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Licensing decision: a rent dissipation lens applied to product market competition, openness to external knowledge and exogenous sunk costs

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Abstract

The fear of rent dissipation has been proposed as the main reason firms are hesitant to enter markets for technology. In this paper we investigate conditions under which firms are particularly reluctant to out-license their technologies due to shifts in the relative magnitudes between potential rent dissipation and revenue effects. Specifically, we offer theoretical arguments and empirical evidence suggesting that firms operating under higher product market competition are more reluctant to license their technologies. Firms' openness to external knowledge, while having a direct positive association with greater licensing rates, also partially mitigates the negative effect of increasing product market competition. Exogenous sunk costs, however, increase firms' reluctance to out-license and also further fuel the negative association between out-licensing and product market competition. The empirical investigation builds on a sample of 227 licensors involved in licensing contracts in the US pharmaceutical industry from 1986 to 2005. The study has substantial implications for management, research, and policymakers.

JEL classification: L24, L65, O32

1. Introduction

Technology licensing offers firms strategic benefits, including learning opportunities (Leone and Reichstein, 2012; Leone *et al.*, 2016; Laursen *et al.*, 2017; Moreira *et al.*, 2018) and monetary gains (Kulatilaka and Lin, 2006; Sakakibara, 2010; McCarthy and Ruckman, 2017). Yet, often firms are reluctant to out-license their technologies and those that do often only select a few of their technologies for licensing. In fact, licensors' reluctance to commercialize technologies through licensing is among the main reasons that markets for technology fail to achieve their full potential (Arora and Fosfuri, 2003; Arora and Gambardella, 2010). Improving our understanding of the way markets for technology work constitutes an important contribution to the licensing and innovation literature. Well-functioning markets for technology not only allow firms to strategically generate rents from R&D investments but also facilitate the access and dissemination of new technologies within and across industries.

In this paper, we explore product market and firm-level conditions under which firms are more or less likely to engage in technology out-licensing. We start by focusing on the effect that product market competition may have on firms' licensing strategy. Then, we expand our analysis by examining the effect that openness to external knowledge and exogenous sunk costs have on firms' licensing behavior.

We build on the idea that fear of rent dissipation is one of the main reasons why firms are reluctant to commercialize their technologies. In the technology licensing literature, rent dissipation refers to *loss of market share* or *reduced price cost margins* caused by increased market competition generated from technology out-licensing (Arora and Fosfuri, 2003). In giving a licensee access to an internally developed technology, a licensor may be providing access to intellectual assets that allow the licensee (or other firms partnering with the licensee) to move into or strengthen its position in the licensor's product market(s) (Laursen *et al.*, 2017). At the extreme, the licensor may lose control of the licensed technology (Zhang and Baden-Fuller, 2010) and become dependent on the licensee to generate revenues.

Given the economic importance of markets for technology, understanding the factors that constrain and enable firms' licensing behavior is paramount. Prior studies have quantified the size and the increasing trend of the markets for technology during the past two decades. In particular, a survey by the British Technology Group (1998) quantified the size of the market for technology in North America to be $25 billion, the one in Europe to be $6.6 billion, and the one in Japan to be $8.3 billion, by using transaction data. Arora and Gambardella (2010) estimated that, from 1985 to 1997, there were 15,000 agreements in the markets for technology with a value of $330 billion, which means an average of almost 1150 transactions worth $27 billion per year. Athreye and Cantwell (2007) analyzed the trends in international royalty and licensing revenues, quantifying the world market of technology at $55–60 billion in the mid-1990s and $90–100 billion in 2000. Using confidential tax data, Robbins (2006) estimated that the size of the technology market was about $27.4 billion for 1995, $29.4 billion for 1996, and $31.8 billion for 1997. Finally, a study by the World Intellectual Property Organization (2011) determined that international royalty and licensing fees had risen from $27 billion in 1990 to $180 billion in 2009. Despite its economic importance, our understanding of how market and firm characteristics affect the way markets for technology work is still limited.

Only a few papers have investigated rent dissipation effects in a technology licensing context. For example, Arora and Fosfuri (2003) suggest that firms with downstream assets weigh rent dissipation against revenues from licensing deals when deciding whether to out-license a technology. Their study indicates that licensing may allow firms to increase their share of industry profits while imposing negative externalities upon other incumbents operating in the same market. More recent evidence suggests that high heterogeneity among firms within the same industry reduces the extent to which licensors will experience rent dissipation (Gambardella and Giarratana, 2013). To our knowledge, only Fosfuri (2006) investigates *empirically* how rent dissipation may be associated with firms' licensing behaviors. This study finds a curvilinear relationship between the rate of technology licensing and the number of potential technology suppliers.

Other supply-side factors may affect markets for technology. For example, licensor characteristics such as size and prestige can have an impact on licensing rates (Ruckman and McCarthy, 2017). Furthermore, when technological knowledge is tacit and context-specific, firms may find it difficult to transfer and commercialize their technologies (Arora *et al.*, 2001). Another condition limiting the growth of technology markets concerns technology holders' lack of organizational capabilities to produce technologies that can be commercialized in different downstream markets (Gambardella and Giarratana, 2013). Also, when licensors do not have the capabilities to develop general-purpose technologies, the scope of applications of licensable technologies may be too narrow (Novelli, 2015) and, consequently, the potential market too small. To the best of our knowledge, no prior study has focused on product market competition, openness to external knowledge, and exogenous sunk costs as relevant contingencies to predict the function of markets for technology. This is surprising, because these are firm-related characteristics that can affect the development of markets for technology (Arora *et al.*, 2001; Gans and Stern, 2003; Gambardella and Giarratana, 2013).

Prior studies have examined how competition among technology holders affects rates of technology licensing (e.g. Fosfuri, 2006). Our approach is focused on how downstream competition between firms in the product market shapes out-licensing strategy. While competition among technology holders has been shown to have a curvilinear effect on observed licensing rates, we propose that product market competition will have a negative effect on firms' decision to license. Additionally, we explore two novel contingencies related to licensors to explain the conditions under which firms will be more, or less, likely to commercialize their technologies. In the first case, we combine the

open innovation and market for technology literature to argue that openness to external knowledge (Chesbrough, 2006) will affect firms' perceived benefits of out-licensing. Second, grounded on Sutton's (1991) work, we propose that exogenous sunk costs will push firms away from the supply side of markets for technology due to less flexibility in dealing with the potential increase in downstream competition triggered by competitors having access to the licensor's technological assets.

Investigating the role of potential rent dissipation on firms' licensing behaviors requires comprehensive data on technology licensing, combined with longitudinal data on technology and firm conditions. In order to test our hypotheses empirically, we combine three databases. We start with a sample of 2427 firms drawn from the Deloitte Recap database from 1986 to 2004. We extract the technology licensing contracts related to these firms to create a panel showing each licensor's yearly licensing activity. We supplement this information on firms' licensing activities with data from Compustat and the United States Patent and Trademark Office (USPTO). Our hypotheses are tested in a longitudinal setting using both negative binomial and logit models with firm- and year-fixed effects. The empirical analysis provides overall support for the hypotheses, suggesting that increasing levels of market competition led to decreased licensing rates among the firms in our sample. Additionally, we find that openness to external knowledge positively moderates this main relationship, while exogenous sunk costs moderate it negatively.

2. Theoretical background

The proliferation of markets for technologies and ideas in recent decades has increased the number of opportunities and strategies available to companies (Arora and Gambardella, 2010). Through technology licensing, companies can generate revenue through up-front fees and royalties from selling the rights to use their intellectual property. This is called the *revenue effect*. Surveys conducted by Gambardella *et al.* (2007) and Zuniga and Guellec (2009) show that the revenues generated from licensing represent one of the main motivations for selling a technology (Arora and Fosfuri, 2003). Despite the potential strategic benefits of technology licensing from an economic point of view, the licensing decision implies a trade-off. The out-licensing of technology can reduce the licensor's market share or price cost margin via additional competition in the product market.

