R&D Collaboration With Common Partners And Knowledge Leakage To Rivals

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Types of common R&D partners and knowledge leakage to rivals: The role of IP litigation reputation

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ABSTRACT

We argue that knowledge leakage may occur between rival firms through indirect ties, i.e., if rivals collaborate on R&D with a common partner, but that firms with an aggressive reputation for IP litigation may be able to restrict such knowledge spillovers. We argue that knowledge leakage is more prominent, and litigation reputation is 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 similarity analysis among dyads of leading pharmaceutical firms provides support for these hypotheses.

1. 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; Puliga et al., 2022; Vanhaverbeke et al., 2015). Firms frequently collaborate on R&D with suppliers and clients, as this may facilitate developing and exploiting their innovations jointly in the value chain, given the absence of the competing interests that characterize collaborations with competitors (e.g., Belderbos et al., 2012). R&D collaborations also involve connections to universities and other public research institutes, as these seek corporate partners to fund research and enhance their impact (Siegel and Wright, 2015; Perkmann et al., 2021). Collaborations with such public research organizations (PROs) provide access to scientific knowledge that can form the basis of new technologies (e.g. Belderbos et al., 2016; Colen et al., 2022; Cassiman et al., 2008; Giuliani and Arza, 2009). In the current paper, we compare the consequences of R&D collaboration with PROs on the one hand and (non-rival) firms on the other.

The preponderance of dense networks of R&D collaborations among firms and between firms and PROs 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 rather avoid collaborating directly because they ultimately aim to outperform each other in the market (Gnyawali and Charleton, 2017), may still find themselves connected indirectly if they collaborate with partners they have in common. These common partners can then function as (unintended) intermediaries of knowledge spillovers between rival firms, which may negatively affect their innovative strength (Pahnke et al., 2015) and performance, by hampering the exploitation of innovations (Teece, 1986).

To curb the risk of undesirable knowledge spillovers, the literature has suggested that formal intellectual property strategies can be effective in deterring direct rivals from expanding into new locational (Onoz and Giachetti, 2021) or technological areas (Ganco et al., 2020; Clarkson and Toh, 2010), by building a reputation for toughness in litigation that strengthens a firm's position vis-à-vis direct competitors (Kafouros et al., 2021; Agarwal et al., 2009; Lang, 2019). However, while prior studies have examined IP litigation threats targeting direct rivals, it is unclear whether a reputation for IP litigation also affects the behavior of intermediaries that serve as the common partner between a firm and its rivals. Here common partners may not fear disputes over patents specifically, but legal disputes about the implementation of collaboration contracts and their nondisclosure clauses.

In this paper, we focus on unintended knowledge spillovers to rival

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firms that can arise due to collaboration with common partners and we develop three core new insights: that the characteristics of the common partner, i.e. whether this is a (non-rival) firm (suppliers, clients, and firms operating outside the core markets of focal firm), or PRO, matters; that a reputation for litigation of intellectual property can curb knowledge outflows through common partners; and that such influences are stronger when common partners are firms compared to when these are PROs.

We develop hypotheses taking the knowledge-based view of the firm (KBV) and combine this with a network embeddedness perspective. The KBV sees knowledge creation as an exchange process among specialized actors (Almeida et al., 2002; Foss et al., 2013; Grant, 1996), and has emphasized the importance of knowledge appropriation, but has paid less to attention to the mechanisms on when and how to do this effectively (Belderbos et al., 2021a,b; Devarakonda and Reuer, 2018; Heiman and Nickerson, 2004). The network embeddedness perspective emphasizes how collaborative relations and networks can act as conduits for knowledge flows as well as for social reputations (Granovetter, 1985; Gulati and Garguilo, 1999; Ghosh and Rosenkopf, 2015; Marra et al., 2015; Ryu et al., 2018). A common partner is the node that connects two actors across which information flows, yet the attributes of such common partners have not been studied in the context of the network embeddedness literature.

A key nodal attribute of a common partner is whether it is a PRO or a private company, and we hypothesize that the risk of knowledge leakage to a rival firm is larger in the case that the common partner is a PRO. Collaboration with a PRO may result in a deeper knowledge exchange between its scientists and the firm's researchers (Belderbos et al., 2016; Cassiman et al., 2008; Zucker and Darby, 2002), and the open science paradigm adhered to by PROs renders it less likely that knowledge shared can be prevented from reaching rival firms with which the PRO is also collaborating (Gittelman and Kogut, 2003; Nelson, 2004; Rothaermel and Deeds, 2006). We argue that a firm that has developed a reputation of toughness in IP litigation to curb the use of its technologies can also influence common partners in restricting outflows of knowledge to the focal firm's rivals, and mitigate the risk of knowledge leakage to them. The effectiveness of IP litigation reputation, however, depends on the type of common partner, since PROs and firms are differentially inclined or capable in acting on knowledge leakage concerns by a focal firm (Frishammar et al., 2015; Ritala et al., 2015).

We study the role of common collaboration partners as a driver of knowledge leakage from a focal firm to its rival, and reputation for ÌP litigation as a potential restrictor of such leakage in the context of the pharmaceutical industry (1995–2015). This is a key industry with major social impact through its contribution to public health, with the leading firms responsible for substantial R&D investments and collaborations with firms and universities. Due to these characteristics, the industry has been the focus of substantial research on innovation (e.g., Belderbos2016; Diestre and Rajagopalan, 2012; Deeds and Hill, 1998; Gittelman and Kogut, 2003; Gilsing and Nooteboom. 2006).

