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Competition, Technology Licensing-in, and Innovation

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Abstract. While the relationship between competition and firm innovation has long been of scholarly interest, prior research has predominantly considered changes in internal R&D as a strategic response to competitors' actions. In this study, we focus on one of the most important and commonly observed contractual mechanisms used to acquire external technologies: technology licensing. Surprisingly, licensing has been mostly overlooked by prior studies examining the effect of competition on firms' allocation of R&D. We take into account the unique properties of licensing, and systematically link them to the demands arising from the competitive pressure caused by rivals' launches of new products. Further, we discuss how licensing-in decisions ultimately shape a firm's subsequent innovation in areas where they are threatened by competitors, and how such innovation depends on the cumulative R&D investments inside the organization into which licensed knowledge is added. We test our theoretical model through a longitudinal design that tracks the licensing-in and innovation outcomes of firms in the global biopharmaceutical industry. Accounting for the endogenous selection of firms into licensing, our findings illustrate that licensing-in is motivated by competitive pressures. We also find that licensing-in increases a firm's capacity to innovate in areas where competitors have exerted pressure, particularly in the presence of cumulative R&D investments. In so doing, the paper anchors technology licensing as a key organizational action that helps increase our understanding of the important relationship between competition and innovation.

Keywords. Licensing; Competition; Innovation; New product development; Pharmaceuticals

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Introduction

The relationship between competition and firm innovation has long been of scholarly interest (Aghion et al., 2005; Cohen & Levin, 1989; Kamien & Schwartz, 1982). Rivals' introductions of new technologies and products have the potential to render a firm's existing technological competencies obsolete and undermine its competitive position (Anderson & Tushman, 1990; Kaul, 2012). Firms have been shown to react to such threats by intensifying their own innovation activities in the form of new products and technologies (e.g., Derfus et al., 2008; Doraszelski, 2003; McGahan & Silverman, 2006). Prior studies have also examined the way firms organize R&D activities when they experience increasing competition, such as emphasizing technology specialization and reducing collaborative efforts among scientists (e.g., Martin & Mitchell, 1998; Toh & Kim, 2013; Toh & Polidoro, 2013). Although these studies have significantly enhanced our understanding of the effect of competition on firm innovation, they have been primarily concerned with how competition shapes internal R&D activities. As a result, relatively little attention has been paid to *how firms can tap into external sources of knowledge to complement their existing internal R&D efforts as a reaction to increasing pressure from competitors*.

A few notable exceptions exploring the relationship between competition and external knowledge sourcing can be found in the context of strategic alliances. In the course of examining the relationship between collaboration and competition, these studies emphasize the inherent challenges faced by firms that use alliances to respond to competitive pressure. For instance, Sakakibara (2002) emphasizes the coordination costs of R&D consortia, and finds that firms only engage in such collaborative modes under weak competition. Ang (2008) suggests that alliances are inherently risky and costly, discouraging firms from using them at very high levels of competition. Eisenhardt and Schoonhoven (1996) find that a greater number of competitors accelerates alliance formation, but emphasize that this relationship only holds in the context of emergent markets. These findings suggest that when a firm's technological position is threatened by rivals, the firm may not prioritize knowledge-seeking actions that are time-consuming, require costly coordination, and have highly uncertain outcomes (Toh & Polidoro, 2013). However, there are alternative forms of knowledge sourcing that allow firms to respond to competition while avoiding the aforementioned challenges. Specifically,

technology licensing is one of the most commonly observed contractual mechanisms used to acquire technologies (Moreira, Markus & Laursen, 2018; Laursen, Moreira, Reichstein & Leone, 2017; Contractor, 1990). Yet, despite its importance, licensing-in has not been considered among the actions that firms take when reacting to competition.

In this paper, we aim to fill this gap by examining whether firms increase technology licensing-in under competitive pressure, and how such licensing decisions ultimately shape a firm's subsequent innovation. Specifically, our focus is on competitive pressure originating from rivals who have successfully launched new products in *areas where a focal firm actively engages in R&D* (Chen et al., 2010). Firms want to respond to such downstream pressures by upgrading their own capabilities upstream, as new products launched by rivals affect their technological position in the industry (Bierly & Chakrabarti, 1996; Martin & Mitchell, 1998). We take into account the specific properties of licensing—such as the fact that the licensee selects specific components of externally developed technological solutions *ex ante*, and the unilateral manner in which technologies are transferred from the licensor—to explain how licensing can be used as a response to competition (Conti, Gambardella, & Novelli, 2013). These properties facilitate firms' efforts to upgrade their R&D capabilities promptly and directly, distinguishing licensing from alternative external knowledge-seeking actions such as alliances (Moreira, Markus, & Laursen, 2018; Steensma & Corley, 2000). Thus, the characteristics of technology licensing are congruent with the strategic demands arising from competition, such that firms increase their use of licensing-in as their rivals develop and bring to market more new technologies.

Beyond the use of licensing as a response to competition, we also examine how licensing-in shapes the subsequent direction of firms' innovation (Doraszelski, 2003; Eggers & Kaul, 2018). Licensing affects innovation, as firms incorporate and recombine licensed knowledge into their ongoing R&D efforts. Drawing on the characteristics of licensing, we suggest that licensing-in facilitates a prompt and focused response to competitors, as firms can integrate existing externally developed technologies with their internal R&D. Thus, licensing is an important means through which firms can innovate in areas where they are under competitive pressure. We further explore this relationship by taking into account firm heterogeneity with respect to accumulated R&D investments (Dierickx & Cool, 1989; Doraszelski, 2003; Sull, Tedlow, & Rosenbloom, 1997), which represent a firm's path-dependent

stock of knowledge and expertise (Amit & Schoemaker, 1993). We argue that firms have incentives to protect such investments by channeling the recombination potential added through licensing towards increasing innovation in the areas where they have been threatened.

We test our theoretical model on a sample of 206 firms operating in the global biopharmaceutical industry through an instrumental variable approach (2SLS) in which we longitudinally track the effect of competition on licensing-in and the subsequent effect of licensing-in on firm innovation. The use of a large longitudinal sample makes it possible to capture competition, in the form of products launched by rivals, as a trigger for licensing, and to track the innovative output of firms following licensing-in decisions. The granularity of data in the biopharmaceutical industry allows us to identify the technological areas of product launches, as well as those of innovative outputs, to determine how firm competition and innovation are connected. The dataset we use to test our predictions combines licensing data from the Deloitte Recap database, product development data from Pharmaprojects to capture competitors' R&D pressures, and patent data collected from the United States Patent and Trademark Office (USPTO) as well as the Derwent World Patents Index to capture firms' innovation outcomes. The findings are in line with our expectations that licensing-in is motivated by the launch of new products by rivals. We also find that licensing-in increases a firm's capacity to innovate in areas where competitors have exerted pressure, and that this relationship is magnified in the presence of accumulated R&D investments by the focal firm.

The paper makes several contributions to the literature on competition, technology licensing, and innovation. First, it extends previous research on how firms deal with competition by expanding the perspective to one of the most commonly used approaches for sourcing external knowledge: technology licensing (Moreira et al., 2018; Laursen et al., 2017). Specifically, to our knowledge, this is the first attempt to connect the properties of technology licensing to the demands firms experience when their rivals are exerting pressure through new product launches. In so doing, we explain how technology licensing is an important mechanism that firms use to access external knowledge so they can react to competitors' moves and keep their upstream R&D competencies relevant within the industry. Second, the paper adds to the competition literature by linking firms' licensing-in activities to their subsequent innovation in areas where they face pressure from rival product launches. This adds to prior studies,

which have examined the technological areas in which firms innovate when faced with competition, and how their technological scope is shaped by competition in general (Eggers & Kaul, 2018; Toh & Kim, 2013). Finally, we discuss the interplay between licensing-in and a firm's internal R&D investment by illustrating that the relationship between licensing and subsequent innovation directed at rivals is shaped by the presence of increasing levels of cumulative and irreversible internal R&D investments. This adds to our understanding of how deploying licensed knowledge in areas where firms are under competitive pressure may ultimately depend on firms' internal R&D organization, and their prior investments in specific technological areas (Kapoor & Klueter, 2015; Laursen et al., 2017). Overall, the paper anchors technology licensing as a key organizational action that helps increase our understanding of the important relationship between competition and innovation. We expand on the paper's contributions in the discussion section.

THEORY AND HYPOTHESES

The development of new products and technologies by competing firms has the potential to destabilize firms' industry position, as it can prompt customers to modify their preferences and purchasing patterns (Aboulnasr et al., 2008). Such competition not only alters an industry's competitive landscape, but also shapes the creation of future technological opportunities (Anderson & Tushman, 1990; Dosi, 1982). If firms do not adjust their R&D to these changes, they may be unable to remain competitive and sustain their capacity to innovate.

A firm has several options when reacting to competition. For example, it can restructure and expand its internal R&D in order to catch up to rivals by developing new technologies (Aghion et al., 2005), or it can attempt to collaborate with other firms and draw on external technological expertise (Ang, 2008). However, when competitors successfully bring a new technology to the market, firms may want to react promptly by adjusting their R&D strategy in order to sustain their capacity to compete on innovation in the future (Doraszelski, 2003). Given this pressing need to respond, firms are unlikely to react to innovation by competitors by relying primarily on actions that take a long time to set up, demand significant coordination effort, and/or have uncertain outcomes (Ang, 2008; Sakakibara, 2002; Toh & Polidoro, 2013). However, there are ways for firms to respond to pressures from competitors without

running into the aforementioned issues. We focus on technology licensing, one of the most important means through which firms can swiftly source external knowledge, and explore how it helps us understand the relationship between competition and innovation.

The Properties of Technology Licensing

Like other knowledge-seeking actions, licensing enables firms to access knowledge and technologies developed outside their organizational boundaries (Anand & Khanna, 2000; Arora et al., 2001). However, technology licensing has specific properties that distinguish it from alternative means of knowledge sourcing. A license deal consists of a contract that affords a licensee the right to exploit a technology in exchange for the payment of upfront fees and/or royalties (Choi, 2002; Sakakibara, 2010). Thus, licensing deals are similar to arm's-length transactions, with one firm selling a technology and another buying it (Moreira, et al., 2019; Conti et al., 2013).

A key feature of licensing lies in the nature of the underlying technological knowledge and the way it is transferred. In a research alliance, two or more firms *collaboratively* combine resources and capabilities to develop a new technology. In contrast, in licensing contracts, the licensor agrees to *unilaterally* transfer *know-how* and *intellectual property* related to a technology to the licensee (Contractor, 1990; Jensen & Thursby, 2001). This characteristic makes licensing a form of external knowledge sourcing that requires significantly less coordination, and reduces uncertainty over whether and how a firm can incorporate and use an acquired technology (Contractor, 1990; Mowery, Oxley, & Silverman, 1996; Steensma & Corley, 2000). Additionally, licensing differs from collaborative forms of knowledge sourcing in that firms can decide the type and characteristics of the technology they wish to acquire *ex ante*. In other words, licensing involves the transfer of *existing technologies*. This means that important characteristics of the technology—such as its stage of development (Laursen et al., 2017), technological breadth (Gambardella & Giarratana, 2013), or potential downstream applications (Fosfuri, 2006)—can be selected by the acquiring firm. As a consequence, firms can predetermine the characteristics of their target technology, and, once it is added into the organization, the licensed technology can be incorporated into the firm's ongoing R&D tasks and efforts (Moreira, Markus, & Laursen, 2018).