The practice of licensing is likely to increase the competition within a licensor's technological niche, as licensing gives potential competitors access to technological knowledge that may prove important in that niche. Well-designed contracts specifying lump sums and royalty rates could be used to account for licensors' risk of rent dissipation (Choi, 2002; Laursen *et al.*, 2017). However, licensing contracts are incomplete by nature (Aghion and Tirole, 1994), as they fail to account for all eventualities that may accrue from the practice of giving away valuable technological knowledge. Indeed, despite the fact that licensing contracts involve the transfer of existing and codified technologies, it is very hard to specify *ex ante* all knowledge assets that will be involved in the deal. For example, licensing contracts often involve the transfer of tacit knowledge (Lowe, 2006; Conti *et al.*, 2013) or are embedded in other forms of more complex inter-organizational agreements (Klueter *et al.*, 2017). Furthermore, the uncertain trajectory inherent to some technologies makes it difficult to specify the protection scope of innovations derived from the transferred knowledge (Choi, 2002; Laursen *et al.*, 2017). One alternative is to set high up-front payments or royalties. However, the resulting increased cost of in-licensing would erode the demand side of the market for technology.

While several studies examine questions related to the revenues generated from technology licensing (Wang, 1998; Choi, 2002; Sakakibara, 2010; Leone *et al.*, 2015), empirical research on the role of rent dissipation is scarce. It is important to consider the circumstances under which the expected *rent dissipation* is likely to be stronger in order to understand the main reasons firms are shying away from licensing and, in turn, blocking the further development of markets for technology. The fear of licensees building on a licensor's in-house technological knowledge can block the supply of technologies in the market (Laursen *et al.*, 2017). Because the fear of rent dissipation is likely to shape licensing behavior, we explore heterogeneity on the supply side of the market in order to understand the conditions under which licensors are more or less likely to engage in out-licensing.

In what follows, we develop hypotheses concerning the association between technology licensing behaviors, on one side, and product market-, technology-, and investment-related conditions, on the other. We thereby open up the possibility that licensors may exhibit heterogeneous responses to the fear of rent dissipation. We argue that, even if dissipation can be counterbalanced with revenues, given the incomplete nature of licensing contracts, the perception of the risks involved in licensing will differ across licensors. We draw on rent dissipation-related arguments to

formulate testable hypotheses and shed light on relatively unexplored organizational and market contingencies affecting the licensing decision.

2.1. Hypothesis development

2.1.1. Product market competition

The decision of firms to license their technologies to other potential competitors is dependent on the firms' position in the product market. This decision involves comparing the revenue from the licensing deal with the potential rent dissipation that they may experience owing to additional competition in the product market (Arora and Fosfuri, 2003). The difference between the direct revenues and the expected rent dissipation is one of the benefits (costs) associated with licensing (Conti *et al.*, 2013). It therefore becomes relevant to ask if the expected net gain/loss depends on the level of product market competition to which the firms already are exposed *ex ante* licensing.

By focusing on the effect that product market competition has on licensing rates, we build on the observation that in competitive product markets, a large number of firms fiercely compete to supply products or services to the same customers (Varian, 2010). Accordingly, we expect that competition will affect firms' expectations regarding rent dissipation, which should affect their decision to allow other firms to access technologies developed in-house through licensing deals.

There are several arguments for why firms may weigh dissipation more heavily in more severe competitive environments than in settings with low competition. Operating in more competitive product markets puts greater strain on firms' profit margins, leaving less room to manouvre. As a result, firms become more aware of their profit margins and avoid strategies that might threaten profits further. Accordingly, in a scenario of intense competition, firms will only out-license their technology if the contract specifies an attractive pecuniary reward (Choi, 2002). Indeed, if licensors become more sensitive to potential competitive threats emerging from other incumbents using their technology, they are likely to request stringent remuneration conditions in the form of royalties and up-front payments. However, more stringent remuneration conditions lower the number of potential licensees and may reduce the chances of finding a match in the market for the technology (Choi, 2002).

Competitive markets also exhibit higher uncertainty related to the industry's future technological developments. For example, product market competition has been shown to be positively correlated with firms' innovation output and R&D expenditure (Blundell *et al.*, 1995; Geroski, 1995; Nickell, 1996). Increasing R&D expenditure is expected to lead to a larger number of different technologies brought to the market, making existing competitive advantages less stable. As a consequence, competition not only makes it harder for incumbents to foresee future competitive patterns shaped by emergent technologies but also makes the lifespan and usability of existing technologies in their portfolio less predictable (Toh and Kim 2013). When the competitive landscape becomes less predictable as an effect of downstream competition, firms will be more reluctant to grant others the rights to use their technologies. Despite the fact that uncertainty can be partially incorporated into licensing deals through contractual clauses (Laursen *et al.*, 2017), such clauses can also lower licensees' incentives to engage in in-licensing, leading to fewer deals.

Furthermore, a licensor that sells a core technological asset is likely to create (new) competitors who offer products that share similarities with the licensor's own products more than with the existing competitive offerings. Thus, any future reductions in profits owing to increased market competition among firms in the market may, for this reason, not be evenly distributed (Arora and Fosfuri, 2003); instead, such reductions are likely to be concentrated on the licensor and have a scant effect on the profits of other firms in the market. For the licensor, the dissipation effect may be much greater than the potential pecuniary gain, as the profit loss of its competitors can be comparably limited. Only in the unlikely extreme in which cross-firm products are perfect substitutes would loss in revenue be equal across all competitors in the product market.

Finally, increased competition is also associated with a *market share shift effect*, where increasing product market competition is associated with firms experiencing greater shifts in market share (Hymer and Pashigian, 1962; Caves and Porter, 1977; Baldwin *et al.*, 1998). In other words, market shares tend to be less rigid in more competitive product markets. Therefore, the dissipation effect may be lower in less competitive product markets with more stable market shares. In less competitive markets, it is more difficult to capture the market shares of incumbents/competitors. Under these conditions, firms may perceive that the revenue effect exceeds the dissipation effect and, thus, favors out-licensing.

While prior studies have empirically examined the effects of competition among technology holders on the rate of technology licensing (Fosfuri, 2006), the question remains whether competition in the product market is relevant to understand firms' licensing behavior. In the first case, a higher rate of technology licensing is expected owing to the fear that a refusal to out-license will lead to negative externalities originating from deals being realized by holders of a similar technology. Building on a different set of mechanisms, we propose that the fear of rent dissipation can be understood by taking into account the fact that licensors perceive technology licensing to be riskier if other firms are likely to use it to erode their positions in the product market. We propose the following:

Hypothesis 1: Higher product market competition is associated with fewer out-licensing deals by a firm.

2.1.2. Licensors' openness to external knowledge

Firms' openness to external knowledge can reduce internal R&D costs and boost innovation activities (Chesbrough, 2006). Even so, some firms choose not to engage in open innovation activities, either for strategic reasons (Giarratana and Mariani, 2014) or because they suffer from conditions such as the not invented here (NIH) syndrome (Katz and Allen, 1982). Therefore, firms vary greatly in terms of the degree to which they are open to external knowledge sourcing. In a similar vein, we also see substantial variations in the degrees to which firms make use of technology in-licensing as a means for external knowledge sourcing (Conti *et al.*, 2013; Laursen *et al.*, 2017). But, what about the association between firms' openness to external knowledge and out-licensing behavior?

