R&D collaboration with common partners and the risk of knowledge leakage to rivals: The role of IP litigation strategy

Sarah Edris
Maastricht University

René Belderbos
KU Leuven, Maastricht University and UNU MERIT

Victor Gilsing
VU Amsterdam

ABSTRACT

We argue that knowledge leakage may occur to rival firms through indirect ties, i.e., if rivals collaborate on R&D with a common partner, but that firms with an aggressive patent litigation strategy may be able to restrict such knowledge spillovers. We expect knowledge leakage to be more prominent, and litigation strategy to be less powerful, when the common partner is a university or public research institution adhering to the open science paradigm, compared with when the common partner is another (non-rival) firm. Patent citation analysis among dyads of leading pharmaceutical firms provides qualified support for these hypotheses.

Keywords: R&D, indirect ties, knowledge leakage, appropriation strategies, litigation
INTRODUCTION

Innovation has become more open and networked, involving an increase in inter-organizational knowledge exchange, which can bring substantive benefits in combining complementary skills, scale economies in research, and the sharing of costs and risks (Laursen and Salter, 2006; Ahuja, 2000a; Gilsing et al., 2008; Hagedoorn, 1993; Pahnke et al., 2015; Phelps, 2010). Firms frequently collaborate on R&D with supplier and clients, as this may facilitate developing and exploiting their innovations jointly in the value chain, in the absence of the competing interests that are characterizing collaborations with competitors (e.g., Belderbos et al., 2012). R&D collaborations also involves connections to universities and other public research institutes, as these seek corporate partners to fund research and enhance their impact (Siegel & Wright, 2015; Perkmann et al, 2021). Collaboration with such public research organizations brings access to scientific knowledge (e.g. Belderbos, Gilsing, Suzuki, 2016; Belderbos et al., 2021; Cassiman et al., 2008; Giuliani and Arza, 2009). The preponderance of dense networks of R&D collaborations among firms and between firms and public research organizations implies that firms embedded in these networks are increasingly linked to each other through indirect ties, i.e., if they collaborate on R&D with partners that are common to them (Granovetter, 1985; Belderbos et al., 2018; Hallen et al., 2013; Hernandez et al., 2015; Mannak et al., 2019; Polidoro et al., 2011; Ryu et al. 2018). Thus, firms that are direct market rivals and that may avoid collaborating directly because they ultimately aim to outperform each other (Gnyawali & Charleton, 2017) may still find themselves connected indirectly if they collaborate with the same partners.

Common partners can function as (unintended) intermediaries of knowledge spillovers between rival firms. The common partner connecting two firms serves as the bridge across which information, reputation, and referrals flow (Ahuja, 2000; Baker, 1990: Gulati & Garguilo, 1999).
Indirect ties can increase opportunities for strategic sensing, fulfilling a “radar” function by bringing new information on relevant technological developments to the attention of the focal firm (Ahuja, 2000; Freeman, 1991; Vanhaverbeke et al., 2012). Yet, the same mechanism that brings novel knowledge from indirect ties to the attention of the focal firm also works in the opposite direction (Gulati and Garguilo, 1999; Ghosh & Rosenkopf, 2015; Marra et al., 2015; Ryu et al. 2018), i.e., (unintended) spillovers of knowledge might occur from the focal firm to its indirect ties. Hence, if rival firms form indirect ties by simultaneously collaborating with the same common partner, even without direct collaboration, proprietary knowledge of the focal firm may reach those competitors, and this may negatively affect their relative innovative strength (Pahnke et al., 2015) and performance, by hampering the exploitation of their innovations (Teece, 1986).

Although knowledge leakage through indirect ties is an issue that has become more relevant with the increase in open innovation strategies, extant literature has not given this due attention. It has either focused on the management of direct ties (Laursen and Salter, 2014), focused on the advantages (rather than the disadvantages) of indirect ties in terms of knowledge sourcing (Ahuja, 2000; Freeman, 1991; Hernandez et al., 2015; Hoffmann et al., 2018; Vanhaverbeke et al., 2012), or focused on knowledge leakage in the narrow context of geographic collocation of R&D activities (Alcacer and Zhao, 2021; Belderbos, Park Carree, 2021). In this paper we argue that knowledge leakages to rivals through common R&D collaboration partners is an important consideration for collaborating firms, while the extent of such spillovers is crucially determined by the type of common partner – as common partners are heterogeneously inclined or able to act on knowledge leakage concerns. We consider whether the common partner is a research organization (RO), i.e., a university, hospital, research or government institute, or another, non-rival, firm (e.g., suppliers, clients, and firms operating outside the core markets of focal firms). We
expect that the open science paradigm adhered to by ROs renders it more likely that knowledge shared also reaches rival firms.

Firms facing the risk of knowledge leakages will adopt strategies and practices to mitigate these. However, traditional formal mechanisms (e.g., contracts) and social mechanisms (e.g., trust) operate between direct collaborators, but are likely to be ineffective to constrain behavior of rivals that obtain knowledge indirectly through a common partner (Hernandez et al., 2015). Following the knowledge-based view of the firm and literature on the influence of patent litigation strategies and reputation for toughness (Agarwal et al. 2009; Ganco et al. 2015; Ganco et al. 2020), we argue that leakage of a firm’s knowledge by rivals obtained through common partners can be reduced if the firm has developed a strong reputation to act against intellectual property infringements. We examine patent litigation actions of firms that create a reputation of toughness and serve as a potential deterrent against common partners’ and rival firms’ exploitation of the focal firms’ knowledge. A strong reputation for litigation may influence the behavior of the intermediary or directly pose a threat to the rival firm in case of knowledge misappropriation. We argue that the effectiveness of a reputation for litigation is higher if the common partner is a firm compared to when the common partners is a RO.

We study the role of common partners as a driver of knowledge leakage, and patent litigation as a potential restrictor of such leakage, in a fixed effect panel analysis of inter-firm citations among major pharmaceutical firms (1995-2015) controlling for R&D co-location, technology similarity, and other strategies to reduce knowledge spillovers. Our research draws on, and contributes to, the literatures on open innovation, knowledge appropriation strategies and indirect ties. To the literature on open innovation, which has emphasized the advantages and risks of direct collaboration with partners, we add insights on the ‘indirect’ effects of collaboration in
terms of knowledge leakage through common partners to rival firms. We contribute to the literature on appropriation and litigation, by showing the effectiveness of IP litigation-based reputation for toughness in the context of knowledge leakage to indirect ties, and by demonstrating the different degrees of effectiveness depending on the nature of the common partner. We complement the literature on indirect ties, which has emphasized social and behavioral mechanisms operating in networks such as reciprocity and trust to address the risk of knowledge misappropriation but has paid less attention to legal mechanisms to address these risks.