Licensing also enables firms to expand their existing knowledge base (Grant, 1996; Klueter, Monteiro, & Dunlap, 2017). Extant research emphasizes that "the number of direct combinations" available as inputs to R&D increases the more items of knowledge a firm has at its disposal (Ahuja & Katila, 2001:200). There are two distinct ways in which licensing expands the range of technological knowledge that a firm can internally leverage. It can be used to add knowledge developed by the licensor—often, a firm working on the scientific and technological frontier—with which the acquiring firm is not familiar (Hagedoorn, 1993). This has been shown by Leone and Reichstein (2012:967), who demonstrate that licensing can function by "[…] extending the licensee's technology search space and facilitating the transfer of otherwise undisclosed knowledge." Thus, licensing can be used to increase *knowledge variety*, and to allow the licensee to deploy, recombine, and use technologies that it did not previously understand, or even know of (Galunic & Rodan, 1998; Grindley & Teece, 1997; Katila & Ahuja, 2002). Licensing also entails a transfer of *legal rights* to grant access and allow the use of specific technologies. In this case, even if the newly acquired IP rights are associated with technological knowledge that is not new to the licensee, having the legal right to use and exploit a technology in R&D activities gives a firm the potential to deploy and further build on it (Ziedonis, 2004). It follows that adding knowledge through licensing allows firms to increase the potential for scale and scope in inventive recombination, and upgrade their R&D capabilities by aligning their internal R&D with a changing technological landscape (Eisenhardt & Martin, 2000; Galunic & Rodan, 1998).

Finally, drawing on licensed technologies allows a licensee to promptly tap into and use ready-made external R&D solutions (Leone & Reichstein, 2012). This approach saves not only time, but also the resources that would otherwise have to be committed to the trial-and-error process of developing technological solutions from scratch (Chesbrough, Vanhaverbeke, & West, 2006). By using licensed technologies, firms can directly build on the accumulated R&D expertise developed by other firms (Anand & Khanna, 2000). Thus, a licensee can focus its R&D on fewer activities and reduce uncertainty related to the development of future innovations, which may ultimately shorten innovation cycles (Markman et al., 2005). Moreover, licensing allows a prompt reaction as it is characterized by lower

setup costs than alternative knowledge-sourcing agreements. Setting up a license requires fewer interactions with the counterparty, and typically fewer resources *ex ante* too (Klueter et al., 2017).

The connection between the characteristics of technology licensing and the motivations that firms have to integrate licensed knowledge with their own R&D activities is echoed by licensee firms. For example, in the context of biopharmaceuticals, Bill Lee, PhD, Executive Vice President of Research at Gilead, highlights that licensing a novel monoclonal antibody platform from Trianni in 2018 "[…] will help enhance our ability to discover human antibodies and to develop new therapies in areas of unmet medical need," and stresses the importance of "integrating Trianni's technology into our research and development program." Relatedly, Dr. Paul Anderson, Vice President R&D at Boehringer Ingelheim, suggests that licensing Galapagos' SilenceSelect technology in 2003 "[…] will give us a cutting edge in the identification and validation of targets that will form the basis of innovative drug design. By concentrating on the drugable genes we will be able to take targets very quickly into drug screens, thereby expediting our drug discovery process." These examples illustrate the idea that licensing can be used to acquire specific ready-made technologies that can improve internal R&D.

Competition and Technology Licensing

Next, we consider these specific properties of licensing and systematically link them to the demands emerging from competition. We focus on competition originating from firms in the same industry successfully launching new products in areas in which a focal firm *actively engages in R&D*. Such competitive actions are significant for firms because they can *objectively undermine* their upstream R&D initiatives and competitive position (Bierly & Chakrabarti, 1996; Martin & Mitchell, 1998). Therefore, these moves from rivals provide an important impetus for firms to react in order to sustain their capacity to compete through innovation. Following the idea that "in some circumstances, it is precisely downstream competition [e.g., competitors launching new products] that drives the way firms utilize upstream resources" (Toh & Polidoro, 2013:1188), we expect there are important reasons that downstream competition will motivate firms to direct their efforts towards upgrading their own R&D.

Firms compete through their technological capabilities, which have been formed over time in a path-dependent manner and with expectations as to how they will perform *vis-à-vis* the firm's

competitors (Levinthal & March, 1993). Rivals launching new products force firms to benchmark their own product pipeline against these new alternatives to ensure their ongoing R&D initiatives remain relevant in a changing landscape (Luo, 2003; Martin & Mitchell, 1998). At the extreme, new rival products render a firm's existing product portfolio technologically obsolete, increasing the risk of a firm falling far behind the industry's technological leading edge (Anderson & Tushman, 1990). This risk is particularly salient when rival products build on technological domains with which the focal firm is familiar (Toh & Polidoro, 2013), requiring the firm to adjust and upgrade its own R&D in order to sustain its ability to compete through innovation (Eisenhardt & Martin, 2000). While such upgrading of technological capabilities may not immediately neutralize or reverse a specific threat in areas where rivals have launched new products, it is still necessary for firms that want to compete when continous innovation is a source of competitive advantage (Bierly & Chakrabarti, 1996).

While competition induces firms to upgrade their R&D, this may be challenging if they rely solely on internal means. Helfat (1994) argues that the path-dependent nature of internal R&D makes it harder for firms to use it as the only way to adjust to a changing technological landscape. Consequently, firms may need to reach beyond their boundaries to add knowledge and solutions that differ from those they already possess in-house (Rosenkopf & Nerkar, 2001). However, research on accessing external knowledge and, in particular, alliances, reveals that such actions can be time-consuming and often generate unexpected results (Gulati & Singh, 1998; Puranam, Singh, & Zollo, 2006; Santos & Eisenhardt, 2005). Licensing, however, enables firms to address the specific demands emerging from competition, as it allows firms to tap into externally developed knowledge and swiftly upgrade their R&D capabilities in a directed manner.

Licensing deals can be contractually designed *ad hoc* to facilitate a unilateral knowledge transfer, avoiding the difficulties that characterize extensive and complex reciprocal interactions with an external partner (Jensen & Thursby, 2001; Laursen et al., 2017; Mowery et al., 1996; Steensma & Corley, 2000). Thus, the time necessary to establish a licensing agreement tends to be shorter than other forms of knowledge sourcing such as alliances. Therefore, firms can access already-existing technologies, which is important when they are trying to prevent their R&D capabilities from becoming obsolete (Leone & Reichstein, 2012). Indeed, prior research has emphasized that licensing offers a way

to promptly access existing external knowledge and technologies (Contractor, 1990; Kotabe, Sahay, & Aulakh, 1996), which is particularly relevant when reacting to rivals' moves.

Moreover, licensing allows firms to respond to competition directly by adding *specific* technological knowledge to enhance their ongoing R&D efforts. Competition indicates the types of technology that allowed rivals to exert competitive pressure on a firm's R&D activities in the first place. Thus, competitors' actions reduce uncertainty over which technologies do and don't work, and how their own ongoing initiatives fit within their external environment (McGahan & Silverman, 2006). When competitors reveal specific technological solutions, licensing enables a focused strategic reaction, as it gives the licensee the opportunity to define *ex ante* the relevant pockets of knowledge that will be acquired (Anand & Khanna, 2000; Teece, 1988). Hence, licensing allows firms to adopt a problem-oriented response by acquiring specific technologies that are ready to deploy into specific R&D efforts. This can be particularly useful when firms are upgrading existing R&D initiatives while taking into account the changing technological landscape to which they are trying to adjust (Kotabe et al., 1996; Zahra et al., 2005). Taking these arguments together, we suggest:

Hypothesis 1: *Competitors' product launches in areas in which a firm actively invests in R&D increase the firm's rate of technology licensing-in.*

Consequences of Technology Licensing: Recombination Potential and Innovation

Thus far, we have argued that upgrading R&D capabilities through licensing-in allows firms to react to competition. Now, we focus on the outcome of such activities by examining the innovation that follows on from technology licensing-in. In general, firms may direct the recombination potential added through licensing towards areas in which they are affected by competition, or they can redirect and redeploy innovative efforts towards alternative or less contested technological paths (Kaul, 2012; Toh & Kim, 2013).

Why would firms want to innovate in areas where they have been threatened by rivals launching new products? The launch of new products by rivals induces changes in the way firms compete. When a firm's competitors successfully bring new technological solutions to market, the firm's existing technologies are likely to become relatively less attractive to customers. In such situations, reacting to

competitors' moves by increasing innovation is an important way for a firm to technologically catch up to its rivals and ensure that its portfolio of technologies remains competitive and up to date (Teece, 2007; Zahra et al., 2005). If firms do not channel their own innovation towards areas where rivals have successfully innovated, they may become technologically irrelevant and lose the capacity to generate future downstream rents from their innovations. By increasing innovation in areas of competition, firms can also broaden their claim of intellectual property (IP) over technologies that are commercially applicable in the space where their existing R&D initiatives are threatened. Doing so safeguards the usefulness of a firm's existing technological capabilities, as well as its ability to appropriate future value in the downstream market from its ongoing innovation initiatives (Utterback, 1994).

We argue that technology licensing is an important means through which firms can innovate in technological areas threatened by competitors. Our arguments build on the idea that innovation is the outcome of a recombination process in which firms synthesize both internal and external knowledge (Zahra et al., 2005). Furthermore, we consider that the extent to which firms apply and deploy external knowledge is determined by the nature of that knowledge, and the mechanism through which it was sourced (Kogut & Zander, 1992; Zander & Kogut, 1995). We suggest that the specific properties of licensing make it more likely that firms will channel the recombination potential added through licensing towards areas in which their rivals have launched new products.

Licensees select specific knowledge *ex ante* and contractually agree how it can be deployed within their internal R&D (Contractor, 1990). Thus, they are unlikely to explore a large set of broader opportunities for recombination (Eisenhardt & Santos, 2002), but will instead focus on visible and available targets, such as those revealed by competitors' product launches. This suggests that the direction and scope of licensed knowledge recombination are shaped by existing needs and goals within a firm's R&D, and that the launch of new products by rivals will serve as an important internal signpost (Zander & Kogut, 1995). Extant research emphasizes that, due to the complexity associated with the development of exploratory and highly novel technologies, firms are more likely to pursue such types of combinations through an iterative, repeated, and reciprocal exchange with outside partners (Eisenhardt & Schoonhoven, 1996; Galunic & Rodan, 1998). However, this is not the case in licensing, which generally reduces the trial and error involved in creating innovations since the recombination

process starts from existing, predefined technological solutions (Leone & Reichstein, 2012). Therefore, licensing allows firms to both deepen and focus their innovation efforts towards the areas in which rivals have launched new products—and such focus is particularly relevant when competition is intense (Toh & Polidoro, 2013).

The recombination potential added by licensing can also allow a firm to react more quickly to competitors than internal R&D would allow. A general concern for firms in competitive environments is that rivals can build on lead-time advantages that can deter other firms from attempting an entry into their technology space, or make such attempts too costly (Toh & Polidoro, 2013). In this sense, a focal firm may want to react in a timely way to competition in areas in which it is actively engaged in R&D, in order to prevent rivals from taking an unassailable lead in terms of their R&D and technological portfolio. This is possible through licensing, which builds on already-developed solutions and, for the most part, reduces mistakes and inefficiencies incurred in the process of creating a new technology (Chesbrough et al., 2006; Markman et al., 2005). As a result, licensing "augments the recipient firm's product development process by reducing invention time" (Leone & Reichstein, 2012:996), which allows the firm to innovate in areas in which competitors have launched new products. It follows that, by relying on the recombination potential afforded by licensing-in, firms can accelerate the creation of inventions in areas where they need to strengthen their strategic position upstream.