Although prior studies have examined licensing decisions mostly from the perspective of pecuniary incentives (Cebrián, 2009; Sakakibara, 2010), among the benefits that licensors may experience is also the possibility to engage in knowledge exchange and learning from licensees (Choi, 2002). Licensors can access the developments built by the licensee on the licensed technology emerging from a licensing deal through direct and indirect knowledge spillovers (Laursen *et al.*, 2017). In the first case, contractual specifications (e.g. the grant-back clause) can require the licensee to share with the licensor any future improvement that is made on the licensed technology (Choi, 2002). In this way, licensors will have access to new technologies that come out of the licensing deal without incurring further internal R&D costs. In the second case, licensors can also benefit from absorbing unintended or indirect knowledge spillovers related to the licensed technology. If the licensee brings a new technology to the market on the basis of knowledge acquired through licensing, licensors are more likely to also reap learning benefits from this technology, as it is likely to be closely related to their own technological portfolio.

In this context, licensing may be translated into long-term pecuniary benefits through cost reductions by increasing R&D efficiency and generating revenue by the development of new products connected to the knowledge acquired from licensees. This means that the more a licensor is open to external knowledge, the more weight it will put on the potential revenue effect originating from licensing. Therefore, technology holders who are open to external knowledge are better able to incorporate pecuniary and nonpecuniary gains related to learning opportunities and knowledge acquisition from licensing deals. We argue that this will then translate into more licensing deals.

Firms that perceive external knowledge as valuable are more likely to consider out-licensing as a means to further develop their technologies through outsiders (Choi, 2002; Leone and Reichstein, 2012; McCarthy and Ruckman, 2017). Therefore, one motive for licensing may be to leverage the resources of external partners to obtain competitive advantages in a technology (Ahuja *et al.*, 2013). In fact, firms that are more open to external knowledge are more likely to search in their industry's technological space, which makes them aware of existing knowledge and technologies held by other organizations (Laursen *et al.*, 2010). As a consequence, firms that are more open to external knowledge are also better able to evaluate their existing technological portfolio *vis-à-vis* competitors and potential partners. In terms of licensing strategic choices, openness allows firms to strategically select technologies to commercialize that will not compromise their competitive advantage. In line with the open innovation arguments, this strategy not only decreases R&D costs but also increases the scope and diversity of licensors' searches in the technological landscape (Fleming, 2001).

Despite the potential strategic benefits of tapping into external knowledge sources, not all firms may value that strategic option in the same way (Chesbrough, 2006; Giarratana and Mariani, 2014). Firms may systematically reject external knowledge for different reasons (Veugelers and Cassiman, 1999) and, hence, to a lesser degree, consider the learning of and access to external knowledge through licensing a strategic option. For example, Giarratana and Mariani (2014) argue that when firms face the risk of other organizations imitating their core knowledge and

capabilities, they will reduce their openness to external sources of knowledge. Eventual disproportionate focus on internal R&D, at the expense of external knowledge sourcing, can have performance implications for firms. A strong focus on internal R&D can create a sense of technological superiority and prevent firms from considering the learning potential in out-licensing their technological assets; this may hamper their technology licensing behaviors. Thus, firms that are more focused on internal knowledge generation, to the detriment of their access to external knowledge, may be much less inclined to license, as they are not equipped to reap the associated potential innovation advantages, meaning that the perceived dissipation effect is more likely to exceed the potential gains (Monteiro *et al.*, 2017).

Firms that are less open to external knowledge are also more likely to have a portfolio of licensable technologies that primarily builds on their in-house–generated technological knowledge (Agrawal *et al.*, 2009), which translates into being more vulnerable to the dissipation effect when choosing to out-license. It is likely that their prior technological achievements are embedded in their new technologies, making these firms even more vulnerable to the dissipation effect. Such firms risk not only the potential dissipation of knowledge of a single licensed core technology but also the rent dissipation of other technologies generated in-house and embedded in similar technological knowledge. Based on the above arguments, we propose the following:

Hypothesis 2a: Openness to external knowledge is associated with more out-licensing deals by a firm.

Two of the core mechanisms that play a key role in reducing firms' inclination to out-license when competition in the market becomes too fierce may be partially mitigated for licensors who are more open to external knowledge. As suggested above, firms that are open to external knowledge are more likely to take into account the potential nonpecuniary benefits associated with the learning of and access to the licensee R&D investments. This means that the balance between potential loss and gains related to a licensing deal can switch. Even if increasing market competition pushes firms to give more weight to the potential loss coming from technology licensing, this inhibiting effect can be compensated if licensees perceive potential nonpecuniary gains coming from access to external knowledge. This counterbalances the negative effect of competition that pushes licensors away from the markets for technology.

Additionally, firms with a more diverse technological portfolio and access to heterogeneous sources of knowledge are better equipped to deal with uncertainty and technological discontinuities in their environments (Fernhaber and Patel, 2012). This means that firms that are able to learn from licensing deals are also equipped to deal with the technological uncertainty caused by increased competition. Firms that are open to accessing external knowledge can use technology licensing as an additional source of knowledge variety, which, in turn, helps them to add diversity to their existing portfolio. For these reasons, we expect openness to external knowledge to not only increase firms' average rates of technology licensing but also reduce the negative effect of increasing product market competition on firms' licensing behavior. Thus, we propose the following:

Hypothesis 2b: Openness to external knowledge positively moderates the association between product market competition and the number of out-licensing deals of a firm.

2.1.3. Exogenous sunk costs

Firms may be subject to sunk costs that, once incurred, cannot be recovered. In general, rationally firms should not allow sunk costs to affect their behavior. However, behavioral economics suggests that loss averseness and framing effects may cause irrational behaviors, in which decisions may be based on incurred sunk costs (Tversky and Kahneman, 1981), leading to what has been termed the *sunk-cost effect* (Arkes and Blumer, 1985). This effect concerns the tendency of decision-makers to continue pursuing an action once they have invested money, effort or time, even when this pursuit may lead to suboptimal economic decisions. Taking into account sunk costs when making decisions may also be rational when the firm is facing uncertainty (Dixit, 1989; Dixit and Pindyck, 1994; Ghosal, 2010), which is particularly the case in industries where R&D and technology development are essential for performance and licensing activities; hence, this is more likely to be part of the firms' strategies.

Sutton (1991) distinguished between exogenous and endogenous sunk costs. An endogenous sunk cost (e.g. R&D or advertisement) may have a direct impact on the demand for the firms' products in the future by enhancing consumers' willingness to pay for the firms' product. Therefore, it entails an escalation of competition. In the context of technology licensing, out-licensing may be a means through which firms seek to transform sunk costs, such as R&D, into regular investments on which they can capitalize so that these costs are no longer sunk. An exogenous sunk cost, on the other hand, involves

acquiring a plant of minimum efficiency scale and developing and setting up a production line—activities that have little impact on the consumers' future willingness-to-pay for the firms' product. The endogenous sunk costs, in particular R&D spending, obviously seem to be positively related to out-licensing. But what about the exogenous sunk costs.

Investment in exogenous sunk costs may, in itself, suggest a shift in strategic focus from revenues based on technological assets to revenues based on formal production. Larger exogenous sunk-cost investments may suggest a reorientation in terms of the value chain of being a technology provider. They may also serve the market directly, as exogenous sunk costs often entail investment in assets that are oriented toward production. Investment in exogenous sunk costs may therefore be a strategic choice by firms that shy away from dissipation effects and, hence, away from licensing.

The dissipation effect may also pose a stronger threat to firms with higher exogenous sunk costs, as exogenous sunk costs pose a problem only if a firm fails. The potential dissipation effect represents a threat to a firm and its position, which is even more severe when higher exogenous sunk costs are incurred. This makes a firm more reluctant to out-license its technologies in an attempt to avoid greater competition and, indirectly, the likelihood of failure.