Empirically, we focus on the 55 major firms in the global pharmaceutical industry and estimate double fixed effects panel analysis of their market rivals' application of similar patents, resulting in an unbalanced panel of 4034 dyads. Since knowledge spillovers occurring through common partner collaboration may bring a rival firm's technology development closer to the focal firm, patent similarity gauges the role of knowledge spillovers that allow the rival to encroach the technology space of the focal firm. This represents knowledge spillovers that are most consequential for the focal firm and hence a potential target of litigation (threats), as exploitation of such spillovers in patents that directly compete with the technology efforts of the focal firm hampers the appropriation and exploitation of knowledge by the focal firm (Grant, 1996; Teece, 1986). Our fixed effect panel analyses provide broad support for our hypotheses. The degree to which rival firms have PROs or non-rival firms as common partners is positively associated with the similarity of patents of the rival firms. This relationship is weakened and rendered insignificant for focal firms with a more aggressive patent litigation reputation – but only when the common partners are non-rival firms.

We contribute to the literature on KBV that has emphasized the importance of appropriation of knowledge but has paid less attention to the mechanisms on when and how to do this effectively (Belderbos et al., 2021a,b; Devarakonda and Reuer, 2018; Heiman and Nickerson, 2004). We show how knowledge leakage to indirect rivals occurs, how IP litigation-based reputation for toughness affects a common partner's propensity to restrict knowledge leakage to rivals, and how this depends on the nature of the common partner. At the same time, we complement the literature on network embeddedness and indirect ties, which has emphasized social and behavioral mechanisms operating in networks (such as reciprocity and trust) to address the risk of knowledge leakage (Coleman, 1988; Gilsing et al., 2008), but has paid less attention to legal mechanisms addressing these risks nor to the role and attributes of the common partner through which knowledge flows to rivals.

2. Theoretical background

2.1. KBV and R&D collaborations: PRO versus (non-rival) firms

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 organization. An important distinction should be made between firms and PROs as collaboration partners. Collaborations with PROs provide firms with access to (scientific) knowledge resources in an open science context, beyond the confines of existing research routines and practices of the focal firm. Collaborations with 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). Yet, firms that engage in research partnerships with PROs or non-rival firms risk that sensitive knowledge and company secrets shared and developed in joint research leaks out to rival firms, when the collaboration partners simultaneously collaborate with them (Pahnke et al., 2015).

The institutional logic that governs PROs vis-à-vis firms carries implications for the risk of knowledge leakage to indirect rivals through a common partner. PROs focus on research deemed valuable by the scientific community, while industrial partners focus on the commercial development of technologies and their marketable applications (Gittelman and Kogut, 2003; Nelson, 2004; Rothaermel and Deeds, 2006). As a consequence, PROs are keen on disclosing new research findings so to gain recognition and prestige, while firms prefer secrecy to facilitate value appropriation. Thus, a PRO as common partner will be (much) less inclined to restrict knowledge leakage to an indirect rival firm than a non-rival firm, which will be more aware of a focal's concerns.

2.2. Indirect ties and knowledge spillovers

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 simultaneously interacting with the same common partner, which establishes an indirect tie between a focal firm and its rivals. Such indirect ties are also likely to involve knowledge spillovers (Laursen and Salter, 2014) to 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; Levin et al.,

1987).

The network embeddedness literature has shown that common partners serve as the bridge across which information, reputation, and referrals flow (Ahuja, 2000; Gulati and Garguilo, 1999), and that 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 and 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.

2.3. Appropriation and IP litigation reputation

Whereas KBV has emphasized that exploitation of knowledge and technologies requires an appropriation strategy, it has paid less attention to the mechanisms on when and how to do this effectively (Belderbos et al., 2021a,b; Devarakonda and Reuer, 2018; Heiman and Nickerson, 2004). A KBV perspective does suggest that firms should guard the appropriation and exploitation of proprietary knowledge, and aim to take action against knowledge reaching market rivals. The literature on patent litigation has suggested that litigation actions of a focal firm that create a reputation of IP toughness may generally serve as a deterrent against other firms' actions to benefit from the focal firm's knowledge. Extant literature on the influence of patent litigation strategies and reputation for toughness (Agarwal et al., 2009; Ganco et al. 2015, 2020) has pointed out the importance of such a reputation. However, firms that possess similar knowledge assets differ in their willingness to bear the organizational costs associated with engaging in litigation, 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.

2.4. Conceptual model

Following this theoretical background, our hypotheses development is structured as illustrated in Fig. 1. As a baseline, we first discuss the mechanisms through which R&D collaboration with partners that are common to a focal firm and a market rival will be associated with knowledge leakage leading to greater similarity of the patents of the rival and the focal firm. We then argue how the risk of knowledge leakage differs between different types of common partners, and that this risk is larger when the common R&D partner is a PRO compared to a non-rival firm. Subsequently, we discuss the role of a firm's IP litigation reputation as an instrument to address the risk of spillovers through common partners to rivals, and argue that a pronounced IP litigation reputation reduces patent similarity of a rival firm through common R&D partners. Finally, we argue that the effectiveness of a focal firm's litigation reputation differs between different types of common partners, and that this effectiveness is smaller when the common partner is a PRO than when it is a non-rival firm.