Overall, our arguments suggest both an important relationship between licensing-in and innovation, due to an increased potential for knowledge recombination, and that such potential is likely to be channeled towards knowledge areas in which firms face competition. We suggest:

Hypothesis 2: *Technology licensing-in will be positively related to a firm's subsequent innovation in technological areas where competitors have launched new products.*

The Role of Cumulative Internal R&D Investments

We now turn to the internal context into which the licensed knowledge is added. This is relevant, as knowledge recombination unfolds within the firm's existing R&D apparatus (Bierly, Damanpour, & Santoro, 2009; Kapoor & Klueter, 2015). We take into account that firms are heterogeneous in the degree to which they have accumulated R&D investments in different technological areas (Helfat,

1997). These investments represent the time, capital, and skills expended to build up the resources and capabilities that position the firm with respect to its competitors (Sull et al., 1997). Such R&D investments lead firms to accrue a stock of path-dependent technological knowledge and expertise (Amit & Schoemaker, 1993; Dierickx & Cool, 1989). Also, it is difficult to redeploy these resources and capabilities to alternative uses (Ghemawat, 1991; Sakhartov & Folta, 2014). Building on this observation, we argue that, when faced with rival launches on their "turf," firms take into account not only potential market revenues, but also the losses associated with relinquishing accumulated R&D (Cockburn & Henderson, 1994; Doraszelski, 2003). In particular, such investments shape a firm's incentives towards exploiting the knowledge recombination potential added through licensing in areas where rivals have launched new products.

In general, firms may deploy innovation efforts towards areas of strong competition, or opt to focus on less-contested paths (Kaul, 2012). Firms have strong incentives to innovate towards their rivals if they have accumulated significant R&D investments in threatened technological areas (Ghemawat, 1991). Prior research shows that firms that lag far behind their rivals have little incentive to innovate to catch up, while firms with substantial R&D investments affected by rivals will compete aggressively through innovation (Aghion et al., 2018). Thus, firms' cumulative R&D investments will pressure them to protect the usefulness of valuable accumulated resources and expertise. To do so, firms are more likely to deploy knowledge from licensing to generate innovations in the areas where they have more at stake.

Significant accumulated R&D also facilitates a more general response to competitors using licensed knowledge. Innovation is a cumulative process, which means that firms' R&D investments feed back into subsequent R&D activities (Helfat, 1997). Having relevant internal R&D accumulated in specific technological areas allows a firm to rely on its own capabilities to support and complement recombination after licensing-in (Cassiman & Veugelers, 2006; Kotabe et al., 1996). This coincides with the idea that R&D responses towards rivals are stronger if a firm has a sufficiently large knowledge stock to facilitate innovation through a larger set of potential combinations between internal and external items of knowledge (Katila & Ahuja, 2002). Based on these ideas, we expect that channeling

recombination potential from licensing towards areas where rivals have launched new products will be intensified in the presence of cumulative internal investments in R&D in those areas. We hypothesize:

Hypothesis 3: *The higher a firm's accumulated R&D investments in the technological areas where competitors have launched new products, the stronger the relationship between licensing-in and subsequent firm innovation in these areas.*

METHODS

Context: The Biopharmaceutical Industry

We provide an empirical test of our hypotheses in the biopharmaceutical industry. There are several reasons why this industry provides an appealing context to empirically examine firms' use of technology licensing as a response to competition, and its subsequent effect on innovation. First, the biopharmaceutical industry is characterized by high research intensity and by the strategic importance of R&D investments (Henderson & Cockburn, 1994). Extant work emphasizes that the industry is primarily knowledge- and technology-driven, as firms continuously expand the scientific and technological frontier (Bierly & Chakrabarti, 1996; Klueter et al., 2017; Roberts, 1999). Starting from the mid-1980s and moving through the following decades, the industry has experienced rapid technological change grounded in biotechnology in the form of new research tools such as immunoassay, gene sequencing, and high throughput screening, as well as new therapies such as monoclonal antibodies, stem cells, and oligonucleotides (Kaplan, Murray, & Henderson, 2003; Kapoor & Klueter, 2015). Owing to this continuous technological change, firms in the industry often need to engage in knowledge sourcing alternatives such as licensing in order to access relevant knowledge and adjust to a shifting technological landscape.

Second, the biopharmaceutical industry is highly competitive, as firms continuously progress new therapeutic treatments towards regulatory approval in order to receive permission to commercialize new drugs and obtain exclusive market access (Cockburn & Henderson, 1994; Doraszelski, 2003). The process of commercializing a new molecular entity is time-consuming; it can be over a decade from the original discovery to market launch (e.g., DiMasi, Hansen, & Grabowski, 2003; Girotra, Terwiesch, & Ulrich, 2007). It is also very costly as firms have to spend, on average, several $100 million in R&D to reach market approval (DiMasi et al., 2003). Once approved, new drugs' earning potential is transient

and temporary, since patents or the products' exclusivity periods have a fixed duration. As a result, firms face an increasing need to update and upgrade their R&D capabilities if they are to sustain the development of their pipeline and continually bring new drugs to market. Indeed, firms' R&D capabilities are considered the *key* determinants of future profitability and competitiveness for firms within the industry (Bierly & Chakrabarti, 1996; Roberts, 1999; Toh & Polidoro, 2013).

Third, prior research within the biopharmaceutical industry has established an important connection between downstream competition and upstream R&D-related actions and, in particular, how product launches by rivals affect firms' R&D activities. For example, Toh and Polidoro (2013) show that product launches by rivals lead firms to reconfigure their R&D activities in specific knowledge areas (e.g., hypertension). Polidoro and Theke (2011) find that rivals' drug approvals can have direct implications for subsequent scientific publication patterns upstream in top medical journals. In a similar vein, qualitative evidence has shown how rival product launches in beta-blockers, calcium channel antagonists, and monoclonal antibodies spurred R&D activities in biopharmaceutical firms affected by those launches (Marks, 2015; Scriabine, 1999). These characteristics make the industry an appropriate setting in which to examine the effect of downstream product launches by competitors on upstream activities in R&D such as technology licensing.

Fourth, licensing is a highly prevalent form of knowledge sourcing in this industry (Nicholls-Nixon & Woo, 2003; Nishimura & Okada, 2014). Prior studies have pointed out that biopharmaceuticals is one of the few industries in which there is a well-established market for technology (Moreira et al., 2019). On the supply side, R&D intensity is high, and technology holders rely on the presence of a strong IP regime that allows them to make technologies available for licensing. On the demand side, firms can systematically rely on a fluid market for technologies to feed and complement their internal R&D efforts (Arora et al., 2001). It is commonly observed that firms use licensing to gain access to proprietary technologies, such as Abgenix's Xenomouse or Human Genome Sciences' gene sequencing technology, to complement their internal R&D efforts in a broad range of therapies. Even when firms license therapeutic solutions that are already in development (e.g., new

chemical or biological entities), they still gain access to novel knowledge such as the mechanisms of actions (i.e., the pharmacological effect of a drug on the human body).

Finally, the biopharmaceutical industry innovation process follows highly regulated and well-documented steps. Firms typically seek to protect their research discoveries by filing patents shortly before testing possible treatments—first on animals in preclinical trials, and then on humans in clinical trials (Girotra et al., 2007). The industry also offers high data granularity with respect to the knowledge that underpins R&D activities. In particular, we can observe R&D activities through the lens of broad therapeutic areas, such as cardiovascular disease and conditions of the central nervous system, in which firms compete (Henderson & Cockburn, 1994; Nerkar & Roberts, 2004). Extant work has characterized therapeutic and disease areas as "specialized" technical knowledge (Lane & Lubatkin, 1998), and has shown that firms within the industry aggregate such specialized knowledge over time in a path-dependent manner (Henderson & Cockburn, 1994; Lane & Lubatkin, 1998). This allows us to identify and connect competitors' product launches (downstream) and innovation activities (upstream) on the therapeutic-area level to test our hypotheses.

Data and Sample

We compiled a novel database combining multiple data sources: Recap Deal Builder, Pharmaprojects, Compustat North America, the Derwent World Patents Index, and the NBER patent project. We constructed our sample of firms based on the following criteria. First, we ensured that selected firms actually deployed technology licensing-in as a mechanism to acquire external knowledge. We used Recap Deal Builder to examine the licensing deals listed in 1989–2004, a period of rapid technological development in the biopharmaceutical industry due to the proliferation of biotechnology tools and novel therapies (Kapoor & Klueter, 2015). Recap is acknowledged as one of the most accurate and comprehensive sources of information regarding partnerships and technology exchange involving biopharmaceutical firms (Schilling, 2009). It allows us to access detailed information regarding the licensing deals, and also to unambiguously identify the licensor and licensee for a given deal. We only included firms that had reported at least one licensing deal as a licensee during the period of empirical

analysis. This sampling criterion led us to remove 34 firms—mostly smaller firms without downstream development activities.

The second step was to obtain consistent information on financials and licensing decisions for our sample firms. In particular, we connected the licensees identified in Recap with the Compustat North America file. We focused on listed firms, as they have more stringent financial disclosure requirements than their privately held counterparts, alleviating concerns over unreported deals.

Next, we ensured that the firms in our sample had an R&D (i.e. drug-development) pipeline that subjected them to pressure from competitors' downstream product launches. We extracted R&D pipeline information from Pharmaprojects, which has been used in prior biopharmaceutical studies to capture drug-development activities (Hess & Rothaermel, 2011; Kapoor & Klueter, 2015). Each drug recorded in Pharmaprojects is associated with a primary therapeutic area, such as "Cancer," "Neurology," or "Cardiovascular." We coded over 13,000 products in development associated with our sample firms to construct the drug-development pipeline of each focal firm. We considered a firm to be actively competing in an area if they had drug-development projects or drugs launched in the previous five years. Pharmaprojects also documents the launch of new drug products in the industry as key events, which allowed us to capture the downstream product market launches from other firms (competitors) in therapeutic areas in which a firm was active.

We captured firm innovation activity by relying on patent information extracted from the NBER patent database. This dataset is compiled based on information from the United States Patent and Trademark Office (USPTO). We then deployed the classification system of the Derwent World Patents Index to connect each USPTO patent to a therapeutic area. Derwent offers a proprietary patent classification system that is applied by professional analysts to facilitate the identification of patents based on the function or application domain to which the invention corresponds (Eggers, 2012). Using this classification system, we could link patent outputs to therapeutic areas where rivals launched new products (Nerkar & Roberts, 2004). This was crucial for identifying a firm's specific technological and technical domains within the industry, as well as connecting upstream (innovation through patents) and downstream (new product launches by rivals) activities.

Finally, to account for the mergers and acquisitions (M&A) that are widespread in this industry, we dynamically tracked changes in the ownership structure of the companies in our sample using the M&A information provided by Recap. This allowed us to build a detailed history of each firm and ensured that our measures accurately captured a firm's activities in a given year.

The sample resulting from matching these datasets was structured as a panel with firm-year observations serving as the unit of analysis. In the final sample we observed 206 firms, with each one appearing 9.6 times on average, with a minimum of four and a maximum of 17 observations. Our dataset included 1,974 firm-year observations covering the period 1989–2004 inclusive. We defined 1989 as the starting year based on the availability of consistent licensing and trials information from Pharmaprojects, and 2004 as the final year based on the patent data compiled by the NBER project.