Investments in exogenous sunk costs may also signal the pursuit of strategies to build entry barriers (Dixit, 1979; Porter, 2008). Firms may use their investments to signal commitment, and such signals will be even stronger if their investments are sunk. Other firms, and in particular follower firms, may interpret these investment choices as signs of poor profitability in the product market in the case of entry. Normally, the incumbent builds up an instrumental infrastructure for the purpose of fighting off potential competition through offensive price strategies. While this translates into lower fear of the dissipation effect among the potential licensors, it also translates into a lower number of prospective licensees, if a firm has incurred larger exogenous sunk costs, making it more difficult to find an appropriate licensee for the developed technological asset. Based on the above, we propose:

Hypothesis 3a: Higher exogenous sunk costs are associated with fewer out-licensing deals by a firm.

There are numerous reasons to invest in exogenous sunk costs (Sutton, 1991). In competitive markets, however, the main reason is for the firm to compete on serving the product market and to compete more forcefully on getting products to market in the right quantum and at the right time. This suggests that the firm has confidence in the offered product and its qualities as a competitive asset. In competitive markets where firms are operating under lower margins, firms will take on such exogenous sunk costs only if they believe their product, and, hence, its underlying technology, is core and will represent a competitive advantage well into the future. Accordingly, they will be more hesitant to license their technological assets, as they otherwise would be risking dissipation effects on their core assets.

For firms operating in very competitive product markets, aversion to loss may be even higher, as potential losses in the form of possible exits may appear more imminent and, hence, more threatening. For this reason, the effect of exogenous sunk costs may be stronger in product markets characterized by intense competition. Both incumbent and follower firms tend to expect lower profit margins from their assets when product market competition is higher. The potential for an imminent exit, in the face of renewed competition, is more likely under these conditions. As a result, the threat of loss in the face of exogenous sunk costs is stronger. It is, therefore, even more likely for exogenous sunk costs to affect decisions under these circumstances, which may precipitate a dissipation effect for the firm.

This mechanism is enhanced by the *market share shift effect*: market shares are more fluid in a competitive product environment. Besides causing firms to operate at smaller profit margins and, hence, making them more vulnerable to shifts in relative competitiveness, the escalating competitive pressure also leads to greater shifts in the market shares of firms. This puts greater pressure on firms that have left themselves more exposed owing to investments in exogenous sunk costs, which may cause those firms to shift their attention to the dissipation effect as opposed to the potential revenues gained from licensing. For these reasons, we propose:

Hypothesis 3b: Exogenous sunk costs negatively moderate the association between product market competition and the number of out-licensing deals of a firm.

3. Data, variables, and methodology

3.1. Sample selection and data

The research setting for this study is the global pharmaceutical industry. Several characteristics of the pharmaceutical industry make it a useful empirical setting for testing the relationship between the rate of technology licensing and our variables of interest. First, licensing is one of the most frequent methods of technology transfer among

pharmaceutical companies. Therefore, it provides an empirical context in which licensing contracts are not restricted to a small number of firms but are used widely as a mechanism of knowledge transfer. Second, the pharmaceutical industry is characterized as both technology-driven and research-intensive, making technological knowledge critical for developing and sustaining competitive advantage (Roberts, 1999). These characteristics imply an industry in which the markets for technology are well developed, thus facilitating technology transactions via licensing contracts. Focusing on the pharmaceutical industry represents a trade-off between generalizability and the exactness of estimates. However, given the scarcity of empirical evidence on this topic, we believe the purposeful choice of this industry to be appropriate for shedding light on an important aspect of technology licensing.

The data used to develop the empirical analyses come from three different sources. First, we used *Compustat North America* to obtain a sample of firms operating in the pharmaceutical industry in the period from 1986 to 2005. We defined our sample on the basis of all the firms listed in two Standard Industrial Classification (SIC) codes: 2834 Pharmaceutical Preparations and 2835 In Vitro and in Vivo Diagnostic Substances.[1] Confining the analysis to firms operating in these SIC codes reduced concerns related to cross-firm differences in licensing rates owing to industry-level characteristics in licensing activities and practices. We also used the financial information from *Compustat* to compute part of the variables used in our empirical analysis. Second, we used the Deloitte Recap database to track the out-licensing behavior of the sampled firms. The Recap database is one of the most accurate sources of information regarding partnerships in the pharmaceutical industry (Audretsch and Feldman, 2003; Schilling, 2009). It also provides access to precise information regarding the nature of licensing contracts, the names of the licensors, and the dates on which the contracts were signed. Third, we obtained information on the patenting activity of licensors from the National Bureau of Economic Research (NBER) patent database.

The focus on public firms listed on *Compustat* reduced the potential for missing or unreported licensing activity. Furthermore, Recap is compiled on the basis of press releases, Securities and Exchange Commission (SEC) contracts, analysts' reports, clinical trials, and requests submitted under the Freedom of Information Act (FOIA). These sources provide extensive coverage of listed firms, thus reducing concerns regarding unreported contracts.

As the next step, we scrutinized Recap to identify out-licensing activities for publicly listed pharmaceutical firms in our sample. When searching for licensing deals, we considered only licensing deals between *firms* and not licensing deals between, for example, firms and universities. Contracts in which the licensee is a university are likely to be associated with a different decision pattern, as university partners are unlikely to cause potential problems of rent dissipation.

We identified 283 unique firms that had *at least one licensing deal* in the period covered in our analysis.[2] This data set is unbalanced, as not all financial information was available for all years for all firms. We observed 227 firms for which all the financial variables of interest were available for at least three periods. This resulted in a total of 2427 firm-year observations, with an average of 10.7 observations per firm (min = 2, max = 21). After linking these databases at the licensor-year level, we observed that the minimum number of licensing contracts in which a licensor was involved in a given year was zero and that the maximum was eight. Considering all the years covered, we observed that around 52% of the firms in the sample out-licensed at least twice. The total number of licensing contracts observed during the period covered by the data was 1040, with approximately 28% of the year-firm observations differing from zero. We then used the *Compustat* firm identifier (GVKEY) to connect the licensors in the sample with the NBER U.S. Patent data file. To ensure accurate matches, we manually checked each individual GVKEY match between the *Compustat* and NBER data sets. Connecting those two databases allowed us to access the licensors' patenting activity over time.

The final data set included 2427 licensor-year observations covering 227 firms tracked from 1986 to 2005.

3.2. Measures

3.2.1. Dependent variable

3.2.1.1. Rate of technology licensing. We measured the dependent variable in two different ways. First and foremost, in order to test our hypothesis concerning firms' licensing behaviors, we tracked the total number of licensing deals

1 We do not include in our analysis biotech firms (SIC: 2836) because their business model, relative to traditional pharmaceutical companies, tends to be more focused on R&D and less on manufacturing and commercialization. This makes downstream product market competition less of a concern for firms in this industry.

2 We decided to remove firms that never license from our sample because we use firm-fixed effects in our analysis.

in which licensor *j* was involved (i.e. through out-licensing) in a given year *t*. In other words, this variable represents the total *number of licensing deals* observed for a licensor in a given year. Considering the panel structure of our data, this variable allows us to observe changes in the number of licensing deals in which a licensor engages from a longitudinal perspective. Second, we computed a dependent variable on the basis of a dummy that takes the value 1 if licensor *j* was involved in at least one licensing contract in a given year *t*, and zero otherwise. The rationale for this second dependent variable is to verify whether our covariates also explain the licensor's decision to operate in the markets for technology in a particular year. One could argue that there are important differences between the number of licensing deals in which a licensor engages in a given year and the decision to operate on the supply side of the markets for technology. We expect that the independent variables used to test our hypotheses will yield congruent results across these regressions.