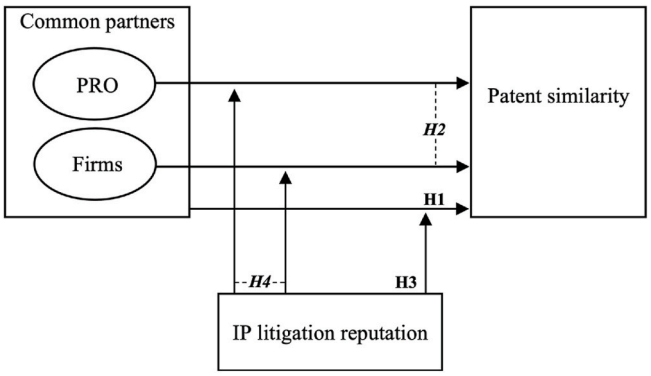

Fig. 1. The relationship between common partner collaborations between a focal firm and a rival on the one hand, and the rival firm's similar patents on the other, moderated by IP litigation reputation
Notes: H1 presents the general effect of having common R&D partners on patent similarity, while H2 compares the effect of different common R&D partner types. H3 presents the moderating effect of IP litigation on the relationship specified in H1, while H4 compares the influence of IP litigation in the effects of PROs vs non-rival firms on knowledge leakage.

3. Hypotheses

3.1. Knowledge outflows via common partners

Following seminal work by Simmel (1950) and Granovetter's influential notion of structural embeddedness (1985), the network embeddedness literature has argued and shown that the structure surrounding a dyad matters, and is essential for the rapid dissemination of information and (technological) knowledge (Coleman, 1990; Rosenkopf and Almeida, 2003; Gulati and Garguilo, 1999; Ryu et al., 2018). Taking a network structural perspective sheds light then on how a common partner connects a firm to indirect ties. The network literature has suggested that indirect ties offer firms the benefits of gathering and assimilating relevant recent knowledge on scientific 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). Although indirect ties operate at larger social distance in the firm's network, a two-step reach may suffice in facilitating knowledge flows, in either direction (Singh, 2003; Li and Rowley, 2002; Ryu et al., 2018).

This also implies that firms engaging in R&D collaboration with a common partner risk that sensitive knowledge and company secrets shared and developed in the joint research leaks out to rival firms. Hence, 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), and may lead to the disclosure of existing proprietary knowledge and technologies of the focal firm. A KBV perspective maintains that 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). The nature of knowledge transfer processes often implies that the translation of knowledge held by individuals into a common language, through codification, not only facilitates internal knowledge diffusion and recombination but also knowledge leakage and imitation (e.g., Levin et al., 1987; Kogut B Zander, 1992). Even when the focal firm and the common partner operate at a cognitive distance (Baum et al., 2013; Nooteboom et al., 2007), knowledge exchange and learning in close inter-personal interactions is likely to facilitate

effective knowledge transfer (Petruzzelli, 2011).

It follows that collaboration with common partners – which may include non-rival firms or PROs – increases the risks of knowledge leakage to a focal firm's rivals and hence the risk that rivals are able to apply for similar patents. This suggests the following baseline hypothesis:

Baseline Hypothesis 1: R&D collaboration with partners that are common to a focal firm and a rival is associated with greater similarity of subsequent patents applied for by the focal firm and that rival.

3.2. Different types of common partners: non-rival firms versus PROs

A focal firm's collaborations may not only focus on partner firms, but may also include collaborations with PROs: universities, research organizations, and government institutes (e.g., Richter Ostergaard and Drejer, 2022). Both non-rival firms and PROs can act as common partners to a focal firm and its rivals. Each type of common partner has objectives that do not necessarily align with a focal firm's interests (Pahnke et al., 2015). Given that non-rival firms and PROs differ in interests and research practices (e.g., Belderbos et al., 2016), we argue that it is important to distinguish between these different types of common partners.

As the network embeddedness perspective maintains that nodal attributes matter in network structures (McPherson et al., 2001), we argue that the risk of knowledge leakage through collaboration with a common partner is likely to differ depending on the attributes of the common partner, and will be higher if this partner is a PRO. Firms benefit from R&D collaborations with PROs, 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 PROs 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 industrial researchers may require secrecy to facilitate value appropriation (Belderbos et al., 2016), university scientists are keen on disclosing new knowledge and to gain recognition. The differences in norms, routines, and work practices renders it difficult for firms to restrict knowledge spillovers through the firm's own scientists and the PRO. PROs 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 (e.g. Colen et al., 2022).

An important part of collaboration with PROs is formed by interactions between firms' scientists and academic researchers. This supports a more profound knowledge exchange that also requires a greater openness of a focal firm and a willingness to share its firm-specific knowledge. As universities operate in a different institutional environment than firms, adhering to the open science paradigm, with research broadly connected and results widely disseminated, that may render it more likely that such firm-specific knowledge also reaches rival firms that collaborate with the same university. PROs generally do not prohibit this, not only because they do not own their partner-firm's technology but also due to lack of sufficient awareness of the risk of spillovers to their partners' rivals through indirect ties altogether.