Measures

Dependent Variables

Technology Licensing-in. To capture firms' strategic use of licensing-in as a reaction to downstream product market competition, we calculated the total number of licensing-in deals that firm *i* had engaged in in year *t*. *Technology licensing-in* is a count variable that takes value 0 if a focal firm did no licensing-in in a given year, and the corresponding number of deals otherwise. Recap includes several types of deals that are distinct from technology licensing-in; to ensure that this measure was aligned with our theoretical constructs, we only counted licensing deals, and not any other form of inter-firm agreement reported in Recap. Given our focus on licensing as a way for firms to complement internal R&D, and not the mere commercial exploitation of technologies, we excluded deals covering technologies that were ready to commercialize downstream[1].

Innovation towards competition. We are interested in examining innovation related to a firm's upstream R&D activities. We captured innovation in areas where rivals had launched new products through a firm's patenting output at the USPTO. In contrast to FDA clinical trials, patents are filed shortly after the research and discovery of a new technology (Rydzewski, 2008). Patents are considered an important step before firms invest in the lengthy and costly clinical testing necessary to

[1] This type of licensing represents less than 5% of the whole population of deals reported in Recap.

obtain approvals for new drugs (Tidwell & Liotta, 2012). Thus, capturing patents allowed us to measure R&D activities in the years before specific products/drugs were tested in trials or launched on the market (DiMasi et al., 2003; Girotra et al., 2007). As an illustration, the patents relating to Lipitor, a statin drug aimed at preventing cardiovascular diseases that was launched on the market in 2001, were filed as early as 1986. Thus, patent applications allow us to capture upstream development activities (and not downstream drug approvals) as an outcome of licensing activities. Finally, patents are strongly correlated with future new product introductions and the ability to remain competitive in the pharmaceutical industry (Bierly & Chakrabarti, 1996; Trajtenberg, 1987).

The focus on a single patent office in the US avoids noise produced by differences in evaluation procedures across locations. Additionally, given that the US represents the world's largest market for high-tech products, global firms have strong incentives to apply for patents at the USPTO as early as possible (Henderson & Cockburn, 1994). We used the patent *application date* because it is closely related to the timing of knowledge creation.

In order to capture innovations in areas where rivals launched products, we connected each patent in our sample to a therapeutic disease area (e.g. oncology, neurology) in which pharmaceutical firms compete (Nerkar & Roberts, 2004). We used the Derwent World Patents Index classification system to connect the descriptions of therapeutic areas of product launches in Pharmaprojects to Derwent codes. The Derwent classification system has a dedicated category "Pharmaceutical Activities," under code B14, that covers the therapeutic areas associated with patents. In many cases, Derwent codes correspond to the therapeutic area in Pharmaprojects. For example, the manual code B14-H ("Anticancer drugs") corresponds to the category of "Anticancer" in Pharmaprojects. When such straightforward linkages were not possible, we categorized based on subcategories and their underlying therapeutic-area keywords as found in Pharmaprojects. All keywords and categories were further examined by two expert medical practitioners with over 15 years' experience. Out of 80 original assignments, the experts suggested three changes to more accurately reflect the match between therapies in Pharmaprojects and therapeutic codes in Derwent (See online appendix Table A1).

Using this classification, a patent generated by the firms in our sample from the NBER patent file could be linked to therapy codes[2]. Then, we measured firm innovation using the count of successful patent applications from firm *i* in year *t* that were associated with therapeutic areas in which rivals exerted pressure on the firm through product launches. Finally, in order to normalize the distribution of our dependent variable, we used the logarithm of *Innovation towards competition* +1 as our measure.

Competitors' product launches. We relied on the Pharmaprojects database to capture the downstream product market moves from other firms (competitors) in the pharmaceutical industry. We measured the extent of competitive pressure by the number of global new drugs launched by competitors in a given year in the therapeutic areas in which a sample firm was active. We focused on the key therapeutic areas in which biopharmaceutical firms competed on an ongoing basis, such as oncology or cardiovascular diseases. Product launches in these areas have the potential to undermine the competitive position of a focal firm by affecting its existing revenue streams (Bierly & Chakrabarti, 1996; Cockburn & Henderson, 1994). On average, fewer than 140 products are launched globally in the pharmaceutical industry in a given year and these launches are extensively covered by the media.

Furthermore, the approval of new drugs is the outcome of substantial investments in R&D activities, with important repercussions for the drug-development pipelines of all firms in the industry that have downstream and upstream activities in the same therapeutic area (Ang, 2008). The measure *Competitors' Product Launches* counts the overall number of drug launches reported in the therapeutic areas in which each sample firm was considered active in a given year. A higher number of launched drugs suggests stronger competitive pressures on the focal firm[3].

Cumulative R&D Investments. To capture cumulative R&D investments in areas where firms were under competitive pressure, we focused on capturing substantial R&D investments that firms had accumulated over time. The use of a general measure of R&D expenditure did not provide enough specific information for us to distinguish between the R&D accumulated across different therapeutic

[2] It is important to note that some patents could be assigned to more than one therapy code. In such cases, we counted a patent once if it fell into at least one of the categories in which rivals had launched new products.
[3] We excluded drugs launched by the focal firm in a given year when constructing the variable. As a robustness test, we built a measure using the same methodology with newly initiated Phase 3 trials by competitors as a proxy for competitive pressures. This measure was highly correlated with the one capturing drug launches, and yielded results that were qualitatively similar to those reported here.

areas. However, we were able to capture this information by looking at the late-stage clinical trials that a firm held in its portfolio. Phase 3 clinical trials reflect path-dependent accumulated investments in R&D, as drug-development projects progress step by step through early-stage discovery, preclinical tests on animals, and early-stage clinical trials (Girotra et al., 2007). Phase 3 investments entail validating the efficacy of a drug in large-scale clinical testing, often through trials involving thousands of patients, which is why such Phase 3 trials outweigh the other activities of the drug development process in terms of cost (DiMasi et al., 2003). The drug development process can take 10 years or more, consuming significant resources, and carries substantial residual uncertainty even in Phase 3, as only about 50–80% of such trials ultimately succeed (DiMasi et al., 2003; Stopke & Burns, 2015). Thus, in the biopharmaceutical industry, Phase 3 projects represent important accumulated R&D investments for firms. The variable *Cumulative R&D Investment* counts the number of ongoing and successfully completed Phase 3 trials of drugs that had not yet been approved for launch as reported by Pharmaprojects in the therapeutic areas in which rivals had launched new products.

Control Variables

Strategic Alliances. Firms engage in strategic external collaborations to develop knowledge and technological capabilities, and to acquire new resources (Mowery et al., 1996). To control for a firm's strategic use of external collaboration, we used the yearly count of R&D co-development and collaboration agreements using information from Recap.

M&A Activities. Firms can use mergers and acquisitions to become more innovative, and also to pre-empt technology competition. We constructed the variable *M&A Activities* by tracking the number of acquisitions firms had made during a given year.

Patenting Experience. We controlled for technological experience using the number of years that elapsed between the first time the firm applied for a patent and year *t*.

Firm R&D Intensity. A firm's expenditure on R&D activities is one of the main determinants of its capacity to absorb external knowledge and generate future innovations (Cohen & Levinthal, 1990). In order to control for firm differences in terms of absorptive capacity, we measured R&D intensity by dividing a firm's R&D expenses by its sales at year *t*.

Downstream Commercial Capabilities. We took into account that firms with more investments in the commercialization of drugs and products may react differently to increasing product market competition. Accordingly, we controlled for the logarithm of the total amount that firm *i* invested in advertising media and promotional expenses at year *t*.

Technological Diversity. A more diverse knowledge base may affect a firm's ability to recombine knowledge and innovate (Cohen & Levinthal, 1990). We controlled for technological diversity using 1- the Herfindahl index applied to the technological classes of the patents that firm *i* produced in the seven years prior to year *t*.

Organizational Myopia. We followed Agrawal, Cockburn, and Rosell (2010) in operationalizing myopia based on a seven-year moving-window ratio between the number of citations firm *i* made to its own patents, and the total number of citations that it made overall.

Evaluation Capacity. Firms differ significantly in their capacity to evaluate external knowledge. On the basis of Arora and Gambardella (1994), we calculated *Evaluation Capacity* using the average number of scientific references in the patents accumulated in the seven years preceding year *t*.

Technological Complexity. We controlled for firms' ability to handle technological complexity by computing the average number of claims on patents applied for by firm *i* during the seven years preceding year *t*. Experience in dealing with complex bodies of knowledge makes it easier for firms to integrate the acquired technology into their own knowledge bases (Leone & Reichstein, 2012).

Firm Size. Larger firms may have a stronger propensity to license and innovate. To control for firm size, we used the natural log of reported sales for firm i in year *t*.

Litigation. To control for licensing-in decisions triggered by patent lawsuits, we used a dummy variable that took value 1 if a firm had been sued at least once for infringing another firm's patents within the five years prior to year *t*, and 0 otherwise.

Competitors' initiations of preclinical trials. Firms may respond not only to competitors launching new products, but also to competitors' earlier R&D activities. We controlled for preclinical trial initiations made by competitors in the areas where a focal firm was active in R&D. We captured initiations through Pharmaprojects by the number of projects by competitors in a given year in the

therapeutic areas where a sample firm was active. Two researchers coded the initiation of trials of approximately 20,000 projects within the industry to identify the initiation of preclinical trials[4].

Overall Industry Commercial Competition. We controlled for commercial competition in order to avoid confounding effects between competitors specifically threatening areas that are relevant for a firm and the overall level of downstream competition in the industry. The variable *Industry Commercial Competition* was based on 1- the Herfindahl index computed using firm sales based on four-digit SIC.

Industry Sales Growth. We controlled for the extent to which specific therapeutic areas may present different levels of opportunities (e.g. due to an aging population). We calculated the average sales growth in the industry in a therapeutic area using data from Evaluate pharma, and then averaged this variable among the therapies in which firms actively invested in R&D. Sales growth is defined as sales in a given year over the sales in the prior year.

Empirical Strategy

We modeled empirically how competition shapes licensing-in and the subsequent effect of licensing-in on firm innovation towards rivals. To test the latter relationship, our technique had to take into account that neither of the variables—licensing-in and firm innovation—is independent from the other. Prior studies have highlighted that knowledge-sourcing strategy is not exogenous to firm innovation (Singh & Agrawal, 2011). It is possible that firms with higher innovation performance may also be more likely to rely on external knowledge-sourcing approaches such as licensing-in. Furthermore, despite our extensive control variables, there may still be unobservable factors affecting licensing-in decisions and also driving changes in the level of innovation in areas where competitors have exerted pressure. To deal with these potential issues, we employed an instrumental variable approach (2SLS) in which we first estimated the effect of competition on licensing-in decisions, and then the effect of licensing-in on firm innovation. The first stage of our 2SLS model was used to test Hypothesis 1, after which we used the second stage to test Hypotheses 2 and 3.

[4] Given the abundance of early-stage projects in the pharmaceutical industry, we limited our investigation to publicly listed firms, while for the variable *Competitors' Product Launches* we captured all global product launches in the industry.

The implementation of an instrumental variable technique requires one or more instruments that significantly predicts the dependent variable in the first stage, but does not correlate with the error term in the second equation (Wooldridge, 2003). As the use of multiple instruments can provide more accurate estimations in 2SLS models, we employed two distinct instruments to strengthen the robustness of our empirical analysis (Angrist & Krueger, 1991).

For the first instrument, we exploited a setup based on the enactment of statutes within the Uniform Trade Secrets Act (UTSA) that took place in 46 US states between 1975 and 2008. The enactment of UTSA by different states over time was driven neither by state-level economic conditions and industry competition, nor by individual firm-level characteristics such as innovation (Png, 2017). This alleviates concerns that the decision to enact the UTSA could be driven by the variables used to test our hypotheses. The implementation of the UTSA has also been used by several studies examining issues related to secrecy and innovation (e.g., Castellaneta, Conti, & Kacperczyk, 2017; Png, 2017).