3.2.2. Independent variables

3.2.2.1. Product market competition. Industrial organization suggests that more concentrated industries are characterized by lower levels of competition, while less concentrated industries exhibit high competition among firms. Based on this observation, we operationalize product market competition using a Herfindahl–Hirschman index (HHI) calculated using *firm sales* data. We use financial information reported in *Compustat* to identify all firms operating in the same primary four-digit SIC code in a given year *t*. Four-digit codes represent the lowest level of aggregation we are able to identify, and they provide the greatest accuracy for capturing the product market and identifying licensors' closest competitors. The measure considers the sales of all firms operating in the same industry, regardless of whether they are included in our licensing sample. The HHI is calculated using the sum of an industry's squared market share, according to the following formula:

$$Product\ market\ competition_j = 1 - \sum_{i=1}^{I} S_{ij}^2$$

where S_{ij} is the market share of firm *i* in industry *j*. We perform the above calculations each year for each industry and attach the resulting measure to the licensors. This measure has been used extensively in previous studies (e.g. Lang and Stulz, 1992; Hou and Robinson, 2006) to measure the effect of product market competition on several dimensions of firms' behavior. Because we are interested in the effect of increased competition on licensing rates, we subtract the original index from 1.

3.2.2.2. Openness to external knowledge. Openness to external knowledge has been conceptualized as the strategic use of knowledge flows to accelerate innovation and improve market position (Chesbrough, 2006). Firms that are more open to external knowledge are significantly more likely to develop strategic collaborations with external partners to complement internal R&D (Laursen and Salter, 2006). We operationalize our measure on the basis of the intensity of collaborative deals that a focal firm engages in. Accordingly, we proxy a firm's openness to external knowledge on the basis of the count of R&D alliances in which licensor *i* has engaged during the three years prior to focal year *t*. We define R&D alliances as a strategic partnership in which a firm in our sample shares the R&D costs for the development of new technologies. We expect that this proxy indicates the extent to which firms see value in accessing knowledge and capabilities from other firms, instead of relying solely on in-house development. Because larger firms tend to have more resources to invest in R&D, we normalize the count of R&D alliances by the total amount of R&D expenditure that firm *i* incurred in year *t*. The information used to count the number of strategic partnerships comes from Recap and that for the R&D expenditures come from *Compustat*.

3.2.2.3. Exogenous sunk costs. Similar to previous studies (Lambson and Jensen, 1998; Henisz, 2000; Karuna, 2007), we compute a proxy for a licensor's exogenous sunk costs using the logarithm for a firm's yearly values for *property, plant, and equipment*, as reported in *Compustat*. Although this proxy may not perfectly distinguish the degree of disposability of a licensor's different asset types, the pharmaceutical industry is reportedly characterized by a high degree of resource specialization (Rothaermel and Hill, 2005), which can significantly reduce firms' capacity to dispose of prior investments related to fixed assets. Therefore, we believe that this is a reliable proxy for empirically measuring how increasing levels of licensors' exogenous sunk costs can affect licensing rates.

3.2.3. Control variables

3.2.3.1. Firm market share. Given that one of our key independent variables regards product market competition, we control for the share of the product market that firm i holds at year t. We expect that firms with larger portions of market share will have more reasons to weigh the potential dissipation more heavily and therefore to license less. This variable also accounts for the effect that firm size has on licensing behavior.

3.2.3.2. R&D intensity. We control for licensors' R&D intensity by including the R&D expenditures incurred by licensor j at year t, divided by its reported total sales in the same period. We expect that licensors with higher levels of R&D intensity will be more likely to engage actively in technology licensing. Indeed, firms at the forefront of new technological developments are both more likely to possess valuable technologies to license and less susceptible to suffering rent dissipation caused by licensees with more technological capabilities and the ability to further develop specific technologies (Choi, 2002).

3.2.3.3. Patent stock. We control for licensors' patent stock by computing the total number of patents accumulated by a licensor in the six years prior to the focal year, weighed by the number of forward citations that these patents received. Our expectation is that firms with larger and more valuable numbers of potential technologies to out-license will be more likely to present higher rates of technology licensing. According to Arora and Ceccagnoli (2006), patenting is a critical requirement for firms in the markets for technology to act as licensors.

3.2.3.4. Previous year licensing. Because firms' current licensing behaviors could be strongly affected by their previous licensing experiences, we control for the total number of licensing contracts in which licensor j engaged one period prior to the focal year.

3.2.3.5. Market growth. This variable is intended to capture the rate of growth in a licensor's product market. It is computed on the basis of the relative change in the licensor's product market. We compute the size of the product market on the basis of total sales reported by firms operating in the same four-digit SIC code. We calculate market growth on the basis of the following formula:

$$Market\ Growth = Market\ Size_t - Market\ Size_{t-1}/Market\ Size_{t-1}.$$

We expect that, as the product market grows, firms will be more likely to increase their technology licensing rates. Specifically, we expect that an expansion in the product market will make both licensors and licensees less likely to compete in the same segments, thereby reducing the possibility of rent dissipation.

3.2.3.6. Number of firms. Another important control variable is the number of firms operating in the same four-digit SIC code as licensor j in year t. This variable seeks to capture two potential effects. On the one hand, a larger number of firms operating in the same product market suggest a larger number of potential licensees, creating demand for the technologies possessed by the technology holder (i.e. licensor). Furthermore, a high number of potential licensees increase the licensor's bargaining power, creating opportunities for larger revenue effects and making licensing a more attractive alternative *vis-à-vis* in-house exploitation (Fosfuri, 2006). On the other hand, technology markets are characterized by high search costs (Contractor and Sagafi-Nejad, 1981), which can make the search for suitable licensees a lengthy and costly process. For these reasons, we expect that a larger number of firms operating within the same product market can lower search costs leading to an increase in the rate of technology licensing.

3.2.3.7. Licensor and year-fixed effects. There are also several time-invariant characteristics related to licensors that need to be included in our empirical model. Previous work shows that firms' licensing behaviors in the markets for technology can be affected by fixed factors, such as geographic location, operating sector, and other characteristics that remain stable over time. To reduce the chances of omitted variable bias from stable firm characteristics, we run our analysis using firm-fixed effects at the licensor level. Furthermore, we use year dummies to capture the overall temporal trends in licensing rates. These specifications are then applied in the models used to estimate our two different dependent variables. Finally, to reduce concern over the simultaneity between our two dependent variables and the independent variable, we apply a one-year lag to our variables. As mentioned earlier, the other variables are computed using different moving windows.

Table 1. Descriptive statistics and correlation coefficients ($N = 2,427$)

	Variables	Mean	SD	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
[1]	Number of licensing deals	0.43	0.85	1										
[2]	Licensing decision (dummy)	0.28	0.45	0.8	1									
[3]	Product market competition	0.9	0.09	0.09	0.09	1								
[4]	Openness to external knowledge	0.01	0.07	0.01	0.03	−0.08	1							
[5]	Exogenous sunk costs	1.01	2.22	−0.10	−0.08	0.11	−0.05	1						
[6]	Firm market share	0.01	0.05	0.05	0.03	−0.18	−0.06	0.17	1					
[7]	R&D intensity	10.97	139.81	−0.02	−0.01	0.01	−0.01	−0.03	−0.02	1				
[8]	Patent stock	853.27	3244.76	0.02	0.01	0.10	−0.04	0.53	0.18	−0.02	1			
[9]	Previous year licensing	0.45	0.90	0.32	0.23	0.08	0.05	−0.07	0.06	−0.02	0.03	1		
[10]	Market growth	1.41	19.17	0.02	0.01	0.01	0.00	−0.02	−0.02	−0.01	−0.02	−0.03	1	
[11]	Number of firms	170.94	74.3	0.18	0.17	0.62	−0.08	−0.19	−0.15	0.00	−0.05	0.18	0.02	1

3.3. Econometric analysis and model choice

Because we use different dependent variables, we use two distinct econometric models. First, as the number of deals engaged in by a licensor in a given year follows a count distribution taking non-negative integer values and a high number of zeros, we model this dependent variable using a Poisson regression with robust standard errors (Hausman *et al.*, 1984). We prefer to use a Poisson specification over the negative binomial because the first is more robust when implementing with fixed effects and robust standard errors (Allison and Waterman, 2002). As mentioned earlier, we choose firm-fixed effects to allow for arbitrary correlations between unobserved time-constant factors and explanatory variables. Although the use of fixed-effect estimators removes both desirable and undesirable variations across subjects (Angrist and Pischke, 2009), failing to control for unobserved heterogeneity might result in significant specification errors (Heckman, 1979). Because the other dependent variable concerns a dummy indicating licensors who engaged in at least one licensing deal in a given year, we use a logistic model that incorporates licensor fixed effects. To check the stability of the results provided by the logit model, we also estimate the models using a probit regression. The results are consistent across both specifications.