THEORETICAL BACKGROUND AND HYPOTHESES

The knowledge-based view (KBV) of the firm suggests that firms’ competitiveness depends on their capacity to create, source, recombine knowledge, as well as their organizational design for effective appropriation of that knowledge (e.g., Grant, 1996; Almeida et al., 2002; Foss et al., 2013). KBV provides us with a framework to understand the tradeoffs firms face as they enter R&D collaborations with different types of organizations, such as ROs and non-rival firms. While collaborations with ROs expose a firm to (scientific) knowledge resources in a more open organizational context, beyond the confines of existing research routines and practices of the focal firm, non-rival firms may assist firms in developing innovations efficiently in their value chain, given the absence of competing interests (e.g., Belderbos et al., 2012). However, the nature of knowledge transfer processes often implies that the translation of knowledge residing in individuals into a common language through codification not only facilitates internal knowledge diffusion and recombination but also knowledge leakage and imitation (e.g., Winter, 1987; Kogut and Zander, 1992). Firms that engage in research partnerships with ROs or non-rival firms risk that sensitive knowledge and company secrets shared and developed in the joint research leaks out to rival firms when the collaboration partners simultaneously collaborate with them.
The literature on knowledge spillovers has focused on the role of geography and has emphasized that these are primarily local and decline in geographic distance (Jaffe et al., 1993). While locating in dense clusters may offer a strong base from which the firm is able to construct an external network of knowledge sourcing (Forman et al., 2008; Cantwell and Mudambi, 2011; Belderbos and Somers, 2015), locating in dense clusters may also increase the risk of outward leakages of knowledge (Alcacer and Chung, 2007; Frost, 2001; Shaver and Flyer, 2000). This may be problematic if such spillovers reach rivals. Knowledge dissipation to rivals increases the knowledge stock of competing firms and hampers the appropriation and exploitation of knowledge by the focal firm (Grant, 1996; Teece, 1986), as these competitors may free ride on the focal firms’ investments at comparably modest learning costs. If this occurs, the rival may exploit this knowledge in the product market and harm the focal firm’s competitiveness and profitability (Teece, 1986; Winter, 1987).

Firms try to manage the flow of spillovers to and from rivals by attempting to minimize outgoing spillovers (Cassiman et al., 2002; Martin, 1999). Spillovers due to the geographic collocation of rival firms may be reduced by adjusting the firm’s internal R&D organization through an internal linkage strategy, partitioning the knowledge generation process, and distributing it across multiple locations (Alcácer and Zhao, 2012; Belderbos and Somers, 2015; Nandkumar and Srikanth, 2016; Belderbos, Park and Carree, 2021). Segmenting R&D activities and spreading internal teams of researchers across subsidiaries makes it difficult for co-located rivals in one area to access the full range of knowledge assets required to interpret firm-specific knowledge and develop their technology.

Knowledge leakage can also be a prominent concern in the absence of collocation, if firms collaborate with geographically distant partners (Belderbos et al., 2021) or if firms collaborate
with the same partners as their rivals. The network literature has suggested that such indirect ties offer firms the benefits of gathering and assimilating relevant recent scientific knowledge and technological developments at little cost (Freeman, 1991; Ahuja, 2000; Nahapiet and Ghoshal, 1998), and that accessing and integrating this knowledge has positive consequences for firms’ innovative performance (Rosenkopf and Almeida, 2003). Studies that build on Simmel’s (1950) notion that the structure surrounding a dyad matters in terms of benefits and costs, have shown that the wider networked system (beyond the dyadic level) is essential for the rapid dissemination of information and (technological) knowledge (Coleman, 1990; Rosenkopf & Almeida, 2003; Gulati and Garguilo, 1999; Ryu et al. 2018). However, this implies that firms that engage in R&D collaboration with a common partner also risk that sensitive knowledge and company secrets shared and developed in the joint research leaks out to rival firms.

The literature on R&D collaboration and technology alliances has put forward several instruments firms can use to reduce the risk of knowledge spillovers: legal instruments such as contracting and limiting the scope of collaboration. The literature on embeddedness has discussed social mechanisms such as trust, relational embeddedness, and structural embeddedness (Gulati & Garguilo, 1999), and ties to centrally positioned partners (Polidoro et al. 2011). Other means of mitigating collaboration hazards that have received attention include the timing of alliance formation or goal adjustment (Katila et al., 2008; Diestre & Rajagopalan, 2012). However, these distinct considerations are based on dyads as standalone organizational configurations and target the direct collaboration partner. They do not consider that collaborations with a common partner may imply a connection – an indirect tie – to a rival firm. The use of an intellectual property protection strategy and the build-up of a reputation for toughness in this regard may be effective
in reducing knowledge outflows (Ziedonis, 2003; Clarkson and Toh, 2010; Somaya, 2012; Ganco et al., 2020) and can have a wider application beyond the direct collaboration partner.

**Knowledge outflows via common partners**

Open innovation strategies and R&D collaborations are likely to involve knowledge spillovers (Laursen and Salter, 2014). Given the importance of external knowledge search (Phene and Almeida, 2008; Monteiro and Birkinshaw, 2017; Laursen and Salter, 2014), and the need to access the best sources of knowledge, rival firms may find themselves in the situation that they simultaneously interact with a common partner. This establishes an indirect tie between rival firms.

Collaboration with a common partner may lead to an increased awareness of the competing firms’ research profile and may lead to knowledge leakage via the common partner and the collaborating researchers. Research conducted by a focal firm in collaboration with a common partner may create new insights that this partner may then use in collaboration with a rival firm (Fershtman and Gandal, 2011). This may be an important channel of knowledge spillovers, since it relies on a chain of inter-personal contacts facilitating knowledge acquisition and integration (Tsai and Wang, 2009), which would be difficult to realize via imitation (Nonaka, 1994). Even when the focal firm and the common partner operate at a cognitive distance (Baum et al., 2006; Nooteboom et al. 2007), the tacit knowledge exchange and learning in close inter-personal interactions is likely to facilitate effective knowledge transfer. In general, the literature on knowledge networks has suggested that knowledge can diffuse rapidly through indirect ties (Katila, et al., 2008) and that although indirect ties operate at larger social distance in the firm’s network, a two-step reach may suffice in facilitating knowledge flows (Singh, 2003; Li and Rowley, 2002; Ryu et al. 2018).
It follows that collaboration with common partners – which may include non-rival firms or public research organizations (ROs) – increases the risks of knowledge leakage to a focal firm’s rivals. This suggests the following hypothesis:

**Hypothesis 1:** R&D collaboration with partners that are common to a focal firm and a rival is associated with greater knowledge outflows from the focal firm to that rival.