Consequently, if a firm has a PRO 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 influence of common R&D partners on rival patent similarity of Hypothesis 1 is greater when the common R&D partners are PROs than if they are non-rival firms.

3.3. The role of IP litigation reputation

A network embeddedness perspective suggests that an indirect tie is by definition a tie over which a firm has no control (Hernandez et al., 2015; Simmel, 1950; Freeman, 1991). While formal mechanisms (e.g., contracts) or social mechanisms (e.g., trust and reciprocity) apply to direct ties, they become ineffective with indirect ties. Still, a firm's reputation can affect the behavior of the direct collaborating partner and so may influence knowledge flows to indirect ties beyond the ego-network (Moynihan, 2012). We argue that the exploitation of a firm's knowledge obtained through common partner collaboration will be reduced if the firm has developed a strong reputation to act against IP infringements.

A KBV perspective suggests that there are several instruments firms can use to reduce the risk of knowledge spillovers to rivals, such as legal instruments (e.g., contracting) or limiting the scope of collaboration (Heiman and Nickerson, 2004). Prior studies on firms' litigation strategies have also suggested the effectiveness of formal intellectual property protecting strategies to limit knowledge spillovers. A firm's aggressive use of patent litigation to enforce its intellectual property can build a reputation for toughness in IP (Somaya, 2003), which can curb the use of its technologies by other firms (Carlton and Perloff, 2005). 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 locations (Onoz and Giachetti, 2021) and technological areas (Ganco et al., 2020). While contractual solutions to personnel mobility-induced spillovers, e.g., noncompete clauses (Gilson, 1999; Agarwal et al., 2009), increase transaction costs and are not always well enforceable (Acemoglu and Pischke, 1998), studies have shown that a pronounced patent litigation reputation can benefit litigious firms in protecting their proprietary knowledge embedded in employees by reducing employee mobility (Agarwal et al., 2009; Ganco et al. 2015, 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 from getting closer in technology space to the focal firm (Kafouros et al., 2021; Galasso and Schankerman, 2015; Clarkson and Toh, 2010; Agarwal et al., 2009). Such an aggressive litigation strategy is likely to be associated with the firm's legal department's decision to put strict limits on employees from exchanging knowledge across firm boundaries (Davis and Harrison, 2001), and with investments in legal teams that enter complex negotiations and 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).

It follows that a tough reputation for litigation of a focal firm is 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. 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 common partner's willingness to reduce knowledge spillovers, as getting entangled in IP litigation may harm its reputation. Hence, despite the common partner's awareness of the focal firm's technological knowledge, the common

partner will be cautious in using knowledge that may stem from its partnership with the focal firm, particularly when the focal firm has a strong reputation for litigiousness and appropriation of its IP. The use of an intellectual property protection strategy and the build-up of a reputation for toughness by the focal firm in this regard may be effective in reducing knowledge outflows through common partners to rivals, and mitigate the risk of knowledge leakage to them, which otherwise could lead rivals to encroach on the focal firm's technology domain.

This will also play a role for PROs as common partners. PROs may want to avoid knowledge leakage because, even in a situation where they are not a defendant in a lawsuit, they would suffer reputation loss and credibility, if exposed as a source of knowledge leakage in such lawsuit. Colen et al. (2022) interviewed R&D managers at pharmaceutical firms and scientists at universities about their research collaborations; they note that university researchers are very much aware that they have to heed non-disclosure agreements to avoid legal repercussions. They find that the risk of a university becoming a source of knowledge spillovers that could be challenged by their collaboration partner is often consciously reduced by the university department not partnering with other firms at the same time: i.e. universities restrict collaborations to establish exclusivity and avoid common partnerships. In terms of litigation involvement, we do observe that universities and firms have also been embroiled in patent-related disputes, which often relate to research collaborations. The case of Genentech litigating against The University of Pennsylvania is a case in point. Here, Genentech claimed that the university failed to make research results available on breast cell research and antibody development, hampering its patent development and in breach of their collaboration contract. In another case, the same university had a patent dispute with Johnson & Johnson concerning a patent that the firm developed based on what the university claimed was its proprietary knowledge. This involved the transfer of knowledge by a university researcher to Johnson & Johnson. In yet another case, pharmaceutical company Biogen refused to pay licensing fees to Columbia University, claiming that the patent base for the licensing agreement had expired, which was disputed by the university.[1] These cases illustrate that universities do get involved in legal IP disputes with firms and have reason to be concerned about such disputes when they collaborate with them.

It follows that a pronounced IP litigation reputation is likely to reduce knowledge outflows through common partners to indirect rivals, and mitigate the risk of knowledge leakage to rivals. This suggests the following hypothesis:

Hypothesis 3. A pronounced IP litigation reputation of the focal firm reduces patent similarity of rival firms facilitated by common R&D partners.

3.4. The effectiveness of IP litigation reputation: non-rival firms versus PROs

We expect that the effectiveness of a pronounced IP litigation reputation is dependent upon the type of common partner, as these differ in their inclination or capability to act on knowledge leakage concerns by a focal firm (Frishammar et al., 2015; Ritala et al., 2015).