4. Descriptive statistics and results

We begin by examining how the number of licensors and licensing deals evolves over the years. We observe that, from 1986 to 2005, there was a significant increase in the number of licensing deals reported in our sample. Despite an overall upward trend, we also observe substantial variation in the number of realized deals across the years. The most active licensors in our sample are Roche with 44 deals, Elan with 37 deals, Eli Lilly with 34 deals, Chiron with 33 deals, and GlaxoSmithKline with 29 deals.

Table 1 reports the means, standard deviations, and Pearson correlation coefficients of the variables used in the fixed-effects models. The correlations do not warrant further examination with respect to multicollinearity. We observe moderate correlations between *Patent Stock* and *Exogenous Sunk Costs* (0.53) and between *Number of Firms* and *Product Market Competition* (0.62). Although these correlations are as expected, we test the stability of the model coefficients by entering them separately. The results remained unchanged.

Tables 2 and 3 report the results for the Poisson and logit fixed models, respectively. The dependent variable in Table 2 is the total number of licensing deals in which a licensor has been involved in a given year,[3] whereas, in Table 3, the dependent variable is represented by a dummy variable that takes the value 1 if the licensor has been involved in at least one licensing deal in a given year and 0 otherwise. The same independent variables are used to test both dependent variables and are entered into the regression in a stepwise manner. In both tables, Model 1

3 To check if our results are sensitive to outliers, we also tested as a dependent variable the logarithm of the number of licensing deals, $ln(number\ of\ licensing\ deals + 1)$, that firm i engages at year t. We used the same set of explanatory variables reported in Tables 2 and 3 to estimate linear modes with fixed and random effects. The results of those additional models remained consistent with those reported in the paper.

Table 2. Longitudinal analysis of firms' licensing behaviors

Variables	Poisson with firm-fixed effects and robust standard errors				
	Model 1	Model 2	Model 3	Model 4	Model 5
Product market competition		−4.540***	−3.478**	−3.861**	−3.490**
		(1.758)	(1.738)	(1.793)	(1.756)
Openness to external knowledge			1.253****	1.146****	1.048****
			(0.241)	(0.235)	(0.234)
Product market competition × openness to external knowledge			0.995****		0.889****
			(0.248)		(0.264)
Exogenous sunk costs				−0.094***	−0.087***
				(0.034)	(0.033)
Product market competition × exogenous sunk costs				−1.447****	−1.333****
				(0.287)	(0.298)
Firm market share	−6.346**	−6.380***	−6.298***	−5.128**	−5.341**
	(2.691)	(2.229)	(2.225)	(2.485)	(2.494)
R&D intensity	0.001	0.001	0.001**	0.001*	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Patent stock	−0.000	−0.000	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Previous year licensing	−0.017	−0.018	−0.054*	−0.044*	−0.065**
	(0.028)	(0.028)	(0.033)	(0.026)	(0.031)
Market growth	−0.025*	−0.025*	−0.025*	−0.025*	−0.025*
	(0.013)	(0.013)	(0.014)	(0.014)	(0.014)
Number of firms	0.011***	−0.000	0.002	−0.004	−0.003
	(0.004)	(0.006)	(0.006)	(0.006)	(0.005)
Year-fixed effects	YES	YES	YES	YES	YES
Number of observations	2427	2427	2427	2427	2427
χ^2	117.653****	110.568****	175.389****	353.307****	376.772****
Log likelihood	−1428.654	−1423.436	−1395.155	−1391.651	−1381.147

*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ****$P < 0.001$, at a two-sided test.

includes only the control variables. Model 2 enters the variable *Product Market Competition*. In Model 3, across both tables, we enter the main term *Openness to External Knowledge* and the interaction term *Product Market Competition* × *Openness to External Knowledge*. Model 4 enters the interaction terms *Exogenous Sunk Costs* and *Product Market Competition* × *Exogenous Sunk Costs*. Finally, model 5 includes all explanatory and independent variables at the same time. Overall the results provided by the Poisson and the logit models are highly comparable.

We will focus the interpretation of the results in Model 5 for both the Poisson and the logit models. *Hypothesis 1* suggests that higher product market competition will be associated with fewer out-licensing deals by firms. The results in model 5 are negative and statistically significant at the 5% level. These results provide strong evidence favoring *Hypothesis 1*. *Hypothesis 2a*, which proposes that openness to external knowledge is associated with more licensing deals by a firm, is also supported in both the Poisson and the logit models. This result suggests a positive association between *Openness to External Knowledge* and a firm's out-licensing activity. This is in line with our argument that when firms are more open to external knowledge, they will see more benefits from engaging in technology licensing. The results also lend support to *Hypothesis 2b*. The results for both dependent variables are positive and statistically significant the 0.1% level. This finding is in line with the idea that openness to external knowledge partially mitigates the negative effect that increasing product market competition has on firms' licensing behavior.

Finally, we examine the effects of *Exogenous Sunk Costs* on firms' willingness to sell their technologies. The empirical results provide support for *Hypothesis 3a* concerning the negative association between higher exogenous sunk costs and the number of out-licensing deals by a firm. The coefficient for exogenous sunk costs is negative and significant for both dependent variables. However, with the Poisson model, this effect is significant at 1%, whereas with the logit model, the effect is significant at 10%. This corroborates our argument that as firms incur more exogenous

Table 3. Longitudinal analysis of firms' licensing behaviors

Variable	Logit model with firm-fixed effects				
	Model 6	Model 7	Model 8	Model 9	Model 10
Product market competition		−5.777***	−4.574**	−5.691***	−4.816**
		(1.828)	(1.849)	(1.887)	(1.871)
Openness to external knowledge			1.968***	1.896***	1.718***
			(0.615)	(0.613)	(0.609)
Product market competition × openness to external knowledge			2.088****		1.926****
			(0.436)		(0.438)
Exogenous sunk costs				−0.096**	−0.083*
				(0.049)	(0.050)
Product market competition × exogenous sunk costs				−2.014****	−1.894****
				(0.407)	(0.415)
Firm market share	−6.988*	−7.096*	−6.731*	−5.332	−5.272
	(4.180)	(3.839)	(3.945)	(3.610)	(3.694)
R&D intensity	0.000	0.000	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Patent stock	−0.000	−0.000	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Previous year licensing	−0.016	−0.028	−0.115*	−0.086	−0.140**
	(0.063)	(0.063)	(0.065)	(0.064)	(0.066)
Market growth	−0.023*	−0.024*	−0.022	−0.023*	−0.023*
	(0.014)	(0.014)	(0.013)	(0.013)	(0.014)
Number of firms	0.014****	−0.001	0.001	−0.006	−0.005
	(0.004)	(0.006)	(0.006)	(0.006)	(0.006)
Year-fixed effects	YES	YES	YES	YES	YES
Number of observations	2427	2427	2427	2427	2427
χ^2	119.627****	129.667****	166.792****	168.657****	189.357****
Log likelihood	−916.355	−911.335	−888.193	−887.260	−876.910

*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ****$P < 0.001$, at a two-sided test.

sunk costs, they tend to be less inclined to commercialize their technologies. Also, *Hypothesis 3b*, which predicts that exogenous sunk costs negatively moderate the association between product market competition and the number of out-licensing deals of a firm, is also confirmed. The interaction term *Product Market Competition* × *Exogenous Sunk Costs* is negative and highly significant for both dependent variables. This finding provides support for the idea that high exogenous sunk costs strengthen firms' reluctance to license under conditions of high competition. Yet again, the results concerning market competition suggest that firms operating under these conditions do not categorically rule out participating in the market for technology; instead, they only display lower levels of activity.