### Non-rival firms versus research organizations as common partners

Inter-organizational collaborative relationships offer opportunities for knowledge recombination and scale economies in research (e.g., Ahuja, 2000; Phelps et al., 2012; Kantola et al., 2017). A focal firm’s collaborations may not only focus on partner firms, but may also include collaborations with universities, research organizations, and government institutes (ROs). Both non-rival firms and ROs can act as common partners to a focal firm and its rivals. Each common partner has its own objectives, which do not necessarily align with a focal firm’s interests (Pahnke et al., 2015). Given that non-rival firms and ROs differ in interests and research practices (e.g., Belderbos, Gilsing, Suzuki, 2016), we argue that it is important to distinguish between these different types of common partners.

Firms may seek new ideas and knowledge from their collaboration partners (Katz and Allen, 2004; Katz, 2004; Coombs et al., 2003) but must balance value creation with value capture. Firms therefore also focus on protecting and capturing returns from their innovations and aim to combine this with accessing external sources of knowledge via R&D collaborations. Laursen and Salter (2014) show that openness and collaboration requires more attention to knowledge protection – which may involve the use of formal methods, such as applying for patents or trademarks, as well as informal methods, such as keeping key technologies secret from competitors, product complexity, and lead times (Arora et al., 2001; Ziedonis, 2004; Ceccagnoli,
The focal firm may also enforce contractual limitations on sharing knowledge developed in collaboration with the common partner to avoid knowledge spillovers to the focal firm’s rivals (Belderbos, Lokshin, Gilsing, 2012).

The risk of knowledge leakage through collaboration with a common partner may be higher if this partner is a university or public research organization. Firms benefit from R&D collaborations with ROs, as they provide access to frontier developments in their epistemic communities (Cockburn and Henderson, 1998), enable them to attract high quality researchers (Deeds and Hill, 1998), and facilitates the assimilation of new scientific knowledge (Giuliani and Arza, 2009). Yet in order to obtain these benefits, firms collaborating with universities and other research organizations may have to adapt their R&D organization by focusing more on the role of ‘open science’ and comply at least partially with the norms and institutionalized practices of research organizations, e.g., participate in academic conferences and internal meetings between scientists, and focus on research that is considered valuable by the scientific community (Gittelman and Kogut, 2003; Nelson, 2004; Rothaermel and Deeds, 2006). While university scientists are keen on disclosing new knowledge and to gain recognition, industrial researchers may require secrecy to facilitate value appropriation (Belderbos et al. 2016). The differences in norms, routines, and work practices renders it difficult for firms to restrict knowledge spillovers through the firm’s own scientists and its university. Universities and research organizations are generally less strict and capable in enforcing restrictions on knowledge disclosure contracts, as the open science paradigm and reliance on public funding limit the use of such restrictions.

An important part of scientific knowledge is non-codified and can only be exchanged through close interaction between individual scientists and researchers (Cassiman et al., 2009; Zucker et al., 1998; 2002). The tacit and complex nature of scientific knowledge induces a need
for close interactions with universities to become more familiar with scientific research and the institutional norms that are dominant there (Belderbos et al., 2018). This is likely to result in a more profound knowledge exchange that requires a greater openness of a focal firm and a willingness to share knowledge. As universities adhere to an open science paradigm, with research broadly connected and results widely disseminated, this may render it more likely that knowledge transferred also reaches rival firms that collaborate with the same university.

Consequently, if a firm has an RO as common collaboration partner this is likely to imply that spillover risks to rivals are generally higher than when a non-rival firm is the common partner. These arguments suggest the following hypothesis:

**Hypothesis 2:** The knowledge outflows of Hypothesis 1 are greater when the common R&D partners are ROs than if they are non-rival firms.

### The role of relative IP litigation strategy

Knowledge leakage to rival firms through common partners is difficult to combat through informal or complex intra-organizational interdependencies, as the firm has no direct relationship with the rival. Firms may therefore be more likely to rely on formal intellectual property protecting strategies to limit knowledge spillovers.

Prior research has suggested the effectiveness of such strategies. While contractual solutions to personnel mobility-induced spillovers, e.g., noncompete clauses (Gilson, 1999; Agarwal, Ganco, and Ziedonis, 2009) increase transaction costs and are not always well enforceable (Acemoglu and Pischke, 1998, 1999), studies have shown that a pronounced patent litigation strategy can benefit litigious firms in protecting their proprietary knowledge embedded in employees by reducing employee mobility (Agarwal et al. 2009; Ganco et al. 2015; Ganco et al. 2020; Tan and Rider, 2017; Ziedonis, 2003). Firms may seek to protect their inventions with
patents and gain reputational benefits through their enforcement, by seeking prosecution for those that infringe on their intellectual property (James et al., 2013; Moser, 2013; Agarwal et al., 2009; Kim and Marschke, 2005). Building up a reputation for toughness in the intellectual property domain by active litigation can strengthen firms’ bargaining position in licensing negotiations and deter potential infringers (Kafouros et al., 2021; Galasso and Schankerman, 2015; Galasso and Schankerman, 2015; Clarkson and Toh, 2010; Agarwal, Ganco and Ziedonis, 2009). Rivals may perceive a credible threat that the focal firm will seek to protect its assets in the event of infringement (Somaya, 2003) and curb the use of its technologies (Carlton and Perloff, 2005), if this risks litigation. A firm’s litigiousness has been found to deter competitors from entering their technology domains (Clarkson and Toh, 2010) and to play a role in decisions to expand into new technological areas (Ganco et al., 2020).