Through the UTSA, a trade secret became more narrowly defined as information that includes formulas, patterns, compilations, programs, devices, methods, techniques, or process. Furthermore, the UTSA also defined civil and criminal procedures for claims and damages, and the corresponding remedies in case of misappropriation (Simon, 1998). Once the secrecy regulations had been implemented in a state, the likelihood of getting involved in a court action due to misappropriation increased, as did the costs of such litigation (Simon, 1998). Although there may be cross-state variations in the extent to which UTSA statutes were implemented, and their interpretation, the enactment of this legislation generally resulted in stricter and clearer trade-secret protection (Png, 2017). Such regulations are particularly relevant to the biopharmaceutical industry, where the reliance on external knowledge may spark costly disputes (Nealey, Daignault, & Cai, 2015).

We expect that this law will increase the number of licensing deals in the pharmaceutical industry by affecting incentives on both the supply and demand sides of the market for technology. Because the law toughened up both the definition of misappropriation and the remediation for violations related to trade secrets, we expect potential licensors to be more willing to offer technologies that are not protected by formal IP mechanisms. In this sense, technologies that are protected by secrecy, as opposed to formal IP, can entail significantly more learning opportunities for the licensee, as such

technologies are strategically kept undisclosed to the general public. Thus, post-UTSA enactment, the market for technologies is likely to exhibit a larger proportion of technologies with greater learning potential, which will be more keenly sought by potential licensees. Furthermore, if the legal remedy for misappropriation is clearly defined, licensors are less likely to be concerned about the potential misuse of their technologies, and therefore engage more actively in helping licensees understand and exploit the technology being transferred (Choi, 2002). This is important, as—in contrast to highly codified knowledge—the transfer of trade secrets requires more commitment from the technology supplier in order to ensure that the licensed technology is actually understood by the licensee. Licensors' commitment to supporting licensees' understanding and use of the licensed technology means that more knowledge flows between the two firms post-licensing (Oxley & Wada, 2009). Technology licensing allows both codified and uncodified technological knowledge to be contracted from the licensor to the licensee. In fact, the complexity of technologies in the biopharmaceutical industry results in licensing deals that include the transfer of knowledge that firms protect through secrecy (Arora, 1995).

We followed prior studies (see Castellaneta et al., 2017) to identify the state and year of enactment of statutes conforming to UTSA. To implement this setup, we tracked longitudinal changes in the status of UTSA enactment for firm *i*, which is located in state *j*, at year *t*. We used a dummy variable that took the value 0 when a state had not yet enacted the UTSA (or never enacted it during the sample period), and 1 once it had done so (or had already done so before the sample period began). With this setting, we captured both *cross*- and *within*-state variation in UTSA legal status. Therefore, we had a treatment group comprising firms in post-UTSA states, and a control group of firms in pre-UTSA states. Accordingly, our instrument was measured using a dummy variable capturing longitudinal and cross-sectional differences in UTSA status.

As a second instrument, we used a variable that influences technology holders' licensing decisions based on longitudinal changes in the supply structure of the market for technology in the biopharmaceutical industry. Prior research emphasizes that technology holders' willingness to license out their technologies reduces friction in the market for technology, making it more fluid (Arora & Fosfuri, 2003; Arora & Gambardella, 2010; Gans & Stern, 2003). As discussed by Teece (1986), one of the main factors driving technology holders' willingness to license-out their technologies is their own

(lack of) commercial capability to market their final products to customers. The stronger firms' commercial capabilities, the more they can profit from their own R&D investments, which induces them to take their technologies all the way from development to commercialization in-house instead of resorting to licensing as an alternative means of commercialization (Gans & Stern, 2003). As the opportunity cost of licensing out a technology as opposed to exploiting it in-house increases, technology holders are not only less likely to offer technologies for sale, but are also more likely to drive a harder bargain with potential licensees. This suggests that the stronger *technology holders' commercial capabilities* are in an industry, the fewer licensing deals we expect to observe in the market for technology.

We operationalized commercial capabilities in the biopharmaceutical industry as an instrument capturing the amounts spent on Selling, General, and Administrative Expenses (SG&A) in a given year (Rothaermel & Boeker, 2008). SG&A expenses are associated with company promotion and the commercialization and delivery of products and services. To do so, we identified all the public firms operating in the SIC codes 2834 ("Pharmaceutical Preparations") and 2836 ("Biological Products"), which represent the most important technology suppliers in the industry. We also restricted the sample used to compute this instrument to firms that had successfully applied for at least one patent within the five years prior to the focal year *t*, to capture only those firms with licensable technologies. Based on this sample we extracted the total amount that each firm spent on SG&A in a given year from COMPUSTAT. We then computed the technology-holding firms' average spend on SG&A in a given year, excluding the focal firm (our possible licensee). We expect that when there is high average SG&A spend for technology holders in the industry, these firms will have higher licensing-out opportunity costs, and thus our focal firm will license less, since the cost of acquiring technologies should increase. While we expect that this second instrument will negatively affect the licensing-in decision for firms, we do not expect it to affect how focal firms deploy licensed technologies to innovate in areas where competitors have launched new products.

Finally, to increase the robustness of our estimations, our empirical analysis also included within-firm fixed effects to account for any additional unobservable characteristics that are stable over time. We also used year fixed effects to capture time trends in licensing and innovation that are common

to all the firms in our sample. Finally, we use different year-lag structures between our dependent and independent variables in order to capture the nature of innovation in the pharmaceutical industry.

RESULTS

Table 1 reports descriptive statistics and simple pairwise correlations between the dependent and independent variables used in the regression analyses. We start by reporting the two dependent variables, and then move into the main explanatory and control variables. Results of the pairwise correlation raised no significant concerns regarding multicollinearity. Particularly, with the exception of one pairwise correlation, the explanatory variables *Competitors' Product Launches* and *Cumulative R&D Investments,* which are used to test the hypothesized effects, do not present any strong correlations, either with each other or with the control variables. The control variable *Competitors' Initiation of Preclinical Trials* shows a high correlation with *Competitors' Product Launches* in the magnitude of 0.82. This correlation is in line with our expectations, given that both variables capture different stages of competitors' drug development. To test whether this was a concern, we estimated our models with and without this control variable, and our main results remained unchanged. Additionally, the mean variance inflation factor (VIF) associated with the variables in our empirical model is very low (Mean VIF=2.94).

[*Insert Table 1 here*]

Table 2 reports the result of the first stage of the 2SLS regressions predicting firms' rate of *Technology Licensing-in*. We reported three different year-lags (*t*+1, *t*+2, and *t*+3) between the dependent and independent variables. Before interpreting the coefficient concerning our hypothesized effects, we examined the validity of the instruments we used to predict changes in *Technology Licensing-in* that are exogenous to *Innovation Towards Competition*. The coefficient for the first instrument, *UTSA Enactment*, reported in Model I indicates that the implementation of the UTSA statutes at the state level is positively and statistically significantly ($p<0.001$) associated with our dependent variable. The coefficient for the second instrument, *Technology Holders' Commercial Capabilities,* is negatively and also highly significantly ($p<0.001$) associated with our dependent variable. The direction and significance level of both instruments are in line with our expectations. We

use the models reported in Table 2 to test Hypothesis 1, concerning the effect of *Competitors' Product Launches* on firms' *Technology Licensing-in.* The estimated coefficient for the variable *Competitors' Product Launches* is positive and statistically significant across the different models, which suggests that competitors exerting pressure downstream through product market launches makes firms react by engaging in technology licensing-in. This lends support to Hypothesis 1, which suggests that *competitors' product launches in areas in which a firm actively invests in R&D increase the firm's rate of technology licensing-in*. Removing the variable *Competitors' Initiation of Preclinical Trials*, the main effect for *Competitors' Product Launches* remained statistically significant at the 5% level.

[*Insert Table 2 here*]

To test Hypotheses 2 and 3, we relied on the estimates of the second stage of the 2SLS regression. We used *Technology Licensing-in*, the dependent variable in the first stage, as an explanatory variable predicting longitudinal changes in *Innovation Towards Competition*. As part of the 2SLS approach, the second-stage models explicitly account for potential endogeneity issues between licensing and innovation. We used Models I, II, and III in Table 3 to test the effect of *Technology Licensing-in* on *Innovation Towards Competition.* Because the process of recombining licensed-in knowledge with a firm's internal R&D may vary over time, we tested the effect of *Technology Licensing-in* on the dependent variable using three different lag structures*: t+1*, *t*+2, and *t*+3. The effect of licensing-in on innovation towards competitors remained statistically significant across the three different lags. This finding provides consistent support to Hypothesis 2, which suggests that *technology licensing-in will be positively related to a firm's subsequent innovation in technological areas where competitors have launched new products.*

[*Insert Table 3 here*]

To test Hypothesis 3, we split the sample into firms below and above the median value for *Cumulative R&D Investments* using *one-year lag t+1* as a reference[5]. We used a split sample approach in order to avoid the complications associated with the selection and variance adjustments in 2SLS estimations (Wooldridge, 2009). Model IV, reported in Table 3, refers to the observations in which the

[5] Using either the two- or three-year lags generated results consistent with those reported below.

values fall below the *Cumulative R&D Investments* median, while Model V refers to those above the median. The comparison of the coefficients for *Technology Licensing-in* indicates the strength of the conditional effect that *Cumulative R&D Investments* has on the main relationship between licensing and *Innovation Towards Competition*. Using the split sample approach, we find that *Technology Licensing-in* only affected our dependent variable significantly for the observations that were above the median value for *Cumulative R&D Investments*. We observe that in Model IV the coefficient for technology licensing is insignificant, while Model V reports a positive and statistically significant effect. This finding is consistent with Hypothesis 3, which argues that *the higher a firm's accumulated R&D investments in the technological areas where competitors have launched new products, the stronger the relationship between licensing-in and subsequent firm innovation in these areas.*

In order to visualize the magnitude of the effect of *Technology Licensing-in* on *Innovation Towards Competition*, Figure 1 shows the marginal effect for different levels of this explanatory variable. The effect of licensing on innovation stays positive and significant for the different values reported in the graph. In terms of size effects, an increase of one standard deviation in *Technology Licensing-in* from its mean is associated with a corresponding change of 46% in our dependent variable. Figure 2 helps visualize the effect of *Technology Licensing-in* on *Innovation Towards Competition* when taking into account different levels of *Cumulative R&D Investments*. The figure shows the changes in the predicted levels of the dependent variable looking at simultaneous changes in licensing and accumulated R&D. There is a peak (i.e., the red area around the upper right side) in the rate of *Innovation Towards Competition* precisely when *Technology Licensing-in* and *Cumulative R&D Investments* are simultaneously at their highest levels. Conversely, when both variables are at their lowest levels simultaneously, *Innovation Towards Competition* reaches its lowest level (i.e., the blue area). In terms of size effect, an increase in *Cumulative R&D Investments* of one standard deviation from its mean leads to an increase of 11% in the effect of *Technology Licensing-in* on *Innovation Towards Competition*.