First, R&D collaboration with PRO scientists tends to involve a greater degree of tacit knowledge exchange (Colen et al., 2022). 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). The network embeddedness literature suggests that collaboration allows for the build-up of trust (Gulati and Garguilo, 1999), which is an important prerequisite for the efficient exchange of tacit knowledge (Gilsing and Nooteboom, 2006). Such trust-based collaboration reduces the likelihood of noise in information exchange and of tacit, fine-grained specificities from 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, following a network embeddedness perspective, a focal firm's reputation for IP litigation may negatively affect its trust-based collaboration with the PRO, and its opportunities for future collaboration with PROs (Powell et al., 2005). PROs 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 PRO to maintain a collaboration network and open scientific exchange with other firms and organizations that fear putting themselves at risk of IP litigation. This makes a focal firm's reputation for litigation less effective when the common partner is a PRO. 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 dealing with legal issues and litigation. It follows that a firm's IP litigation reputation is likely to be less powerful to combat knowledge outflows to rivals if the common collaboration partners are PROs, compared to when the common partners are non-rival firms. We hypothesize:

Hypothesis 4. The influence of IP litigation reputation of *Hypothesis 3* is smaller when the common R&D partners are PROs than when they are non-rival firms.

4. Data, variables and methods

We examine the relationships between collaboration with common partners, patent similarity of rival firms, and patent litigation reputation for the 55 largest firms active in the pharmaceutical industry, 1995–2015. The firms have been selected as the top patentees and R&D spending bio-pharmaceutical firms as identified in the 'EU Industrial R&D Investment Scoreboard', which lists the top 500 corporate investors in R&D. The focal firms were observed for at least 10 years to allow systematic analysis in fixed effects models.[2] We examine patent similarity among dyads of the 55 focal firms, but also consider knowledge outflows and patent similarity of these focal firms with respect to 21 other firms with at least 40% of their sales in pharmaceuticals (such as Bayer) and pharmaceutical firms observed for shorter periods. This allows for a greater representation of the consequences of reputation and common partner collaboration, as increased competition in the pharmaceutical market posed by these firms due to knowledge spillovers will also be a relevant consideration for the focal market leaders. This resulted in an unbalanced panel of 4036 firm dyads.

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

[1] See for public information on these cases: https://casetext.com/case/genentech-4; https://scholar.google.com/scholar_case?case=860,163,471,651,483,228&q=+%22Retin-A%22&hl=en&as_sdt=2006&as_ylo=1989&as_yhi=1991; https://casetext.com/case/biogen-idec-ma-inc-v-trustees-of-columbia-university.

[2] The observation period can be reduced due to major mergers and acquisitions, such as the merger of Ciba-Geigy and Sandoz to form Novartis in 1996 and the creation of AstraZeneca through a merger in 1999.

affiliated with the firms on a consolidated basis. Publications co-authored by the focal firm and a PRO 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 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 (e.g., universities, research institutes, and government institutes), or the 76 rival firms operating in pharmaceutical markets. 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. Patent similarity of rival firms was computed using the measure due to Arts et al. (2017) of text-based similarity between any two patents granted by the USPTO.

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 4290 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, as prior litigation may involve more intensive interactions between firms on their proprietary knowledge bases (James et al., 2013; Devlin, 2010; Ouellette, 2012).

4.1. Variables

We rely on Arts et al. (2017) to measure technological similarity between patents of any two pairs of rival firms. This text-based similarity measure is an improvement on measures that make use of the United States Patent Classification System (USPC), which do not capture all technological characteristics of an invention (Singh and Agrawal, 2011). The similarity between two firm's patents indicates how close the firms are operating in technology space, with closeness bringing firms into direct competition for novel technologies and affecting their appropriation potential. Knowledge spillovers, such as those occurring through common partner collaborations, may bring a rival firm's technology development closer to the focal firm. A patent similarity measure to gauge the role of knowledge spillovers that harm the interests of the focal firm has clear advantages over a patent citation measures. Although patent citations have been shown to correlate (weakly) with actual knowledge flows (e.g., Jaffe et al., 2000; Jaffe et al., 1993; Belenzon and Schankerman, 2013), they remain noisy and incomplete (Moser et al., 2017; Alcacer and Gittelman, 2006), and may not necessarily be against the cited firm's interest if the knowledge is used to develop non-competing technologies.