The use of a firm’s knowledge by rivals that may arise from collaboration with common partners may also be reduced if the firm has developed a strong reputation to act against IP infringements. Patent litigation actions of a focal firm that creates a reputation of IP toughness may generally serve as a deterrent against rival firms’ actions to benefit from the focal firm’s knowledge, particularly if rival firms have a lesser reputation in this regard. In general, firms that possess similar knowledge assets can differ in their willingness to bear the organizational costs associated with engaging in litigation as plaintiffs and to absorb the legal risks and uncertainty around the outcomes of legal conflicts (Foss and Foss, 2005; Galasso, 2007; Bessen and Meurer, 2008). Litigations may involve complicated law procedures (Somaya et al., 2007), requiring managerial attention and disrupting employee participation in ongoing R&D projects (Encaoua and Lefouili, 2005). Hence, litigation is costly, and firms need to consider whether the benefits are greater than such costs (Kafouros et al., 2021; Nam et al., 2015). Firms that have made prior
commitments to a tough IP litigation strategy and that have invested in legal expertise will face reduced marginal costs of starting a new legal procedure against infringement or to defend their own IP use (e.g. Ganco et al., 2020), which adds to the credibility of legal IP threats. In contrast, firms that have invested little in legal IP actions, are much less able to act as plaintiff or defendant and are more likely to abstain from exploiting knowledge coming from rivals with a strong IP litigation reputation. Hence, it is the relative IP strength of litigation strategy of the focal firm vis-à-vis the rival that is likely to reduce knowledge leakages and exploitation by the rival.

A tougher patent protection and litigation stance of a focal firm is also likely to influence behavior of the common partner. Given that knowledge tends to be built cumulatively – the knowledge gained by the common partner in its collaboration with the focal firm may be useful in the partner’s collaboration with a rival firm – it may be costly and difficult for the common partner to build ‘firewalls’ between different collaborations to restrict spillovers. Brokering is moreover an attractive role for a common partner because the more agreements and collaborations it has, the more it may attract new partnerships (George et al., 2002; Stuart et al., 2007; Belderbos et al., 2015). Greater litigiousness of the focal firm and the associated threat that the focal firm takes legal action against the common partner if its proprietary knowledge reaches rivals due to the lack of a proper firewall may, however, increase the willingness to take actions by the common partner to reduce such knowledge spillovers, as getting entangled in IP litigation will harm its brokering position. The common partner will be particularly sensitive of knowledge leakage concerns of the firm with the toughest reputation it collaborates with.

It follows that a pronounced IP patent litigation strategy, stronger than the rival firm, is likely to reduce knowledge leakage stemming from collaborations with common partners. This suggests the following hypothesis:
Hypothesis 3: An IP litigation strategy of the focal firm that is more pronounced than that of its rival firm reduces knowledge outflows to that rival firm via common R&D partners.

The effectiveness of relative IP litigation strategies: non-rival firms vs ROs

A firm’s legal department can put strict limits on employees exchanging knowledge across firm boundaries (Davis and Harrison, 2001), and legal teams may enter complex negotiations to manage knowledge flows (Kafourus et al., 2021) through detailed collaboration agreements (Alexy et al., 2009). These may serve as mechanisms that ensure secrecy and discourage partners from engaging in informal exchanges with other actors (Liebeskind, 1997; Laursen and Salter, 2006). Such practices will strengthen the threat of IP litigation in case of knowledge leakage. However, we expect that a reputation for litigation will be less effective when the common partner is a RO.

First, R&D collaboration with RO scientists tends to involve a greater degree of tacit knowledge exchange (Belderbos et al., 2021). Although new scientific knowledge disseminates through publications, an important part of it tends to be non-codified and can only be exchanged through close interaction in teams of university and firm scientists (Zucker et al., 1998; 2002; Cassiman et al., 2008). Firms are more likely to adopt academic principles if they need to access scientific knowledge that they consider important for their innovation (Simeth and Raffo, 2013). Collaboration allows for the build-up of trust (Gulati, 1995a), which is an important prerequisite for the efficient exchange of tacit knowledge (Gilsing & Nooteboom, 2006). Such trust-based collaboration reduces the likelihood of noise in information exchange and of tacit, fine-grained specificities getting lost, which mitigates the risk of misunderstanding (Ahuja, 2000). Yet tacit knowledge spillovers are more difficult to monitor, and this makes it harder for a focal firm to impose sanctions in case of knowledge leakage (Nooteboom, 2004), reducing the potential for litigation threats to combat such leakage.
Second, a focal firm’s threat to litigate may negatively affect its trust-based collaboration with the RO, and its opportunities for future collaboration with ROs. ROs may not be willing to (continue to) collaborate with a litigating firm, as getting involved in legal IP conflicts will render it more difficult for the RO to maintain a collaboration network and open scientific exchange with other firms and organization that fear to put themselves at risk of IP litigation. This makes a focal firm’s reputation for litigation less credible and effective when the common partner is a RO. In contrast, when the common collaboration partner is a firm, such considerations are much less prominent, as non-rival firms do not follow an open science paradigm and are used to deal with legal issues and litigation. It follows that IP litigation strategies are likely to be less powerful to combat knowledge outflows to rivals if the common collaboration partners are ROs compared to when the common partners are non-rival firms. We hypothesize:

Hypothesis 4: The influence of relative IP litigation strategy of Hypothesis 3 is smaller when the common R&D partners are ROs than when they are non-rival firms

DATA, VARIABLES AND METHODS

We examine the relationships between collaboration with common partners, knowledge outflows to rivals, and patent litigation strategy for the 70 largest firms active in the pharmaceutical industry, 1995-2015. The firms have been selected as the top patentees and R&D spending biopharmaceutical firms as identified in the ‘EU Industrial R&D Investment Scoreboard’, which lists the top 500 corporate investors in R&D. The firms were required to have at least 40% of their sales in pharmaceuticals (e.g., Bayer) to represent a pharmaceutical industry rival. By the end of the period of analysis, the 70 firms had reduced, due to merger and acquisition (M&A) activity, such as the merger of Ciba-Geigy and Sandoz to form Novartis in 1996 and the creation of AstraZeneca through a merger in 1999, while other firms gradually withdrew from pharmaceuticals. This left
us with 55 focal firms that we observed at least for 10 years to establish the calculation of variables. We examine knowledge leakage through common partners from these 55 firms to all (69) rivals. Hence, we have an unbalanced panel of pharmaceutical firms.

We constructed a dataset on the patent activities of these firms drawing on data available at the United States Patent and Trademark Office (USPTO). We extracted all patents granted to these firms and their yearly consolidated subsidiaries and examined the backward and forward citations of these patents. We also extracted all publications indexed in Scopus and PubMed that included at least one author affiliated with the firms on a consolidated basis. Publications co-authored by the focal firm and a RO or other firm serve as our measure of collaborations. We applied an annual corporate consolidation of the assignee and author’s affiliation information through an extensive search using D&B Who Owns Who directories, Bloomberg, and Thomson Reuters. Acquired firms and their patents and publications were considered part of a parent firm from the year of acquisition onwards.