Finally, we comment on some interesting patterns revealed by our control variables. In Model I Table 2, the control *Competitors' Initiation of Preclinical Trials* is significant and negative predicting technology licensing-in. However, some of this effect is driven by the correlation of the variable with

other covariates. Indeed, *Competitors' Initiation of Preclinical Trials* without including *Competitors' Product Launches* in the model shows no statistically significant effect on licensing. In principle, reacting earlier to rivals' actions may have advantages, as firms may keep their R&D capabilities relevant, and at the technological frontier. However, this industry is characterized by a large number (possibly thousands) of new projects, which still entail substantial levels of uncertainty (DiMasi et al., 2003; Girotra et al., 2007), and this could make it difficult for firms to identify which project initiations to react to. Indeed, we know that one of the key issues firms face in environments of technological change is the issue of limited attention, which may be salient when there are too many different preclinical initiations by rivals (Eggers & Kaul, 2018). The patterns observed for *Competitors' Initiation of Preclinical Trials* suggest that, in contrast to *Competitors' Product Launches,* early-stage R&D activities by competitors do not predict licensing-in.

Additional Analyses

The central idea in this paper is that firms use technology licensing-in to acquire external knowledge that they can subsequently incorporate into internal R&D activities. However, with our empirical setup, we do not observe directly the knowledge transfer and learning shaping firm innovation. Thus, we complemented our initial results with additional analyses to demonstrate the underlying mechanism through which licensing affects the licensee's R&D activities more directly.

We distinguish three important areas that help explicate the relationship between licensing and innovation: first, whether licensee firms leverage specific in-licensed technologies; second, whether licensee firms leverage the licensors' technologies in general; and third, changes in the patterns of the licensee R&D output following licensing. The results for these additional tests are reported below.

Use of licensed technologies. In order to determine whether firms do increase their patenting activities using specific licensed technology, we examined a subset of licensing deals for which we could capture the underlying technology of the deal and track the subsequent citation patterns for the focal firm (the licensee). We examined licensing deals available in Recap for which we could access and download the actual licensing contract between licensee and licensor, and for which we could find a specific seven-digit patent number in the contract that was registered at the USPTO and represented

the licensed technology. Next, we looked at the backward citations in the patents that the licensee firms had produced before and after the licensing deal. As a dependent variable, we used the cumulative number of citations that a licensee firm made to a specific licensed technology during the four years preceding a licensing deal, and the four years following. The main explanatory variable is a dummy for the post-licensing period that takes value 0 pre-licensing and value 1 post-licensing. The results are reported in Model I in Table 4. The coefficient of the post-licensing indicator suggests a positive relationship of citations to a specific technology post licensing, supporting the idea that firms learn about specific technologies through licensing.

One potential issue with this approach is that licensing could occur simultaneously with the decision to focus the firm's R&D on specific technological areas. Thus, we used a more stringent econometric specification in which each licensed patent was matched to a comparable control group. We matched licensed against non-licensed patents on the same technological classes, application year, and the value of the patent (measured based on forward citations). Based on the two groups, licensed and non-licensed, we performed a difference-in-differences analysis in which we compared the citation patterns of licensee firms to the two groups of patents, pre and post a licensing deal. The dummy variable *post-licensing* takes a value of 0 for the pre-licensing period and 1 for the post-licensing period, for both groups' control and licensed patents. The dummy *treated* takes value 1 if a patent belongs to the licensed group and 0 if it belongs to the control group. The main result comes from the interaction between these two dummies and is reported in Model II in Table 4. The interaction *post-licensing x treated* captures the longitudinal changes in the citations received by a licensed technology in the post-deal period while accounting for the rate of citations to a patent that has similar characteristics but has not been licensed. This interaction effect is positive and statistically significant. We take this test as important additional evidence that firms are making productive use of the licensed technologies by incorporating them into their own R&D.

Finally, we went through the broad list of licensing deals in our sample and searched for their history using multiple data sources including LexisNexis, Pharmaprojects, Adis R&D Insight, and Evaluate Pharma. We found several instances where we had sufficient information to conclude that licensed knowledge had been incorporated in a firm's R&D activities. For example, licensing deals

including Xenomouse technology (licensee Pfizer), human leucocyte antigen blocking technology (licensee Merck & Co.), or gene expression technology (licensee Immunex) led to the creation of a new product in preclinical trials, and firms typically patent such products prior to testing them on humans (Girotra et al., 2007). In the identified cases, about 2.3 years separated the licensing agreement and the initiation of preclinical trials. Given that patenting typically takes place even earlier, this also gave us confidence that our window of 1–3 years is adequate to test for firm patenting following licensing.

Licensor–licensee knowledge transfer. Next, we consider that the knowledge transferred between licensee and licensor can also extend beyond the licensed technology. Therefore, we examine citation patterns of licensee patents, which use the patents produced by the licensor as an input. We expect that such citations capture the knowledge flow from licensor to licensee following a licensing deal. Following our theoretical arguments, we expect that, post-licensing, firms will also tend to significantly increase their reliance on the licensor's technologies to feed their own R&D efforts. Conversely, if licenses are signed purely for the transfer of IP rights, we would not expect the licensee to increase their use of the licensor's wider technological portfolio; instead, they would confine themselves to the single licensed technology.

Specifically, we examine the number of citations made by the licensee to the licensor's patents as evidence for learning between the firm providing the knowledge and the licensee. Similar to the technology-level analysis, we capture the number of citations that the licensee makes to the licensor pre- and post-licensing deal using four-year windows. The analysis is on the level of the licensee-licensor dyad. The key explanatory variable takes a value of 0 for the pre-deal period and 1 for the post-deal period. Results of a negative binomial count model are reported in Model III in Table 4. The positive and highly significant coefficient for *Post-Licensing* suggests a strong increase in the licensee's citations of the licensor's patents post-licensing, which offers further evidence to support a knowledge transfer and learning mechanism.

We wanted to ensure that these results were not driven by the fact that larger firms are also more likely to have more patents, and therefore also cite more patents from any other firm, including the licensor. Thus, we calculated the ratio between total citations to licensor patents and the licensee's total citations. This alternative dependent variable is bounded between 0 and 1, and we used a Tobit

model with the same setup as in the previous test. Model IV in Table 4 once again shows strong evidence that licensees cite licensors more frequently post-licensing—even when normalizing the citation counts.

Post-licensing innovation. In the third set of analyses, we examined the post-licensing patenting patterns of the licensee. While we show that firms create more inventions in areas where rivals have launched new products, we also wanted to test whether a licensee changes in terms of its technological profile after licensing.

First, we calculated firms' *Scope of Recombination* by looking at how many different technology classes they cited in a given year, to capture the extent to which they recombined knowledge from a wider range of technological fields. In detail, we capture a licensee's yearly count of different technological classes that they cite in patents (Gruber, Harhoff, & Hoisl, 2013). The key explanatory variable is the number of licensing deals in a given year by a focal firm. As shown in Model V in Table 4, this variable has a direct (positive) effect on the scope of recombination. Focusing on patents filed in the areas where rivals have launched new products also validates these results.

Next, we wanted to more directly capture the exploration of new technologies by the licensee as a result of licensing activity. The dependent variable is *Use of New Technologies* at the firm level, captured through the ratio between the number of new citations and the total number of citations that firms make each year. Following prior work, we consider a citation to be "new" if it has not been used for 7 years prior to the focal year (Phelps, 2010). Model VI in Table 4 shows the Tobit model results using *Use of New Technologies* as the dependent variable. As the coefficient of yearly licensing deals shows, we find strong evidence that firms are able to explore more new technologies following licensing. Once more, this strengthens our overall premise: that licensing facilitates learning and new recombinations. These results suggest that licensing-in, in our context, is not merely an exchange of IP rights, but shapes firms' recombination of knowledge within their R&D activities.

[*Insert Table 4 here*]

Alternative Explanations and Robustness Checks

We performed several additional analyses to test alternative explanations as well as the robustness of our results (available from the authors upon request). First, to test whether technology licensing also

affects firms' general innovation in the same way as it affects innovation towards competition, we replicated our main models using the number of patents in areas not affected by competitors as a dependent variable. We found no statistically significant effect for licensing-in on this alternative dependent variable. This suggests that licensing as a reaction to competition has an effect on innovation in areas where a firm has been threatened, but not necessarily on its overall innovation output. Interestingly, though, we did find that the variable *Strategic Alliances* had a positive and significant effect ($p<0.05$) on general innovation. These findings reveal that licensing is more likely to be used as a form of knowledge sourcing when firms have clear R&D targets—as distinct from alliances, which tend to be deployed in a more general way.

Second, studies (e.g., Laursen & Salter, 2006) have indicated that firms that over-rely on (over-utilize) knowledge outsourcing are likely to harm their innovation outcomes. If this idea held for technology licensing-in, we would expect a non-linear relationship between the number of licensing-in deals and firm innovation. We investigated whether such a relationship was present in our sample by adding the squared-term of the number of licensing-in deals. The coefficient for the non-linear term was positive and statistically insignificant. This finding provides no indication that too much licensing reduces firms' capacity to innovate in the focal areas in which competitors have launched products.

Third, we also examined whether product launches by competitors have different effects on firms' decision not to license in a given year and the amount of licensing deals that firms engage. We use a zero-inflated negative binomial model with the first equation estimating the likelihood that a firm will engage in licensing and the second stage the total number of licensing deals in a given year. The results for the variable *Competitors' Product Launches* not statistically significant, on the first-stage but positive and significant effect on the second-stage of the zero-inflated model.

Fourth, we investigated not only whether firms do more licensing-in when competition is more intense, but also whether the characteristics of the deals then change. We split the licensing deals into deals realized under high and under low competitive pressure (based on the mean value of *Competitors' Product Launches*). We then used a set of t-tests to investigate whether three technology-related attributes were statistically different across the two subsamples: the *Stage of Development of the Licensed-In Technologies*, whether the *Licensor is a University*, and the *Amount of Royalty Payment*

agreed in the licensing remuneration scope[6]. We did not find any statistically meaningful differences for these three attributes. With respect to the licensing deals, we also explored an additional check related to the use of exclusivity clauses in the contractual scope of the licensing deals involved. Exclusive deals can affect the incentive that the licensee firm has to commit resources in the upstream development of the licensed technology. We estimated our models having removed from our sample those deals in which the licensee had exclusive rights to exploit the licensed technology, and the results remained very similar to those obtained with the full sample of licensing deals. In this regard we found no evidence that exclusivity clauses will significantly shape the extent to which the firms in our sample increase innovation towards competition. We also ran a robustness test in which we used an alternative measure for cumulative R&D investments by including all products launched in a given year. The results using this alternative operationalization are very similar to the ones reported in our main results.

Finally, we examine licensors' and licensees' industry affiliation, as the predominance of licensing deals between firms within the same industry could suggest stronger knowledge overlap pre-licensing, and possibly that licensing is done for IP motives such as pre-empting litigations due to patent infringement, rather than to acquire new knowledge with the intention of learning and strengthening the firm's internal R&D. In our sample, 70% of the licensees come from SIC 2834 ("Pharmaceutical Preparations"). Conversely, licensors are more evenly spread, with the main industries including 2834 (36%), 2835 ("In Vitro and In Vivo Diagnostic Substances," 10%), and 2836 ("Biological Products, Except Diagnostic Substances," 36%). Based on the industry distribution, licensee firms are 75% more likely to license from a firm located in a different SIC code.

DISCUSSION AND CONCLUSION

How are competition and innovation connected? The question has attracted longstanding interest (Aghion et al., 2005; Cohen & Levin, 1989; Kamien & Schwartz, 1982). In this paper, we approach it by anchoring technology licensing as a key organizational action that helps increase our understanding of the important relationship between competition and innovation.

[6] To perform this test, we changed the level of analysis from firm-year observations to deal level, as the same firm can engage in more than one licensing deal in the same year.