Our dependent variable measures the similarity of new patents filed (in year t) by a rival firm. *Patent similarity*$_{ij,t}$ is the number of patents filed by firm *j* in year *t* with a substantial level of similarity to the patents of focal firm *i*. Substantial similarity is defined as a patent with a Jaccard similarity index of at least 0.10, with similarity data retrieved from Arts et al. (2017). Arts et al. (2017) provide the 200 closest matches of any patent applied for in the same year as a focal with a minimum similarity of 0.05. The patents of the focal firms that have a closely (>0.10) matched patent of one of its rivals are a subset of these, which amounts to 55 patents on average. The mean of similarity of the patents of rivals at 0.202. We observe these bilateral patent similarities between rival firms from 1995 to 2015. As we have an unbalanced panel of rival 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 identify R&D collaboration using the publication libraries of Scopus and PubMed, retrieving all publications with authors listing the sample firms as affiliation. An R&D collaboration is identified if authors affiliated with the sample firm and an author affiliated with another firm or PRO are jointly listed on a publication. A common partner arises if two sample firms have a joint publication with the same PRO or non-rival firm. We calculated the Jaffe index of similarity of collaboration patterns of firms *i* and *j* with the same individual PROs or non-rival firms *k* (Jaffe, 1986; Breschi, Lissoni, and Malerba, 2003) as $S_{ijt} = (\sum_{k=1} C_{ik} * C_{jk}) / (\sqrt{\sum_{k=1} C^2_{ik}} * \sqrt{\sum_{k=1} C^2_{jk}})$, where C indicates the number of collaborations of firm *i* or *j* with *k*. Similarly, to measure *PRO common partner*$_{ij,t-1}$, we calculated the Jaffe index of similarity of collaboration patterns with the same individual universities and research institutions, using publications co-authored by the focal firm and PROs.[3] To calculate *Firm common partner*$_{ij,t-1}$, we calculated the Jaffe index of similarity of collaboration patterns with non-focal and non-rival firms, using publications co-authored by the focal firm and other firms. We took the natural logarithm of the focal collaborative overlap variables (after adding the value 1) to 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 reputation$_{i,t-1,\ t-5}$ 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. *Focal litigation reputation*$_{ij,t-1}$ is the natural logarithm of focal firms' litigation reputation. The interaction terms of focal litigation reputation and the common partner variables test for Hypotheses 3 and 4.

The analysis controls for the potential impact of *Rival litigation reputation*$_{ij,t-1}$ measured in a similar way as focal litigation reputation, and for the direct collaborations between the focal and rival firm. The latter (*Focal-rival collaboration*) is measured as 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 between rivals (Alcacer and Zhao, 2012; Belderbos et al., 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. Technological similarity is associated with a greater relevance of, and absorptive capacity for, rival firms' knowledge (e.g. Cantwell and Colombo, 2000; Ghosh and Rosenkopf, 2015). Since it is conceivable that firms are attracted to the same technologies and collaboration with firms and universities in these technologies, leading to patent similarity, we also control for *overlap in fast growing technologies*$_{ij,\ t-1}$. This is the natural logarithm of the number of growing technology classes (measured as the top 25th percentile at the 3-digit level in the previous five years) that focal and rival firm pair are active in. In addition, we control for *Overlap in research*$_{ij,\ t-1}$, the Jaffe index of firm *i* and *j*'s publications over MeSH terms (publication key words).

We control for the size of the patent stock of firm *i* and of firm *j*, operationalized as patents granted in the last three years, by taking the multiplication of the citing and citable patents *(Patent stocks*$_{ij,t-1\ -\ t-3}$*)*. As

[3] We left out collaborations with hospitals, as these often focus on clinical trials rather than research.

patent similarity is determined for patents applied for in the same year *t*, past patent stocks control for the expected volume of patenting of the focal and rival, and hence the average probability that some of these patents are similar. Since firms with valuable patents are more likely to have rival firms aiming to mimic their technologies, the analysis includes *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 et al., 2021), we include the average number of locations in which co-inventors of firm *i*'s patents are residing, *Co-inventor linkages*$_{i,t-1}$). We also include a measure of the general geographic spread of the focal firm's inventive activities (*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). Finally we add focal and rival firm size, measured as the log of the number of employees. Given that our sample covers a long time series including M&As, about 18 percent of observations are missing. To avoid making the sample less representative by omitting observations, we added two dummy variables taking the value 1 if the focal (rival) employment information is not available.

The analysis also controls for the (average) degree of enforcement of intellectual property rights in the focal and rival firm's home countries (*avg IPR enforcement*$_{i,t}$). We follow recent work (Belderbos et al., 2021a, b; 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., Branstetter et al., 2006; Nandkumar and Srikanth, 2016), it does not capture the enforcement level of these laws. *Avg IPR*$_{i,t}$ *enforcement* is defined as *(GP*$_{ct}$*/MaxGP*$_t$*) * (IC*$_{ct}$*/MaxIC*$_t$*)*. Finally, we include *Same Country*, which takes the value 1 if the focal and rival firm are headquartered in the same country.

One limitation of our analysis is that we do not have data to control for other means of (direct) knowledge transfer in a dyad. We control for direct collaboration, geographic proximity, technological overlap, and same country of origin. We envisage that this set of control variables may pick up most of such other influences as employee mobility and licensing, which research has shown are predominantly taking place in spatial proximity (e.g. Mowery and Ziedonis, 2015). Moreover, licensing contracts may contain clauses that restrict the partner in their use of a technology, and firms are unlikely to license out technologies that would aid rivals to encroach on their core technology. Hence, since the focal firm has agency over licensing (in contrast with knowledge spillovers through common partners), we may not expect a direct influence of licensing on patent similarity.

4.2. Methods

Since the dependent variable is a count variable, we estimate Poisson regressions with cluster-robust standard errors at the firm-pair level. Poisson models are the most generic, unbiased, specification for count models, while the estimation with error terms clustered at the firm-pair level corrects for overdispersion (Wooldridge Jeffrey, 1999). We include two sets of unconditional firm fixed effects (focal and rival firm dummies) throughout to control for unobserved firms' heterogeneity that may be associated with higher or lower similarity. 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 patent similarity and possible remaining truncation in patent measures.

5. Results

Tables 1a and 1b presents the descriptive statistics and pair-wise correlations. The correlations do not indicate multicollinearity concerns.

Table 1a
Descriptive Statistics and correlations.