We retrieved 205,716 publications (including 1,429,970 co-author records) and 111,566 patents (including 1,276,092 backward citations) of the focal firms. The patent assignee information of the cited patents and the affiliations of co-authors of publications (other than those of the focal firms) were consolidated and categorized as belonging to non-rival firms (e.g., suppliers, clients, firms operating outside pharmaceutical markets), research organizations such as universities, hospitals, research, and government institutes, and the 70 rival firms. Locational information of focal firms and partner organizations was recorded at level-2 statistical areas as defined by the OECD (2018), covering NUTS-2 in European countries, Metropolitan Statistical Areas in the United States, prefectures in Japan, and comparable geographic delineations elsewhere.
We also collected detailed information from the USPTO on patents involved in litigation cases. These data include information about plaintiffs and defendants, relevant information of the attorneys who represent them, and case details, including district court name, case name and number, case cause, and the nature of the suit. We combined this with data collected from the Public Access to Court Electronic Records (PACER) to supplement information that may be missing in the USPTO docket reports data, such as the date of filing. We coded the number of times a firm in our sample appeared as plaintiff on a patent infringement case in each year. This resulted in 4,290 unique cases in which the sample firms acted as plaintiffs. We also recorded whether defendants on those cases included other focal firms from our sample and omitted these from variable construction, because prior litigation may also involve more intensive interactions between firms on their proprietary knowledge bases, potentially leading to increased citations (e.g., James, Leiblein and Lu, 2013; Devlin, 2010; Ouellette, 2012).

Variables
Patent records include citations that represent relevant prior knowledge and that delineate the novelty of an invention compared to the parts that are attributable to earlier patents. If a patent cites another patent, this suggests that the knowledge embodied in the cited patent has been useful in developing the novel knowledge in the citing patent (e.g. Jaffe et al., 1993; Frost, 2001). In the case of USPTO patents, patent applicants are legally required to list all known relevant ‘prior art’ (prior patents) to substantiate their patent claim (Jaffe et al., 2004; Strumsky and Lobo, 2015). Hence, patent citations can be considered explicit and validated records of knowledge flows. Moreover, since the citing firm is able to build upon cited patents to claim patent rights for a novel technology itself with the potential to commercialize, patent citations reflect knowledge flows that may be exploited by the citing firm. This can increase technology and market competition for the
focal firm of which the patents are cited. In this context, limited external citations to a firm’s patents and an large share of self-citations has been related to the market and technological power of firms (Akcigit and Ates, 2021). Hence, the dependent variable representing knowledge leakage between two rival firms, $Outflows_{ij,t}$ is the number of citations patents of focal firm $i$ receive from rival firm $j$ in year $t$. We observe these pairwise outflows between rival firms during 1995-2015. As we have an unbalanced panel of pairwise outflows due to mergers and the disappearance of firms, this leads to a sample of 48,138 observations.

The first focal independent variable represents the extent to which focal and rival firms’ have common R&D collaboration partners, which we term $common\ partner_{ij,t-1}$. testing for Hypothesis. 1. We first calculated the Jaffe index of similarity of collaboration patterns with the same individual organizations ($k$) (Jaffe, 1986; Breschi, Lissoni, and Malerba, 2003): $S_{ijt} = (\sum_{k=1}^{k}C_{ik}*C_{jk}) / (\sqrt{\sum_{k=1}^{k}C_{ik}^2} * \sqrt{\sum_{k=1}^{k}C_{jk}^2})$, as well as the Jaffe index of the overlap in focal and rival firms’ patent citations to the same individual organizations. We then weighted the collaboration similarity with the citation overlap to arrive at a measure of effective knowledge sourcing through R&D collaborations with common partners. This weighting is important, since indirect ties may differ greatly in the extent to which they imply knowledge flows given the frictions that may occur in both the focal firm’s and rival firm’s collaboration (Ghosh & Rosenkopf, 2015). Taking the similarity of knowledge sourcing patterns as a weight ensures that the common partner collaborations that create substantial knowledge flows on both the side of the focal and rival firms gain in importance.

Similarly, to measure $RO\ common\ partner_{ij,t-1}$, we calculated the Jaffe index of similarity of collaboration patterns with the same individual universities, research institutions, and hospitals and the Jaffe index of the overlap in focal and rival firms’ backward citations to these partner
institutions. We then weighted collaboration similarity with the citation overlap. To calculate Firm common partner\(_{ij,t-1}\), we weight the similarity of collaboration patterns with non-focal and non-rival firms with the overlap in citations to patents of these firms. These variables test for Hypothesis 2.

We follow prior studies in using patent infringement lawsuits as proxy for a reputation of toughness in patent enforcement (Agarwal et al. 2009; Ganco et al. 2020). Litigation strategy\(_{i,t-1,t-5}\) is calculated as the cumulative number of patent infringement cases filed by firm \(i\) in the previous five years divided by the cumulative number of patents over the respective prior five years, for convenience weighted by 1000. Relative litigation\(_{ij,t-1}\) is the focal to rival ratio of the firms’ litigation strategy. The interaction terms of relative litigation and the common partner variables test for Hypotheses 3 and 4.

We control for the direct collaborations between the focal and rival firm, by including the number of focal-rival collaborations scaled by the total number of collaborations of the focal firm. Another key control variable is co-location\(_{ij,t-1}\): the Jaffe index of similarity of the geographic distribution of focal and rival firms’ patent inventors, which is likely to facilitate knowledge spillovers (Alcacer and Zhao, 2012; Belderbos, Park, Carree, 2021; Ryu et al. 2018)). Similarly, we include Overlap in technologies\(_{ij,t-1}\), the Jaffe index of firm \(i\) and \(j\)’s patents over technology classes at the 3-digit level. Technology similarity is associated with a greater relevance of, and absorptive capacity for, rival firms’ knowledge (e.g. Cantwell and Colombo, 2000; Ghosh & Rosenkopf, 2015).

