the engine of innovation in the

pharmaceutical industry. We have pointed to the specific character and economic significance of licensing exchange, which represents the major source of revenue for dedicated (bio)technology firms, and which should be more prominent on the research agenda of marketing scholars. We hope that, despite its limitations, this study raises enough questions to further this line of inquiry.

Envoy

As a final note, the importance of the board interlock phenomenon urges us to draw the reader's attention to a decade-old, yet vibrant debate in which opponents have pointed to a dark side of board interlocks: board interlocks can impede independent decision making and lead to economically suboptimal terms of exchange (e.g., see Mizruchi, 1996). Such critiques date back to the beginning of the 20th century, when Supreme Court Justice Brandeis, one of President Wilson's chief advisors, posited: "The practice of interlocking directorates is the root of many evils. […] it leads to inefficiency; for it removes incentive and destroys soundness of judgment" (Dooley, 1969). While we showed that board interlock centrality stimulates exchange (in terms of obtaining more new licensing deals), we also examined its additional effect on profitability in an exploratory fashion. We estimated a profitability equation—controlling for a firm's licensing deals (which is endogenous and was thus instrumented for)—and found that board interlock centrality has an additional negative effect on profitability (beyond its indirect positive effect on profitability through obtaining more new licensing deals). The combined insights offer a possible solution to the debate: board interlocks appear to *stimulate* exchange but at *inferior* exchange conditions. This assertion may inspire further research as it reconciles the seemingly contradictory arguments of both proponents and opponents of board interlocks.
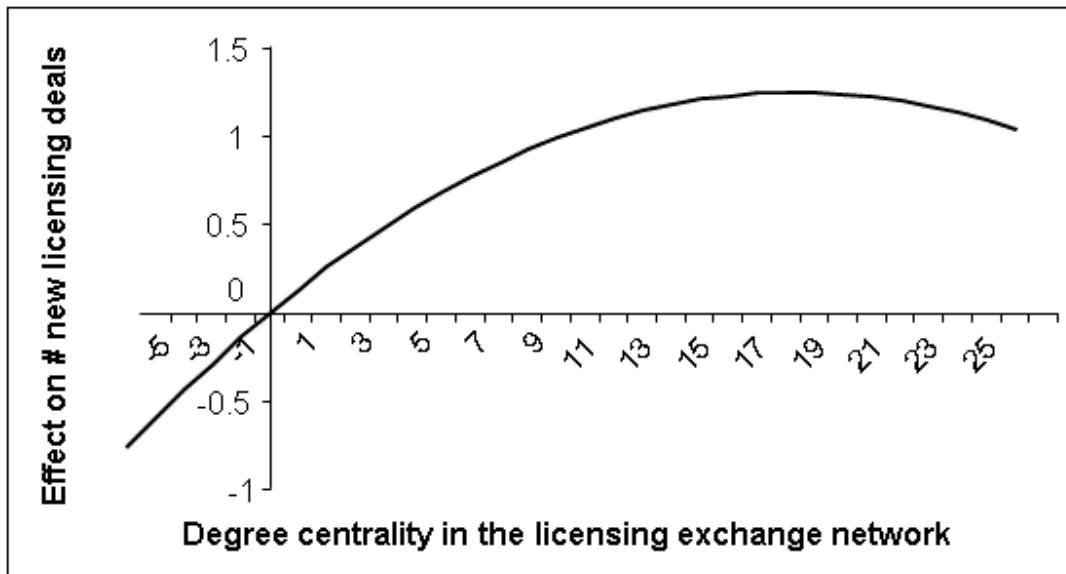
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Figure 1

The inverted-U effect of voluntary information disclosure on # new licensing

deals
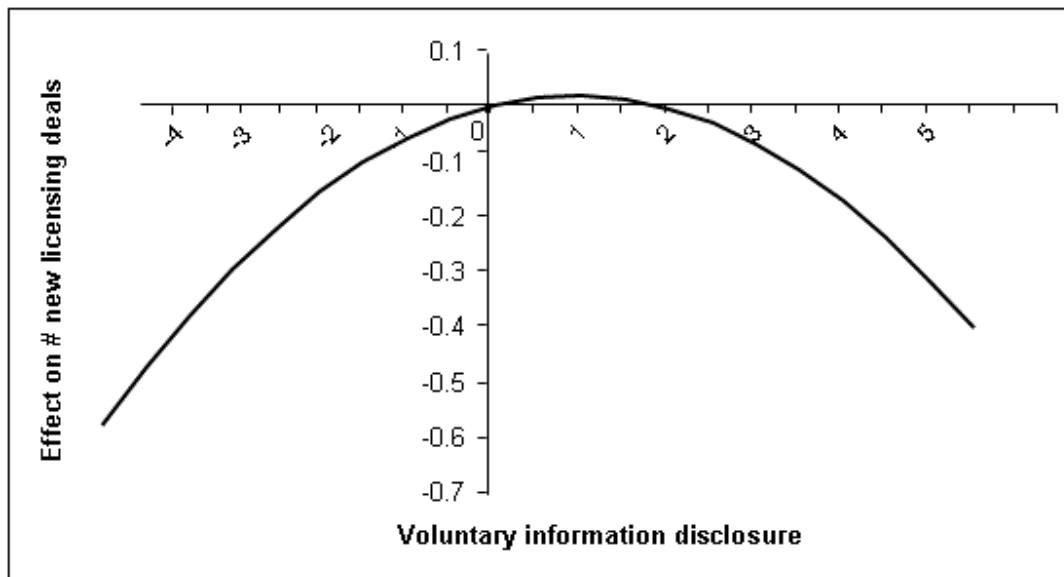
Figure 2

The curvilinear effect of degree centrality in licensing exchange network on #

new licensing deals

Table 1

Summary table: description and expectations regarding antecedents of # new licensing deals