To test whether including the interaction terms that we use to test Hypotheses 2b and 3b significantly improve the model fit, we run a Wald test of the interaction terms against the main variables that are used to compute them. In the case of the interaction term *Product Market Competition* × *Openness to External Knowledge*, we find that it is not simultaneously equally to zero when compared to *Product Market Competition* and *Openness to External Knowledge* ($\chi^2 = 42.32$; $P > \chi^2 = 0.00$). Regarding the interaction terms *Product Market Competition* × *Exogenous Sunk Costs*, we find a relatively similar pattern to the main terms *Product Market Competition* and *Exogenous Sunk Costs*. In this second case, the inclusion of the interaction term also improves the overall model fit ($\chi^2 = 32.21$; $P > \chi^2 = 0.00$).

Finally, in order to interpret the size of the effects of the relevant coefficients, we estimate the predicted values of our dependent variable on the basis of the mean values for the coefficients in our Poisson model. First, we predict the number of licensing events when *Product Market Competition* is set at its mean and then when it increases by one standard deviation. The results show that an increase of one standard deviation in *Product Market Competition* will lead to a reduction of 16% in the predicted number of licensing deals. Second, we observe that an increase of one

standard deviation in *Openness to External Knowledge* leads to an increase of 11% on the effect of *Product Market Competition* on firms' licensing decisions. Finally, when *Exogenous Sunk Costs* increases by one standard deviation, the effect of *Product Market Competition* on the predicted values of our dependent variable decreases by 18%. Figure 1 illustrates the effect of *Product Market Competition* on our dependent variable (count of licensing deals), where the effect remains significant across the different levels of product market competition. We also graph the magnitude of the moderating effects of *Openness to External Knowledge* and *Exogenous Sunk Costs* on the predicted values of the dependent variable. Figure 2 shows the effect of *Product Market Competition* on our dependent variable, conditional on low and high values of *Openness to External Knowledge*. Figure 3 shows the effect of *Product*

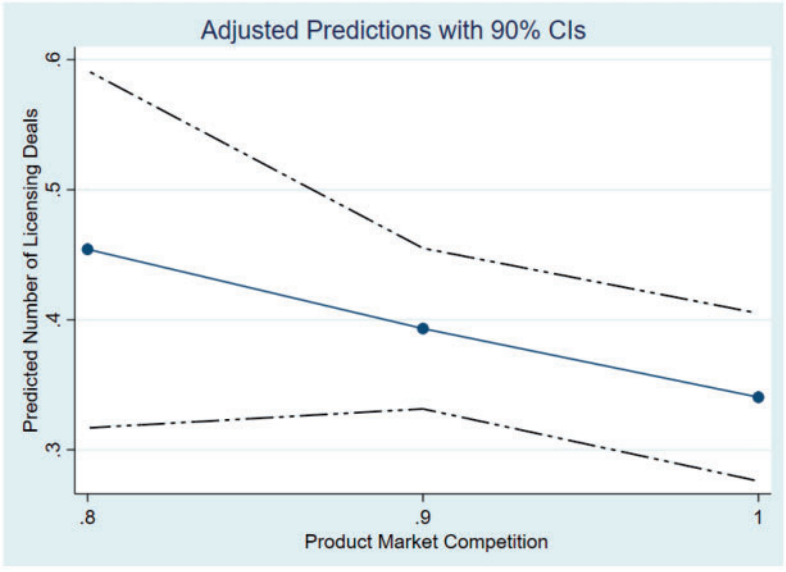

Figure 1. Predicted number of licensing deals, product market competition.

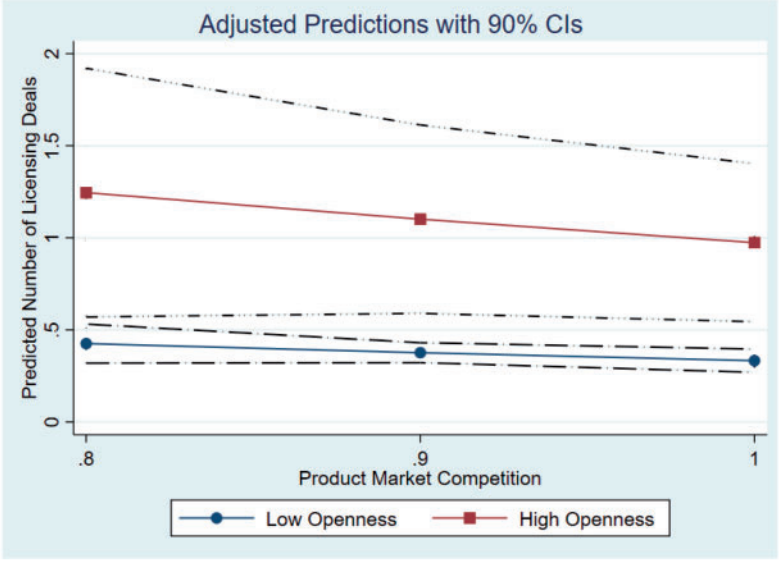

Figure 2. Predicted number of licensing deals, interacting product market competition, and openness to external knowledge.

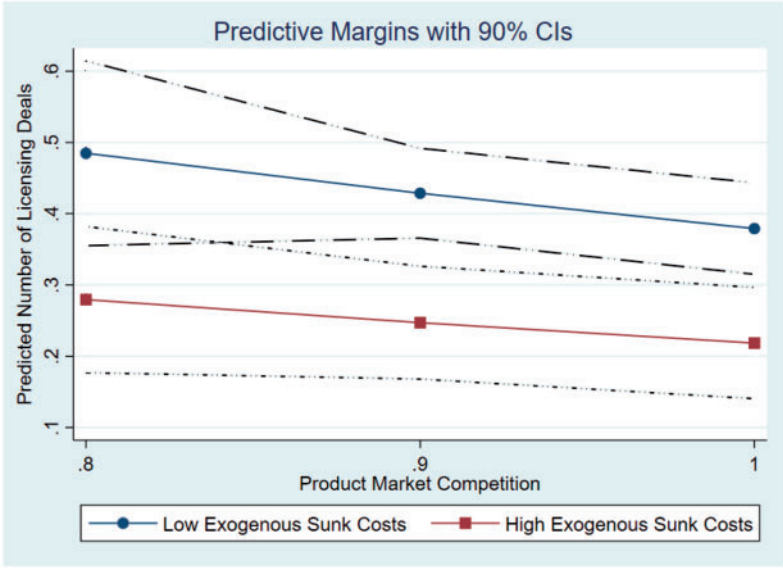

Figure 3. Predicted number of licensing deals, interacting product market competition, and exogenous sunk costs.

Market Competition on our dependent variable, conditional on low and high values of *Exogenous Sunk Costs*. Both figures exhibit patterns in line with our expectations.

4.1. Supplementary analysis

We argue that firms that are more open to external knowledge are also more likely to weigh rent dissipation less, owing to the nonpecuniary benefits that they obtain from out-licensing. In order to test if this assumption is confirmed in our data, we extract information pertaining to the royalty rates of the licensing contracts available at Recap. Unfortunately, the royalty rate, most of the time, is not disclosed by the parties, so we run the analysis in a small subset of observations that have this information available. Accordingly, we compute the yearly average royalty rate in the contracts for the licensors in our sample and use it as a dependent variable. The results of a simple ordinary least square (OLS) model confirm our expectations that more open firms tend to request, on average, lower royalty rates in their licensing deals.