We focus on the characteristics that make licensing an important response when firms are under competitive pressure from rivals' new products (downstream) and try to upgrade their own technological capabilities (upstream). These characteristics include the *ex-ante* definition of the knowledge to be acquired and the *unilateral* manner in which it is transferred. Further, we investigate the outcomes of technology licensing-in by examining how licensing relates to firm innovation. We emphasize that licensing is particularly relevant for the creation of innovation in technological areas in which firms are under pressure from rivals. At the same time, this relationship is contingent on a firm's cumulative R&D investments that are threatened by competitors. Thus, the way licensing connects competition and innovation may be contingent on what is "at stake" for a firm's internal R&D. We find support for our predictions using a sample of firms within the biopharmaceutical industry.

Our study makes important contributions to the research on competition, licensing, and innovation (Aghion et al., 2005; Arora & Gambardella, 2010; Toh & Kim, 2013). First, we demonstrate the role of licensing as a way for firms to tap into *external* sources of knowledge to complement their existing *internal* R&D efforts. In so doing, we clarify the distinct role of licensing versus other knowledge-seeking actions, such as alliances, as a response to firms' upstream capabilities being threatened by competitors. Prior research examining the relationship between competition and collaboration has suggested that the inherent coordination costs and risks of strategic alliances discourage firms from using them when competition is very intense (Ang, 2008; Sakakibara, 2002). We show that licensing is an important mechanism that firms can use to promptly access external knowledge when under pressure from rivals.

Second, we add to the innovation literature by linking licensing to subsequent innovation in areas in which firms are under pressure from rivals. This expands on the general idea that downstream competitive pressure may have important implications for firms' upstream activities (Toh & Polidoro, 2013). Specifically, our study joins a recent research stream (e.g., Eggers & Kaul, 2018; Martin & Mitchell, 1998; Toh & Kim, 2013) that goes beyond examining how competition affects innovation in general by accounting for the direction of a firm's innovative efforts when reacting to competitors. We add to this literature by examining innovation directed towards areas in which rivals have put firms under pressure, and by testing how licensing-in allows firms to innovate in such areas.

On a more general level, we throw more light on the question of how firms can derive innovation benefits from licensing, or whether licensing is simply a "handoff" that has no effect on a firm's capacity to innovate (Eisenhardt & Schoonhoven, 1996; Koza & Lewin, 1998). By showing that licensing-in actually triggers changes in the way firms innovate, we provide more evidence that licensing goes beyond the transfer of IP rights, and also opens up recombination opportunities for the licensee. This adds to the understanding of firms' demand for licensing (Arora & Gambardella, 2010), and to the analysis of the repercussions of licensing on firms' capacity to innovate (Johnson, 2002).

Finally, we illustrate the interplay between licensing-in and a firm's internal R&D by showing that the relationship between licensing and subsequent innovation directed at rivals is shaped by the presence of cumulative R&D in specific technological areas. This adds to our understanding of how integrating, recombining, and deploying external knowledge in general may depend on the internal R&D organization to which such knowledge is added (Bierly et al., 2009; Kapoor & Klueter, 2015). In particular, we explicate that licensed knowledge is deployed towards innovations in areas in which rivals are exerting competitive pressure in the presence of internal cumulative R&D investments in those same areas. Thus, cumulative investments shape a firm's incentives towards exploiting the knowledge recombination potential added through licensing in areas where rivals have launched new products. With less cumulative investment in those areas, firms may have little to gain from channeling their recombination potential from licensing towards these areas of competitive pressure, and may opt for alternative paths. This adds to the broader conversation in the literature about the conditions under which firms will try to innovate in areas where they are under competitive pressure, or when they will avoid confronting their rivals directly (Clarkson & Toh, 2010; Kaul, 2012).

This study also has limitations, which provide ample opportunities for future research. Starting at the relationship of rival product launches and licensing, we considered rival product launches as possible threats to firms, as any successful launch of a new drug in a therapeutic area in which a focal firm is actively investing in R&D gives the competitor an edge. However, it is possible that such threats also present opportunities for firms to examine relevant technological domains. Future studies could carefully examine the types of rivals' product launches, in order to unpack whether increasing patenting activity in the related areas could be driven by either opportunities or threats.

With respect to the relationship between licensing and innovation, we emphasize that licensing-in may help firms innovate and stay competitive *vis-à-vis* their rivals. However, we have not examined whether the licensing activity ultimately leads to future product launches, which will allow firms to compete in commercial markets. Given the lengthy R&D cycles in the pharmaceutical industry, establishing a clear linkage between licensed knowledge and launched drugs may be challenging. Even so, future studies on the licensing level may reveal how licensed knowledge is, ultimately, transformed into marketable products. Relatedly, we have not taken into account that licensing might impose costs over the *longer term.* Previous research has suggested that firms need to maintain a satisfactory level of internal R&D in order to sustain innovation (Cohen & Levinthal, 1990). Therefore, heavy reliance on mechanisms such as licensing agreements may upset the appropriate balance between internal and external knowledge flows (Mulotte, Dussauge, & Mitchell, 2013) or lead to the emergence of path dependences and core-rigidities. Given that firms can use technology licensing to channel their R&D, this may lead to R&D myopia and a lack of capacity to shift to alternative paths. This raises the question of whether firms that boost innovation in the short term through licensing may face issues over the long term, as their capacity to innovate based on their own R&D may be impaired. Thus, future studies should track more systematically how licensing shapes long-term internal innovation.

Another limitation is that we focus on just one contingency related to cumulative R&D investments—albeit an important one. However, it is well known that external knowledge sourcing, and the integration and recombination of licensed knowledge, are contingent on many factors, including a firm's absorptive capacity (Moreira et al., 2018), attention from scientists and managers (Klueter et al., 2017), the structure of collaboration networks among scientists (Moreira et al., 2018), or the diversity of the knowledge base of the firm (Laursen et al., 2010). These factors have been shown to be relevant for the general innovation outcomes of firms. Future research could build on our study and explore additional firm-level contingencies that can moderate or directly affect the relationship between technology licensing-in and innovation within the context of high competition.

With respect to our empirical setting, we used biopharmaceuticals as the empirical context to test our hypotheses. This industry made an adequate setting, since it is characterized by R&D competition and licensing is common. However, it also raises concerns regarding the generalizability

of our findings. Future research should aim at extending this study into different empirical settings in which the acquisition of external knowledge plays a key role, such as the semiconductor and electronics industry. Relatedly, an important extension of our study is to move beyond the year 2004, which is where our sample period ended. For this study we took a 15-year period for which we collected all relevant data, including licensing, patenting, and rival product launches. We know that licensing has played an important role for firms in the last decade, and, despite some consolidation, competition remains fierce, with new players emerging (e.g. Gilead or Regeneron) (Giniatullina et al., 2013; OECD, 2013). However, the rise of information technology may shape how firms observe their competitors and the landscape of licensing opportunities, which is why testing our model post-2004 would be interesting.

Concerning our analysis related to the additional tests, we believe that the robustness of the econometric specifications has substantially reduced empirical concerns. However, in our empirical setup we do not connect directly how specific licensed technologies are deployed by the licensee firm to create innovations. This limitation leaves space for future studies aiming at further understanding knowledge transfer and recombination in the context of technology licensing. Particularly, we encourage future research examining the existence of a causal link between licensing and innovation, using alternative identification strategies and different levels of analysis such as the level of the licensed technology or dyadic licensor-licensee level. We also note that we only take into account endogeneity related to licensing-in and innovation, and therefore do not fully account for potential issues in the first stage of our 2SLS models. Unobserved factors could simultaneously drive competitors' new-product launches and firms' licensing-in decisions. This issue is partially mitigated by the way we operationalize competitive pressure from competitors. In the biopharmaceutical industry, rival product launches require approval from an external authority (e.g. the FDA in the US), which is a very complex and costly process that mostly ends in failure. This suggests that neither competitors nor a focal firm in our sample will have full control over the product launches and the areas in which new drugs are approved.

In conclusion, we believe that licensing-in plays a central role in helping us understand the relationship between competition and innovation. This creates a promising avenue for future studies aimed at connecting drivers of licensing, such as competition, and outcomes, such as innovation. The present paper constitutes a first step towards exploring this research agenda.

Table 1. Descriptive Statistics and Correlation Coefficients (N =1,974; Groups=206)

	Variable	Mean	S.D.	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
[1]	Technology Licensing-in	2.47	4.53	1.00									
[2]	Innovation towards competition	1.08	1.34	0.58	1.00								
[3]	Competitors product launches	47.91	34.94	0.61	0.60	1.00							
[4]	Cumulative R&D Investments	1.44	2.12	0.64	0.58	0.59	1.00						
[5]	Strategic Alliances	0.21	0.62	0.54	0.41	0.40	0.37	1.00					
[6]	M&A Activities	0.18	0.50	0.38	0.23	0.26	0.27	0.20	1.00				
[7]	Patenting Experience	10.16	8.07	0.37	0.36	0.37	0.35	0.14	0.19	1.00			
[8]	Firm R&D Intensity	25.16	30.40	0.26	0.36	0.27	0.21	0.18	0.14	0.10	1.00		
[9]	Downstream Assets	0.75	1.85	0.29	0.25	0.35	0.40	0.11	0.14	0.44	0.07	1.00	
[10]	Technological Diversity	0.50	0.35	0.25	0.29	0.24	0.23	0.16	0.12	0.35	0.06	0.27	1.00
[11]	Organizational Myopia	0.13	0.15	0.04	0.21	0.03	0.07	0.02	-0.03	0.18	0.01	0.03	0.09
[12]	Evaluation Capacity	27.60	32.10	-0.14	-0.08	-0.12	-0.19	-0.06	-0.10	-0.25	0.06	-0.19	-0.16
[13]	Technological Complexity	18.78	9.26	-0.07	-0.05	-0.08	-0.08	-0.04	0.04	-0.12	0.04	-0.16	-0.14
[14]	Firm Size	3.94	3.17	0.59	0.53	0.61	0.55	0.32	0.28	0.64	0.23	0.57	0.43
[15]	Litigation	0.24	0.43	0.38	0.42	0.39	0.38	0.21	0.16	0.38	0.26	0.31	0.20
[16]	Competitors Initiation of Preclinical Trials	283.23	206.93	0.54	0.59	0.82	0.58	0.32	0.20	0.34	0.28	0.39	0.25
[17]	Overall Industry Commercial Competition	0.16	0.15	-0.16	-0.22	-0.23	-0.20	-0.10	-0.10	-0.12	-0.09	-0.16	0.03
[18]	Industry Sales Growth	1.20	1.06	-0.03	-0.01	0.04	-0.01	-0.02	-0.04	-0.06	-0.00	-0.03	-0.05

	Variable	Mean	S.D.	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
[11]	Organizational Myopia	0.13	0.15	1.00							
[12]	Evaluation Capacity	27.60	32.10	-0.05	1.00						
[13]	Technological Complexity	18.78	9.26	-0.04	0.19	1.00					
[14]	Firm Size	3.94	3.17	0.04	-0.30	-0.14	1.00				
[15]	Litigation	0.24	0.43	0.04	-0.08	-0.07	0.48	1.00			
[16]	Competitors Initiation of Preclinical Trials	283.23	206.93	0.06	-0.11	-0.12	0.56	0.41	1.00		
[17]	Overall Industry Commercial Competition	0.16	0.15	0.02	0.10	-0.07	-0.15	-0.12	-0.14	1.00	
[18]	Industry Sales Growth	1.20	1.06	0.02	0.09	0.01	-0.08	-0.03	0.09	0.06	1.00