We also control for the size of the citable patent stock of firm \(i\) and the potentially citing patent stock of firm \(j\), operationalized as patents granted in the last three years, by taking the multiplication of the citing and citable patents (\(Patent\ stocks_{ij,t-1 \cdot t-3}\)). Since valuable patents are
more likely to be cited, the analysis includes \( \text{Patent quality}_{i,t-1} \), calculated as the share of firm \( i \)'s patents that have been cited more than the average of all patents identified for all focal firms in year \( t-1 \). To control for the extent to which firms may rely on internal cross-unit or cross-country collaborative R&D linkages to reduce outgoing spillovers (Alcacer and Zhao, 2012; Belderbos, Park, and Carree, 2021), we include the average number of locations in which co-inventors of firm \( i \)'s patents are residing \( \text{Co-inventor linkages}_{i,t-1} \). We also include a measure of the general geographic spread of the focal firm’s inventive activities \( \text{Location diversity}_{i,t-1} \), as the number of countries in which the firm has inventors and maintains R&D units (Kafouros et al., 2018).

The analysis also controls for the (average) degree of enforcement of intellectual property rights in the focal and rival firm’s home countries \( \text{avg IPR enforcement}_{i,t} \). We follow recent work (Belderbos et al., 2021; Hu and Png, 2013; Maskus and Yang, 2013) by constructing a composite index based on Ginarte and Park’s (GP) IPR index and a country’s score on Impartial Courts (IC) in the EFW report. While the GP index is widely used in the literature, since it’s based on statutory information on patent laws (e.g., Athukorala and Kohpaiboon, 2010; Branstetter et al., 2006; Nandkumar and Srikanth, 2016), it does not capture the enforcement level of these laws. \( \text{Avg IPR enforcement}_{i,t} \) is defined as \( (GP_{c,t}/\text{Max}GP_{t}) \times (IC_{c,t}/\text{Max}IC_{t}) \). Finally, we include \( \text{Same Country} \), which take the value 1 if the focal and rival firm are headquartered in the same country.

**Methods**

Since the dependent variable is a count variable, we estimate Quasi Maximum Likelihood (QML) Poisson regressions with cluster-robust standard errors. Poisson models are the most generic, unbiased, specification for count models, while the QML estimation with error terms clustered at the firm level corrects for overdispersion (Wooldridge, 1999). We include unconditional firm fixed effects (firm dummies) throughout to control for unobserved firms’ heterogeneity that may be
associated with higher or lower outflows. The firm fixed effects also subsume the effects of home country and industry dummies. In addition, the models include a full set of year dummies to control for general time trends in knowledge spillovers and possible remaining truncation in citation measures.

**RESULTS**

Table 1 presents the descriptive statistics and pair-wise correlations. The correlations do not indicate multicollinearity concerns. Table 2 reports the empirical results of the fixed effects QML Poisson models. Model 1 presents results when only the control variables are included. Most coefficients have the predicted sign and are significant. Knowledge outflows to a rival increase with co-location, co-specialization, direct collaborations, patent quality, citable and citing patent stocks, and location diversity. Somewhat surprisingly, internal co-inventor linkages have a marginally significant positive sign, while, after all pairwise control variables are included, a rival headquartered in the same country as the focal firm has a lower inclination to draw on knowledge from the focal firm. The average IPR protection level has no significant effect.

The main effect of \( \text{Relative litigation}_{ij,t-1} \) is positive and significant, suggesting that greater litigation may be associated with an increase in outflows to rivals. This may occur because litigation involves detailed testimonies by expert witnesses that explain the nature of the IP covered in patents. Litigation therefore also reveals and codifies firm-specific information on patented inventions (James, Leiblein and Lu, 2013; Devlin, 2010; Ouellette, 2012; Awate and Makhija, 2021), which may increase visibility and citations to the firm’s patents.

Model 2 tests for Hypothesis 1 by including \( \text{common partners}_{ij,t-1} \). The positive estimated coefficient (\( \beta=1.809, p<0.01 \)) supports Hypothesis 1, i.e., common R&D partners of a focal firm
and its rival is associated with greater knowledge outflows to the rival firms. Model 3 tests Hypothesis 2 by including $RO \ common \ partners_{ij,t-1}$ and $Firm \ common \ partners_{ij,t-1}$ separately instead of $common \ partners_{ij,t-1}$. Knowledge outflows are smaller if the common R&D partners are ROs ($\beta=0.973$, $p<0.01$) than if they are non-rival firms ($\beta=1.318$, $p<0.01$), rejecting Hypothesis 2. A Chi-square test suggest that the difference is not significant (chi2=0.42; $p=0.517$).

$Insert \ table \ 2$

Model 4 tests Hypotheses 3 by including the interaction effect of relative litigation and common partner. The negative and marginally significant coefficient of the interaction effect provides qualified support for Hypothesis 3 ($\beta=-0.721$, $p=0.096$). In model 5, finally, relative patent litigation strategy significantly reduces the effect of Firm common partner ($\beta=-1.705$, $p=0.031$) but not of RO common partner ($\beta=0.208$, $p=0.406$). These coefficients are significantly different (chi2=3.99; $p=0.046$), such that the results provide support for Hypothesis 4.

The estimated coefficients provide no direct indication of marginal effects, and the different interaction terms imply that the differences between the effects of having ROs and non-rival firms as common partners depend on the level of relative litigation strategy. In figure 1, we depict the effects of a standard deviation change in RO and firm common partner collaboration respectively, as a function of relative litigation strategy. The marginal effects are based on incidence ratios, exponentiated coefficients reflecting the proportional increase in outflows due to a change in the explanatory variables. While the effect of ROs as common partners on outflows is lower than the effect of firms as common partners when the focal firm does not litigate (relative litigation is zero), the reverse ranking starts to be observed if IP litigation strategy exceeds 0.3. This implies that support for Hypothesis 2 is conditional on relative IP strategy and is found only for higher levels of the focal firm’s relative IP litigation use. Figure 1 also shows that at the higher
levels of relative IP strategy, the effect of firm common partners becomes negligible, and subsequently negative, attesting to the important influence of IP litigation strategies on spillovers. The significantly negative influence of having non-rival firms as common partners may be due to the fact that the common collaboration partner brings a much greater awareness and perceived risk of litigation on the part of the aggressive litigious firm, reducing use of the latter firm’s patented knowledge.

*Insert figure 1*

We conducted several tests to examine the robustness of our findings, results of which are available from the authors. Results were broadly similar when we restricted the observations on outflows by omitting rival firms with less than a majority interest in pharmaceuticals. Qualitatively similar, but statistically weaker, results were also obtained when we only used common partner collaboration as focal variables without weighing them with their importance in terms of knowledge sourcing. If we substitute only focal firm IP litigation for relative litigation, the interaction effects were only marginally significant, attesting to the importance of taking both the focal and rival firms’ IP strategy into account. Adding an interaction term between relative litigation and direct R&D collaboration between rivals did not alter findings, while the interaction term was negative but not statistically significant.