Although our empirical setting is robust to alternative explanations, we investigate two potential issues related to our estimates. First, despite the fact that the Poisson estimator with firm-fixed effects and robust standard errors is a more conservative model (Allison and Waterman, 2002), one might be concerned that our results are affected by overdispersion in the dependent variable. In order to test if that is the case, we estimate a negative binomial with firm-fixed effects by using the count of licensing deals as a dependent variable. The results are highly comparable to those obtained from the Poisson models; therefore, we find no evidence that overdispersion could be biasing our main results.

Finally, we also check whether the inclusion of firm-fixed effects in our estimates reduces a substantial part of the variation in the main variables of interest. These variables might be fixed over time, in which case, we would be removing much of the variation central to our investigation. If our variables present low levels of within-group variance over time, this might originate in either cross-firm differences or the existence of abnormal values in our sample. To investigate this, we compare within- and between-group variance among the variables used to test our hypotheses, using an ANOVA test. Based on the findings displayed in Table 4, we observe that much of this variation stems from both within- and between-group (firm) variance. For some of the variables, we observe wide within-group variance, likely because we are considering a 20-year period, which gives firms time to change. Nevertheless, these patterns suggest that, even in the presence of firm-fixed effects, there is a substantial degree of variation in the estimates and that the estimates do not rely exclusively on a few extreme values or between-firm variations.

Table 4. Analysis of variance

Variable		Sum of squares (SS)	Share (%)
Number of licensing deals	Between groups	470.719	26.39%
	Within groups	1312.881	73.61%
	Total	*1783.600*	
Licensing decision (dummy)	Between groups	85.196	17.24%
	Within groups	409.067	82.76%
	Total	*494.263*	
Product market competition	Between groups	13.792	63.66%
	Within groups	7.872	36.34%
	Total	*21.664*	
Openness to external knowledge	Between groups	2.604	20.80%
	Within groups	9.913	79.20%
	Total	*12.517*	
Exogenous sunk costs	Between groups	4857.135	40.66%
	Within groups	7087.135	59.34%
	Total	*11,944.271*	

5. Discussion and conclusions

Despite the pecuniary and strategic benefits to licensors of technology licensing, many firms are reluctant to out-license their technologies. One of the main reasons for this reluctance is the potential for rent dissipation. Drawing on rent dissipation arguments, we first argue that, when competition in product markets increases, firms will tend to license less. Furthermore, we also emphasize that openness to external knowledge will not only increase firms' rate of technology licensing but also mitigate some of the negative effects related to product market competition that will move firms away from the market for technology. We also discuss the effects of exogenous sunk costs on firms' out-licensing behavior and show that when firms incur high exogenous sunk costs, they exhibit a higher reluctance to licensing. This paper is among the first to offer an empirical investigation of organizational and market circumstances as determinants of firms' out-licensing behavior.

To test our hypotheses, we use a comprehensive data set on the basis of data drawn from Deloitte's Recap, *Compustat* and USPTO databases. This data set allows us to test our hypotheses in a longitudinal setting using both Poisson and logit models with firm- and year-fixed effects. In line with our hypotheses, the empirical analysis suggests that higher levels of market competition will push firms away from licensing and that this effect increases in the presence of high exogenous sunk costs and decreases for firms that are more open to external knowledge. These results are robust to different econometric specifications.

Our study contributes to various strands of the literature. First, we contribute to the literature on the markets for technology by increasing our understanding of the determinants of the rent dissipation effect, which has been acknowledged as one of the main obstacles to developments in the markets for technologies. Second, we add to the work focused on the effect of competition in technology markets and the licensing trade-off (e.g., Choi, 2002; Fosfuri, 2006). Prior studies examining the rent dissipation effect are primary concerned with competition in the technology market (i.e. among potential licensors), linking rent dissipation to product market only indirectly. We take a step forward and examine the effect of downstream competition on licensing rates.

Third, by examining the effect of openness to external knowledge, we contribute to the literature on innovation. Previous studies have discussed the benefits for firms that are open to collaborate with external partners on the inflow of external knowledge; the present paper is an attempt to connect this effect to knowledge outflow. We identify several mechanisms through which a high level of openness to external knowledge could increase firms' willingness to grant access to internally developed technologies. We also expand the licensing literature by examining the role of exogenous sunk costs on out-licensing rates. In this paper, we discuss how the strategic implications of exogenous sunk costs can have direct repercussions on firms' licensing strategy.

Our findings have some limitations. First, the literature on the markets for technology conceptualizes the dissipation effect as the direct effect of increased competition in the licensor's product market. Similarly to previous studies

(Fosfuri, 2006), we use an indirect measure of rent dissipation proxied by the firm's yearly out-licensing rate. Although this is an indirect measure, we believe it is a good indication of the potential rent dissipation that firms might experience. Future studies could develop an empirical operationalization of rent dissipation that accounts directly for shifts in the licensor's market share as a consequence of technology licensing.

Second, we do not distinguish between licensors who are incumbents in the market of the licensed technology and licensors who are not. The dissipation effect should be of less concern to licensors whose main markets are not related to the market of the licensed technology. We believe that our empirical strategy addresses this issue by restricting the sample to firms operating in the pharmaceuticals industry, meaning that licensing contracts are related to only the exchange of pharmaceutical-related technologies and that both the licensor and licensee firms are pharmaceutical companies. Therefore, we expect that the licensing deals in our sample could result in rent dissipation for the licensors.

Third, we build our arguments around the supply side of markets for technology to explain out-licensing behavior. However, because we only observed *realized deals* in our sample, we cannot rule out that the reduction in licensing activity that we observe in our analysis may be driven by licensees' willingness to buy and not licensors' willingness to sell technologies. This is less of a concern when we examine licensors' organizational factors as determinants of the observed numbers of licensing deals. Licensors' characteristics such as openness to external knowledge and exogenous sunk costs are less likely to be directly related to in-licensing decisions. Given that very few studies have examined the drivers of firms' decisions to in-license, this is a promising research venue.

Finally, our results are not directly generalizable. Some characteristics of the pharmaceutical industry make our sample dependent on our empirical context. First, the pharmaceutical industry is a specific case whose characteristics provide the necessary conditions for a well-functioning market for technology. Second, due to the complexity and the risk in developing innovations, pharmaceutical firms tend to rely more heavily than other industries on external knowledge. Despite that, we still see substantial variation in the extent to which the firms in our sample are more or less open to external collaboration. Third, the pharmaceutical sector offers strong appropriability conditions, and this may constrain the amount of product market competition that firms can expect to experience as a consequence of out-licensing their technologies. Despite these particular characteristics of this industry, we believe that this study sheds light on important and relatively unexplored dimensions of the licensing literature.

Our findings have implications for firms and policymakers. The finding that firms tend to move away from technology licensing when markets become increasingly competitive reinforces the need for using appropriability mechanisms to keep markets for technology working. Firms can improve licensing and contract strategies to avoid incurring the risk of being overtaken by rivals. Well-designed contracts can significantly mitigate the risks of licensees using the licensed technology to compete with the licensor in the future. Furthermore, policymakers can strengthen the appropriability regime through the enforcement of intellectual property rights. This would also reduce firms' reluctance to out-license in competitive markets. Another important implication of our study is the evidence that open innovation strategies will benefit firms by not only making them better able to absorb external knowledge but also improving their capacity to benefit from knowledge outflows. By acknowledging this, firms can incorporate openness as part of their strategic choices to appropriate more value from technology licensing. Given our focus on out-licensing behavior, we would encourage future research to explore the role of organizational contingencies on the demand side of markets for technology. For example, examining the role of R&D and product market competition on firms' decisions to license-in would be an interesting venue for future studies.

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