		Min	Max	Mean	Std. Dev.
1	*Patent similarity*	0	3462	66.022	182.400
2	*Common partner*	0	0.588	0.079	0.115
3	*PRO common part.*	0	0.595	0.083	0.121
4	*Firm common part.*	0	0.693	0.013	0.053
5	*Focal litigation*	0	7.373	2.271	1.904
6	*Rival litigation*	0	7.373	2.047	1.888
7	*Focal-rival collab.*	0	4	0.004	0.049
8	*Co-location*	0	1	0.418	0.414
9	*Overlap in tech.*	0	1	0.486	0.353
10	*Overlap in growing tech.*	0	3.497	0.865	0.742
11	*Overlap in research*	0	0.794	0.045	0.112
12	*Patent quality*	0	19	0.633	1.216
13	*Patent stocks*	0	14.849	6.890	4.115
14	*Location diversity*	1	19	4.158	3.600
15	*Co-inventor link.*	0	3	1.529	0.557
16	*Avg IPR enf.*	0.619	0.957	0.863	0.047
17	*Same country*	0	1	0.215	0.411
18	*Focal empl*	0	4.918	2.183	1.670
19	*Focal empl NA*	0	5.091	2.110	1.706
20	*Rival empl*	0	1	0.168	0.374
21	*Rival empl NA*	0	1	0.231	0.421

Table 2 reports the empirical results of the fixed effects Poisson models. Model 1 presents results when only the control variables are included. Most coefficients have the predicted sign and are significant. Patent similarity of the rival firm increases with co-location, overlap in technologies, direct collaborations, patent quality, citable and citing patent stocks, location diversity, firm size, and the average IPR protection level. Firm litigation reputation reduces similarity. Somewhat surprisingly, overlap in research has a negative sign. Perhaps similar scientific research profiles allow firms to develop rather different technology profiles. A rival headquartered in the same country as the focal firm has a higher inclination to draw on knowledge from the focal firm. Internal co-inventor team linkages have no significant effect.

The main effect of *focal litigation reputation*$_{ij,t-1}$ is negative and significant, suggesting that greater litigation is associated with a decrease in patent similarity of technology efforts of rival firms. The effect of *rival litigation reputation*$_{ij,t-1}$ is negative and significant as well. Model 2 tests for Hypothesis 1 by including *common partners*$_{ij,t-1}$. The positive estimated coefficient ($\beta = 0.235$, $p = 0.038$) supports Hypothesis 1, i.e., common R&D partners of a focal firm and its rival is associated with greater patent similarity of the rival firm. Model 3 tests Hypothesis 2 by including *PRO common partners*$_{ij,t-1}$ and *Firm common partners*$_{ij,t-1}$ separately instead of *common partners*$_{ij,t-1}$. Patent similarity with rival firms is greater if the common R&D partners are PROs ($\beta = 0.271$, $p = 0.01$) than if they are (non-rival) firms ($\beta = -0.086$, $p = 0.531$), supporting Hypothesis 2. A Chi-square test suggest that the difference is significant (chi2 = 3.29; $p = 0.070$).

Model 4 tests Hypotheses 3 by including the interaction effect of focal litigation reputation and common partner. The negative and significant coefficient of the interaction effect provides support for Hypothesis 3 ($\beta = -0.178$, $p < 0.01$). In model 5, patent litigation reputation of the focal firm significantly reduces the effect of Firm common partner ($\beta = -0.406$, $p < 0.01$) and of PRO common partner ($\beta = -0.134$ $p = 0.01$), where the reduction is stronger from firm common partner. These coefficients of the interaction terms are significantly different (chi2 = 7.66; $p = 0.006$) from each other. This stronger moderation effect of litigation reputation provides support for Hypothesis 4.

The estimated coefficients provide no direct indication of marginal effects, and the significant interaction term for firms as common partners implies that the influence on patent similarity of rivals depends on the level of the focal firms' litigation reputation. In Fig. 2, we depict the effects of a standard deviation change in common partner collaboration with firms and PRO respectively, as a function of litigation strategy. The