**DISCUSSION AND CONCLUSIONS**

While prior literature has emphasized the benefits of direct R&D collaboration as well as structural embeddedness through indirect ties in a firm’s alliance network, the risk of knowledge leakage through indirect ties has not received due attention. In this paper, we argue knowledge leakage to rival firms with potential harmful consequences for a firm’s competitiveness can occur if rival firms collaborate with a common partner, but that the degree to which this occurs crucially depends
on the attributes of the common partner. We distinguish whether the common partners are non-rival firms (e.g., suppliers, clients, firms operating outside the core markets of focal firms) or ROs (universities, hospitals, government institutes). Moreover, we argue that an IP litigation strategy of a focal firm that is more pronounced than that of a rival firm will mitigate knowledge leakage through common partners. Such mitigation is expected to be more effective when non-rival firms serve as common partners rather than ROs, with the latter’s emphasis on open science rendering spillovers greater and litigation strategies less effective. Findings from patent citation analysis among leading pharmaceutical firms show that the degree to which rival firms have ROs or non-rival firms as common partners is positively associated with inter-firm knowledge outflows. This relationship is weakened for focal firms with a more aggressive patent litigation strategy – but only when the common partners are non-rival firms.

Studying knowledge leakage to indirectly connected rivals via common partners is important, as such leakages are more difficult to combat through detailed collaboration agreements (Kafourus et al., 2021; Alexy et al., 2009) or intra-organizational strategies (Alcacer and Zhao, 2012). Our findings on the pronounced differences in the effectiveness of IP litigation strategies between ROs and non-rival firms as common partners therefore lend credence to the claim that the attributes of the node connecting the focal firm with its rivals matters for the consequences of such indirect ties. The lack of effectiveness of IP litigation to combat knowledge leakage through collaboration with ROs may be related to the possibility that tough IP actions may have further repercussions in terms of tarnishing the firm’s reputation as a loyal collaborator for ROs. Universities and other ROs rarely employ patent attorneys in-house\(^1\), and the lack of in-house legal

\(^1\) https://www.ucop.edu/knowledge-transfer-office/
IP expertise makes it difficult for universities to seek effective external counsel.\(^2\) This may make ROs reluctant to collaborate with firms that target universities in IP lawsuits. A focal firm’s attractiveness as a collaboration partner for ROs may diminish and it may be locked out from future access to scientific knowledge. Given the strategic benefits of collaborations with ROs, firms can neither easily avoid or terminate ties with ROs to address the risk of spillovers (Hernandez et al., 2015). That would imply that firms need to systematically exclude ROs as a collaboration partner, and access to state-of-the-art knowledge. We suggest that future research examines to what extent IP litigation strategies differentially affect the propensity and success of direct R&D collaboration with firms and ROs.

Our paper makes several contributions. We complement the network literature on indirect ties that has primarily focused on the benefits of larger network structures – building on the influential notion of Granovetter (1985) of structural embeddedness and its benefits, e.g., in the form of transitivity of trust, social control, and reputation. This literature has paid less attention to its risks and has remained agnostic of the role and features of the common partner establishing indirect ties. While it has emphasized social and behavioral mechanisms operating in networks such as reciprocity and trust to address the potential risk of knowledge misappropriation (Coleman, 1990; Ghosh & Rosenkopf, 2015; Gilsing et al. 2008; Hallen et al., 2013; Hernandez et al., 2015; Ryu et al. 2018), it has paid less attention to legal mechanisms to address these risks. Our paper shows that legal IP strategies can work to reduce knowledge leakage to indirect ties, but that both the risk of such leakage and the effectiveness of IP strategies depend on whether the common partner is a RO or a firm.

We also contribute to the literature on open innovation, which has emphasized the advantages and risks of direct collaboration with partners and the governance and IP issues related to these, but that has not examined the role of indirect ties and knowledge leakage in this context (Bigliardi et al., 2021; Kumar Singh et al., 2021; Lyu et al., 2020; Ovuakpori et al., 2021). We add new insights on the ‘indirect’ effects on collaboration in terms of knowledge leakage through common partners (Ahuja, 2000; Freeman, 1991; Vanhaverbeke et al., 2012). Finally, we contribute to the literature on appropriation and litigation (Agarwal et al. 2009; Ganco et al. 2015; Ganco et al. 2020; Awate and Makhija, 2021), by showing the effectiveness of IP litigation-based reputation for toughness in the context of knowledge leakage to indirect ties, and by demonstrating the different degrees of effectiveness depending on the type of common partner. At the same time, we confirm the notion of Awate and Makhija (2021) that IP litigation may also have a direct effect in terms of increasing knowledge outflows, as the litigation process itself reveals more details on a firm’s technologies.

Our findings suggest that it is important for managers to look beyond their dyadic collaborations alone and examine with whom their partners are collaborating. In case their partner collaborates with a rival firm, our study shows that there is a high likelihood of undesirable knowledge leakage. To address this risk, litigation can be highly effective when the common partner is a (non-rival) firm, and an existing reputation for toughness can offset this risk. However, when the common partner is a RO, litigation loses its effectiveness. Another risk of building an IP litigation is that lawsuits increase the exposure of a firm’s technological knowledge to its rivals. This suggests that firms and their managers should use litigation tools carefully, and that they should take in to account the differential roles of ROs and firms as (common) collaboration partners.
Our study is not without limitations. First, we relied on patent citations to measure knowledge leakage. While these have been shown to correlate with actual knowledge flows to firms and inventors and have been frequently used (e.g., Jaffe et al., 2020; Jaffe et al., 1993; Belenzon and Schankerman, 2013), they remain noisy and incomplete (Moser et al., 2017; Alcacer and Gittelman, 2016). We also assumed that the knowledge outflows, as measured by citations, are unwanted, but this may not always be so. Belenzon (2011) observes that firms may be able to build on the contributions other firms make to their research, and that such patterns increase the market value of the focal firms. Second, we did not examine detailed heterogeneous traits of individual common partners – as we were interested in the distinction between ROs and non-rival firms.