Variable	Description	Measure (source)	Expected effect	Finding
Voluntary information disclosure	The firm's voluntary (i.e., intentional) action of disclosing firm-specific strategic information	# disclosed information items, lagged one period (SEC)	∩ (H1)	∩
Licensing centrality	The firm's degree centrality in the licensing exchange network (where ties are defined by licensing deals)	Cumulative # licensing deals from the inception of the firm, depreciated over time, lagged one period (Recap)	∩ (H2)	∩
Board interlock centrality	The firm's degree centrality in the industry's social network (where ties are defined by board interlocks)	# board interlock ties, lagged one period (Recap)	+ (H3)	+
Log(R&D investments)	The degree to which the firm invests in research and development activities	Log of R&D expenditures, lagged one period (SEC)	+	+
Log(Firm size)	The size of the firm	Log of # employees, lagged one period (SEC)	-	n.s. (-)
Technological breadth	The scope of technological domains covered by the firm's licensing deals	Cumulative # technological domains in which the firm has signed licensing deals from its inception, lagged one period (Recap)	+	+
Quality-weighted patents	The quality of the firm's internal knowledge base	# patents weighted with average received patent citations, lagged one period (NBER)	+	n.s. (+)
Self-citations	Degree to which the firm relies on its own proprietary knowledge for developing new knowledge	Average proportion of patents cited that are the firm's own, lagged one period (NBER)	-	n.s. (-)
Age	The age of the firm	# years that the firm exists (firm websites)	-	-
Drugs	The propensity of the firm to develop its own drugs	Dummy indicating whether (1) or not (0) the firm has had any drugs approved in its lifetime	-	n.s. (-)
Time	Captures industry-specific time trend in the number of new licensing deals	Year t	+/-	n.s. (-)

Table 2

Sample descriptors

Variable	Minimum	Maximum	Mean	Standard deviation
New licensing deals	0	15	1.76	2.38
Voluntary information disclosure[§]	4	14	8.80	2.01
Licensing centrality[§§]	0	52	9.11	8.15
Board interlock centrality	0	21	4.49	4.08
Log(R&D investment)	11.62	20.53	16.58	1.17
Log(Firm size)	0.96	3.81	2.15	0.52
Technological breadth	0	30	7.03	4.38
Quality-weighted patents	0	631.85	10.37	43.33
Self-citations	0	50	0.08	0.11
Age	0	39	12.42	5.62

[§§] before mean-centering
[§] before knowledge depreciation and mean-centering

Table 3

Correlations (N = 474)

	#LIC DEAL$_{i,t}$	DISCL$_{i,t-1}$	LIC CENTR$_{i,t-1}$	BI CENTR$_{i,t-1}$	logRD$_{i,t-1}$	logSIZE$_{i,t-1}$	TBREADTH$_{i,t-1}$	PAT QUAL$_{i,t-1}$	PAT SELF$_{i,t-1}$	AGE$_{i,t}$	YEAR$_t$
Number of new licensing deals (#LIC DEAL$_{i,t}$)	1										
Voluntary information disclosure (DISCL$_{i,t-1}$)	**0.16**	1									
Licensing centrality$_{depreciated\ \varphi}$ (LIC CENTR$_{i,t-1}$)	**0.70**	**0.20**	1								
Board interlock centrality (BI CENTR$_{i,t-1}$)	**0.23**	-0.06	**0.22**	1							
Log R&D (logRD$_{i,t-1}$)	**0.47**	**0.14**	**0.58**	**0.25**	1						
Log firm size (logSIZE$_{i,t-1}$)	**0.41**	**0.25**	**0.55**	0.09	**0.77**	1					
Technological breadth (TBREADTH$_{i,t-1}$)	**0.48**	**0.19**	**0.70**	**0.13**	**0.47**	**0.49**	1				
Quality-weighted patents (PAT QUAL$_{i,t-1}$)	**0.16**	0.08	**0.21**	-0.09	**0.29**	**0.27**	0.11	1			
Self-citations (PAT SELF$_{i,t-1}$)	-0.02	0.11	0.09	**-0.18**	0.07	**0.13**	**0.20**	**0.18**	1		
Age (AGE$_{i,t}$)	-0.00	**0.13**	0.11	-0.09	0.03	**0.28**	**0.26**	**0.13**	**0.30**	1	
Year (YEAR$_t$)	0.09	-0.02	0.10	**0.25**	0.04	0.00	**0.12**	**-0.35**	-0.02	0.05	1

Correlations in bold are significant at 0.05

Table 4

Drivers of # new licensing deals:

Random effects negative binomial estimation results (N = 474)

Variable	Coefficient (standard error)
(Voluntary information disclosure $_{i,t-1}$)	0.038 (0.030)
(Voluntary information disclosure $_{i,t-1}$)^2	-0.020 (0.009) **
(Licensing centrality$_{i,t-1}$)	0.136 (0.023) ***
(Licensing centrality$_{i,t-1}$)^2	-0.004 (0.001) ***
Board interlock centrality$_{i,t-1}$	0.025 (0.012) **
Log(R&D$_{i,t-1}$)	0.192 (0.086) **
Log(firm size$_{i,t-1}$)	-0.071 (0.190)
Technological breadth$_{i,t-1}$	0.025 (0.015) *
Quality-weighted patents$_{i,t-1}$	0.001 (0.001)
Self-citations$_{i,t-1}$	-0.819 (0.583)
Age$_{i,t}$	-0.019 (0.011) *
Drugs$_i$	-0.075 (0.130)
Year$_t$	-0.016 (0.039)
Constant	29.608 (78.761)

 * $p<0.10$
 ** $p<0.05$
*** $p<0.01$

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