Table 2. First-stage firm fixed effects regressions predicting Technology Licensing-in

	it+1	*it+2*	*it+3*
Variables	Model I	Model II	Model III
Competitors product launches	0.017***	0.023***	0.013**
	(0.004)	(0.004)	(0.006)
Cumulative R&D Investments	0.040	0.076	0.026
	(0.050)	(0.050)	(0.162)
Strategic Alliances	0.519***	0.568***	0.360*
	(0.102)	(0.101)	(0.191)
M&A Activities	0.624***	0.127	0.670**
	(0.123)	(0.119)	(0.213)
Patenting Experience	6.152***	5.768***	5.780***
	(0.430)	(0.429)	(0.700)
Firm R&D Intensity	-0.001	0.008**	0.000
	(0.003)	(0.003)	(0.003)
Downstream Assets	-0.246***	-0.124**	-0.282**
	(0.063)	(0.062)	(0.143)
Technological Diversity	-0.142	-0.052	-0.344*
	(0.185)	(0.189)	(0.180)
Organizational Myopia	0.153	0.345	-0.050
	(0.559)	(0.558)	(0.581)
Evaluation Capacity	0.000	0.005	0.004
	(0.003)	(0.003)	(0.003)
Technological Complexity	0.005	0.004	0.006
	(0.008)	(0.009)	(0.008)
Firm Size	0.166**	0.055	0.295**
	(0.076)	(0.080)	(0.094)
Litigation	0.141	0.456*	0.125
	(0.260)	(0.261)	(0.354)
Competitors Initiation of Preclinical Trials	-0.002**	-0.003***	-0.000
	(0.001)	(0.001)	(0.001)
Overall Industry Commercial Competition	3.204***	5.208***	4.143***
	(0.721)	(0.753)	(1.225)
Industry Sales Growth	0.064	0.053	0.079**
	(0.052)	(0.053)	(0.040)
UTSA Enactment	3.036***	3.908***	1.937**
	(0.919)	(0.922)	(0.830)
Technology Holders' Commercial Capabilities	-0.131***	-0.122***	-0.122***
	(0.009)	(0.009)	(0.015)
Year Fixed Effects	YES	YES	YES
Constant	63.537***	55.746***	53.215***
	(4.968)	(4.774)	(7.313)
Number of Observations	1,974	1,768	1,562

Two-tailed tests for all variables; standard errors in parentheses.
*** p<0.001, ** p<0.05, * p<0.1

Table 3. Second-stage 2SLS firm fixed effects regressions predicting *log*(*Innovation Towards Competition*+1)

	it+1	*it+2*	*it+3*	Low Cumulative R&D Investment	High Cumulative R&D Investment
Variables	Model I	Model II	Model III	Model IV	Model V
Technology Licensing-in	0.099***	0.102***	0.097***	-0.118	0.075**
	(0.019)	(0.023)	(0.029)	(0.243)	(0.023)
Competitors product launches	0.002	0.002*	0.002	0.000	0.002
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Cumulative R&D Investments	0.076***	0.070***	0.053**		
	(0.015)	(0.016)	(0.017)		
Strategic Alliances	-0.065	-0.098**	-0.136**	0.241	-0.052
	(0.040)	(0.045)	(0.051)	(0.311)	(0.047)
M&A Activities	-0.094**	-0.058	-0.077	0.358	-0.149**
	(0.043)	(0.048)	(0.054)	(0.227)	(0.054)
Patenting Experience	0.036***	0.037**	0.041**	-0.006	0.108***
	(0.011)	(0.012)	(0.014)	(0.018)	(0.018)
Firm R&D Intensity	0.001*	-0.000	-0.002**	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.005)	(0.001)
Downstream Assets	-0.109***	-0.103***	-0.094***	-0.020	-0.067**
	(0.018)	(0.020)	(0.022)	(0.061)	(0.021)
Technological Diversity	0.081	0.036	0.041	0.078	0.039
	(0.054)	(0.061)	(0.065)	(0.068)	(0.084)
Organizational Myopia	0.283*	0.083	-0.089	0.949***	-0.122
	(0.162)	(0.185)	(0.206)	(0.222)	(0.241)
Evaluation Capacity	0.001	0.000	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Technological Complexity	0.002	0.005*	0.003	0.000	-0.001
	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)
Firm Size	0.044**	0.060**	0.066**	0.103**	0.019
	(0.022)	(0.024)	(0.027)	(0.031)	(0.035)
Litigation	0.450***	0.407***	0.319***	0.396**	0.407***
	(0.075)	(0.082)	(0.086)	(0.173)	(0.096)
Competitors Initiation of Preclinical Trials	0.000**	0.000**	0.001**	0.001**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Overall Industry Commercial Competition	0.634**	0.286	-0.075	-0.083	0.899**
	(0.227)	(0.255)	(0.284)	(0.307)	(0.377)
Industry Sales Growth	-0.003	-0.020	-0.015	-0.014	0.021
	(0.015)	(0.016)	(0.015)	(0.016)	(0.025)
Year Fixed Effects	YES	YES	YES	YES	YES
Constant	-1.067***	-0.995***	-0.796***	-0.342*	-1.849***
	(0.162)	(0.174)	(0.184)	(0.190)	(0.335)
Number of Observations	1,974	1,768	1,562	812	1,162

Two-tailed tests for all variables; standard errors in parentheses.
*** p<0.001, ** p<0.05, * p<0.1

Table 4. Licensing and Knowledge Transfer

Variables	Model I Number of Citations to Licensed Technology	Model II Number of Citations to Licensed Technology	Model III Number of Citations to Licensor Technologies	Model IV Ratio of Citations to Licensor Technologies	Model V Scope of Knowledge Recom-bination	Model VI Use of New Technologies
Treated x Post-Licensing		0.242**				
		(0.114)				
Treated		0.193***				
		(0.050)				
Post-Licensing	0.272**	0.030	0.322***	0.010***		
	(0.109)	(0.030)	(0.092)	(0.002)		
Technology Licensing-in					0.011**	0.025**
					(0.004)	(0.010)
Competitors product launches	-0.004*	-0.002*	-0.002	-0.000	0.000*	0.008***
	(0.002)	(0.001)	(0.005)	(0.000)	(0.000)	(0.002)
Cumulative R&D Investments	-0.061**	-0.032**	0.077**	0.001**	0.033***	0.006
	(0.026)	(0.013)	(0.024)	(0.000)	(0.008)	(0.020)
Strategic Alliances	0.038	0.034	0.049	0.001	0.037**	0.024
	(0.043)	(0.026)	(0.060)	(0.001)	(0.017)	(0.053)
M&A Activities	0.293**	0.128**	0.085	0.001	0.005	0.051
	(0.116)	(0.062)	(0.096)	(0.002)	(0.021)	(0.065)
Patenting Experience	0.011	0.006*	0.015	0.000	0.077***	0.001
	(0.007)	(0.004)	(0.009)	(0.000)	(0.004)	(0.006)
Firm R&D Intensity	-0.005	-0.002	0.003**	0.000*	0.002***	0.002
	(0.003)	(0.002)	(0.001)	(0.000)	(0.000)	(0.001)
Downstream Assets	-0.000**	-0.000**	-0.000**	-0.000*	-0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Technological Diversity	0.164	0.094	0.061	-0.013*	0.079**	0.341**
	(0.178)	(0.090)	(0.462)	(0.008)	(0.033)	(0.112)
Organizational Myopia	1.951*	0.960*	2.749***	0.046***	-0.107	-0.680**
	(1.045)	(0.528)	(0.691)	(0.012)	(0.091)	(0.232)
Evaluation Capacity	0.006	0.003	0.012**	0.000*	-0.001*	-0.006***
	(0.008)	(0.005)	(0.005)	(0.000)	(0.000)	(0.001)
Technological Complexity	0.046*	0.023*	-0.002	-0.000	0.001	-0.001
	(0.025)	(0.013)	(0.011)	(0.000)	(0.002)	(0.004)
Firm Size	-0.088	-0.046	0.022	-0.000	-0.448***	-0.372***
	(0.061)	(0.031)	(0.061)	(0.001)	(0.020)	(0.058)
Litigation	0.156	0.067	-0.004	-0.001	0.092**	-0.079
	(0.211)	(0.107)	(0.186)	(0.003)	(0.042)	(0.087)
Competitors Initiation of Preclinical Trials	0.002*	0.001*	0.000	-0.000	0.000*	-0.000
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Overall Industry Commercial Competition	0.173	0.072	-0.124	0.005	-0.026	0.029
	(0.999)	(0.511)	(0.770)	(0.013)	(0.136)	(0.250)
Industry Sales Growth	-0.442	-0.222	0.078	0.002	-0.009	-0.005
	(0.445)	(0.238)	(0.077)	(0.002)	(0.009)	(0.031)
Year Fixed Effects	YES	YES	YES	YES	YES	YES
Constant	-0.617	-0.403	-4.015***	-0.078***	-0.406***	0.669**
	(0.514)	(0.263)	(0.814)	(0.015)	(0.090)	(0.251)
Number of Observations	809	1.618	4.863	4.863	1.749	1,749

Two-tailed tests for all variables; standard errors in parentheses.
*** p<0.001, ** p<0.05, * p<0.1

FIGURES

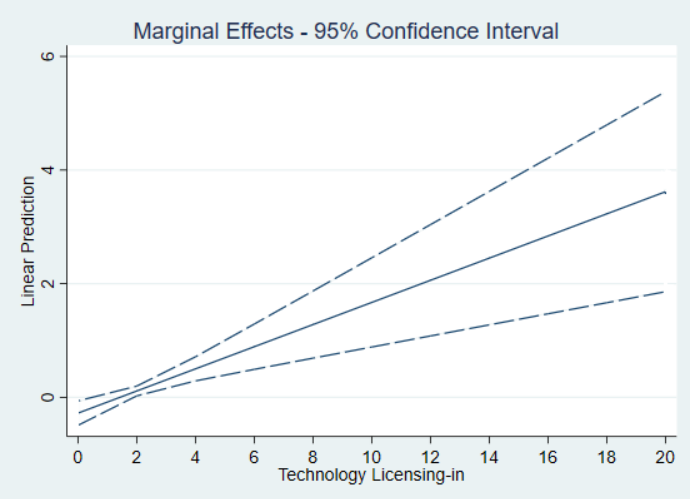

Figure 1. Marginal Effect of Technology Licensing-in on Innovation towards Competition (95% confidence interval)

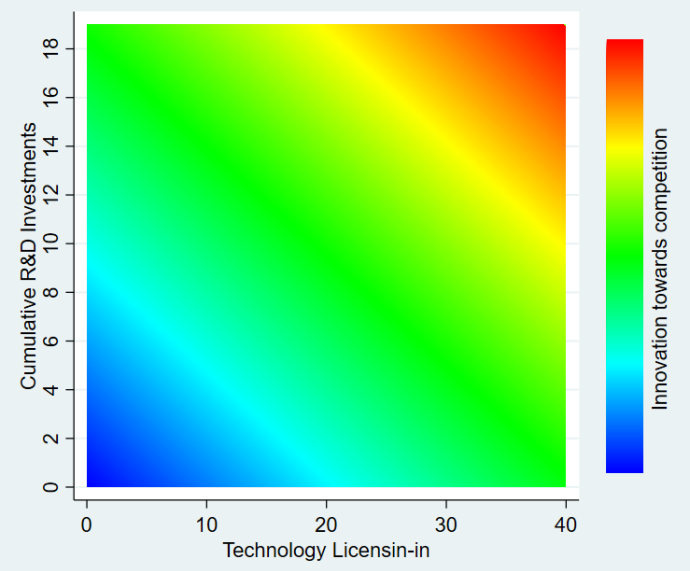

Figure 2. Linear Prediction for Innovation Towards Competition conditional on Technology Licensing-in and Cumulative R&D Investments

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