Third, our study was restricted to the major R&D intensive firms in the biopharmaceutical industry. This is an important industry in terms of R&D expenditures, health and social impact, and RO as well as firm collaborations, but our findings may not be fully generalizable to other industries or to sets of smaller firms with fewer resources to build up a reputation for litigation. Future research should investigate patterns and relationships in other industries and broader sets of firms. Finally, reputation for litigation may be stronger if plaintiffs were to win a high percentage of their cases, but we did not have access to detailed information on the outcomes of legal IP cases. In future research, the outcome of the litigation cases could be individually coded from the court transcripts, as well as the outcome of lawsuits settled before trial.

Finally, our research focused on knowledge leakages to indirect ties, via common partners, as this has not been given due consideration in extant work. In collaborating with (common) RO or firm partners, learning and incoming knowledge is a key consideration as well, and there will be tradeoffs between the two (Laursen and Slater, 2014) that our current study is not able to
uncover. The consideration of maintaining successful knowledge collaborations in the long term may also explain why focal firms collaborate with ROs while these induce a risk of spillovers to rivals. Greater insights gained from RO partners may be compensating the costs of knowledge leakage, and the focal firm itself can also benefit from incoming knowledge from their rivals through the common RO partner. Not litigating against knowledge leakage involving ROs may be favorable to sustain collaborative relationships based on trust and reciprocity. Hence, litigation strategies have longer term effects on firms’ ability to establish beneficial collaborations and to source external knowledge. These considerations provide interesting avenues for further research.

REFERENCES


Gnyawali D, Charleton RT. 2017. Divergence and Convergence of coopetition research: Bridging the conversations and shaping the research agenda. *Academy of Management Proceedings*.


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Table 2. Firm fixed effects Poisson analysis of knowledge outflows to rival firms

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<td>Avg. IPR enforcement</td>
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<td>(0.158)</td>
<td>(0.218)</td>
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<td>year fixed effects</td>
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<td>-228,053</td>
<td>-227,008</td>
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</table>

Notes: Results of Quasi Maximum Likelihood Poisson models. Cluster-robust standard errors in parentheses. *p<0.10; **p<0.05; ***p<0.01. RO is Research Organization (e.g., universities, hospitals, research institutes).
Figure 1: Effects of common partner collaborations on knowledge outflows to rivals: the role of relative IP strategy

Notes. Effects of a standard deviation increase in common partner collaboration (with non-rival firms or ROs) in terms of a percentage increase in knowledge outflows to the rival firm (citations). The solid vertical lines indicate the 95% confidence interval. The graphs are drawn until the 99th percentile of relative IP litigation.
R&D collaborations with common partners and the risk of knowledge leakage to rivals:

The role of IP litigation strategy

Appendix for the review process

This appendix reports results of supplementary analyses. Model 1 in Table A1 presents results of fixed effects QML Poisson models when we restrict the observations on outflows to non-diversified pharmaceutical and biotech firms that were observed for at least 10 years, and omitting rival firms with less than a majority interest in pharmaceuticals, e.g., chemical firms such as Bayer. This leads to a sample of 38,676 observations on 55 rival firms. We find similar effects as those reported in the paper. Relative patent litigation strategy reduces the effect of non-rival firm as common partners ($\beta=-1.919; p=0.035$) but not of RO as common partners.

Qualitatively similar, but statistically weaker, results are obtained when we only use common partner collaboration as focal variables without weighing these with their importance in terms of knowledge sourcing. Model 2 presents results using the sample of 48,138 observations but with the focal common partner variables only on the basis of collaborations and not on knowledge flows. We find marginally significant support for the hypothesis that relative patent litigation strategy reduces the effect of non-rival firms as common partners ($\beta=-1.716; p=0.084$). The moderating effect on RO as common partners remains insignificant, as before.

If we substitute focal firm IP litigation for relative litigation in model 3, the interaction effect of litigation and firm common partners is only marginally significant ($\beta=-0.014; p=0.087$). This attests to the importance of taking both the focal and rival firms’ IP strategy into account. In model 4, we add the interaction term of relative litigation and direct firm-rival collaborations. The coefficient has a negative sign as expected but is not statistically significant. This may be related
to the limited occurrence of direct R&D collaboration between rivals. The focal results remain unchanged.
## Appendix A1. Firm fixed effects Poisson analysis of knowledge outflows to rival firms; alternative models

<table>
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<tr>
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<th>(1) smaller sample of focal firms</th>
<th>(2) common partner collaboration unweighted</th>
<th>(3) litigation not relative</th>
<th>(4) focal-rival * relative litigation</th>
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<td>RO common partner†</td>
<td>1.068***</td>
<td>0.857*</td>
<td>1.006***</td>
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<td>Firm common partner†</td>
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<td>(0.480)</td>
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<td></td>
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<td></td>
<td>(0.788)</td>
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<td>RO common partner † * relative litigation</td>
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<tr>
<td>Firm common partner † * relative litigation</td>
<td>-1.716**</td>
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<td>RO common partner * relative litigation</td>
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<tr>
<td>Firm common partner * relative litigation</td>
<td>-1.919**</td>
<td>-1.715**</td>
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</tr>
<tr>
<td>RO common partner * IP litigation</td>
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<td>0.565***</td>
<td>0.638***</td>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>Relative litigation</td>
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<td>0.816**</td>
<td>0.969***</td>
<td>0.855**</td>
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<td>(0.424)</td>
<td>(0.385)</td>
<td>(0.300)</td>
<td>(0.363)</td>
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<td>Focal-rival collab</td>
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<td>0.816**</td>
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<td>(0.385)</td>
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<td>0.915***</td>
<td>0.924***</td>
<td>0.875***</td>
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<td>(0.214)</td>
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<td>(0.231)</td>
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<td>Overlap in technologies</td>
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<td>(0.054)</td>
<td>(0.062)</td>
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<td>(0.107)</td>
<td>(0.107)</td>
<td>(0.075)</td>
<td>(0.101)</td>
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<td>0.034*</td>
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<td>(0.018)</td>
<td>(0.015)</td>
<td>(0.019)</td>
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<td>0.121</td>
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<td>0.113</td>
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<td>(0.215)</td>
<td>(0.196)</td>
<td>(0.210)</td>
<td>(0.206)</td>
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<tr>
<td>year fixed effects</td>
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</table>

Notes: Results of Quasi Maximum Likelihood Poisson models. Cluster-robust standard errors in parentheses. *p<0.10; **p<0.05; ***p<0.01. † common partner variables without weighing these with their importance in terms of knowledge sourcing.