Table 1b
Correlations.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	*Patent similarity*																				
2	*Common partner*	0.434																			
3	*PRO CP*	0.431	0.995																		
4	*Firm CP*	0.239	0.348	0.346																	
5	*Focal litigation*	0.106	0.240	0.246	0.133																
6	*Rival litigation*	0.143	0.287	0.283	0.113	0.124															
7	*Focal-rival collab*	0.052	0.048	0.046	0.010	−0.006	0.060														
8	*Co-location*	0.204	0.394	0.398	0.107	0.136	0.240	0.046													
9	*Over in tech*	0.271	0.275	0.272	0.122	0.115	0.232	0.042	0.076												
10	*Over in grow. tech*	0.406	0.324	0.321	0.192	0.121	0.252	0.037	0.204	0.391											
11	*Over in research*	0.263	0.662	0.620	−0.100	0.095	0.223	0.053	0.244	0.181	0.200										
12	*Patent quality*	−0.011	−0.029	−0.029	−0.004	0.080	0.046	0.014	0.081	−0.058	−0.059	−0.028									
13	*Patent stocks*	0.250	0.342	0.342	0.171	0.248	0.416	0.042	0.277	0.337	0.404	0.208	0.050								
14	*Location diversity*	0.297	0.294	0.300	0.225	0.307	0.066	−0.008	0.098	0.141	0.300	0.069	−0.107	0.215							
15	*Co-inventor link*	0.086	0.219	0.222	0.093	0.211	0.157	0.016	0.293	0.013	−0.030	0.125	0.121	0.158	0.141						
16	*Avg IPR enf*	0.018	0.060	0.063	0.009	−0.012	−0.031	0.000	0.262	−0.161	−0.049	0.032	−0.029	0.000	−0.016	0.143					
17	*Same country*	0.057	0.252	0.258	0.031	−0.022	0.000	0.022	0.563	−0.031	−0.030	0.163	−0.020	0.065	−0.068	0.144	0.227				
18	*Focal empl*	0.278	0.278	0.286	0.224	0.405	0.069	−0.010	0.070	0.158	0.276	0.040	0.034	0.230	0.645	0.092	0.041	−0.052			
19	*Focal empl NA*	0.264	0.288	0.277	0.091	0.075	0.400	0.084	0.119	0.169	0.317	0.290	0.029	0.352	0.031	0.098	0.007	−0.077	0.029		
20	*Rival empl*	−0.090	−0.146	−0.149	−0.078	−0.211	−0.110	−0.020	−0.139	−0.044	−0.048	−0.055	−0.099	−0.188	−0.167	−0.218	−0.138	−0.053	−0.588	−0.062	
21	*Rival empl NA*	−0.102	−0.195	−0.194	−0.045	−0.114	−0.316	−0.033	−0.221	−0.129	−0.164	−0.150	−0.045	−0.383	−0.057	−0.149	−0.046	−0.027	−0.059	−0.677	0.096

marginal effects are presented as incidence ratios, exponentiated coefficients reflecting the proportional increase in the number of patents with similarity due to a (standard deviation) change in the explanatory variables. In the absence of litigation reputation, the effect of PROs as common partners on patent similarity is 11.7 percent, whereas this is about 5 percent for firms as common partners. At higher levels of focal firm litigation reputation, the influence of PROs as common partners turns insignificantly different from zero. In contrast, at higher levels of litigation, the influence of firms as common partners turns significantly negative. These patterns attest to the important influence of IP litigation reputation on knowledge spillovers and patent similarity. The (significantly) negative influence of having non-rival firms as common partners may be due to the fact that collaboration with a common partner brings a greater awareness and risk perception to the rival firm regarding the aggressive focal litigious firm, reducing the use of the focal firm's knowledge.

5.1. *Supplementary analyses*

We conducted several tests to examine the robustness of our findings. Results are reported in Table 3. Model 1 presents results when we replace the dependent with the number of citations patents of focal firm *i* receive from rival firm *j* in year *t.* Very similar patterns are observed, though with higher estimated standard errors, suggesting that our focus on similar patents is more appropriate. A complication with the use of citations is that we would preferably conduct this analysis excluding examiner given citations, but this distinction is only available from the year 2001 (Lemley and Sampat, 2012). Model 2 presents results when we restrict the observations on leakage to non-diversified pharmaceutical firms and hence omit 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 and produces consistent results. Similar results are also obtained when we weigh common partner collaboration with their importance in terms of knowledge sourcing, i.e., a Jaffe index of the overlap in focal and rival firms' patent citations to the same individual organizations, to arrive at a measure of effective knowledge sourcing through R&D collaborations with common partners (Ghosh and Rosenkopf, 2015). Finally, robust results are obtained when we apply a stricter threshold to count patents with similarity (Model 4) – with the Jaccard index for thepatent pairs set at 0.2.[4]

6. 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 they are non-rival firms (e.g., suppliers, clients, firms operating outside the core markets of focal firms) or PROs (universities and research institutes).

We argue that the IP litigation reputation of a focal 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 PROs, with the latter's emphasis on open science rendering spillovers greater and litigation reputation less effective. Findings from patent analysis among leading pharmaceutical firms show that the degree to which rival firms have PROs or non-rival firms as common partners is positively associated with the similarity of patents of the rival firms. This relationship is weakened and rendered

[4] We also did not observe significantly different results for the focal variables for the subset of focal firms based in the United States.

Table 2
Common partners and patent similarity of rival firms: results of fixed effects Poisson analysis.

	(1)	(2)	(3)	(4)	(5)
Common partner		0.235**		0.815***	
		(0.113)		(0.223)	
PRO common partner			0.271**		0.774***
			(0.108)		(0.206)
Firm common partner			−0.086		1.156***
			(0.137)		(0.282)
*Common partner * focal litigation*				−0.178***	
				(0.056)	
*PRO common partner * focal litigation*					−0.134**
					(0.053)
*Firm common partner *focal litigation*					−0.406***
					(0.083)
Focal litigation	−0.103***	−0.104***	−0.104***	−0.077***	−0.072***
	(0.012)	(0.012)	(0.012)	(0.013)	(0.012)
Rival litigation	−0.068***	−0.069***	−0.069***	−0.070***	−0.070***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Focal-rival collaboration	0.007	0.012	0.012	0.040	0.047
	(0.123)	(0.124)	(0.124)	(0.119)	(0.119)
R&D co-location with rival	0.684***	0.673***	0.671***	0.667***	0.664***
	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Overlap in technologies	1.004***	1.000***	0.999***	0.993***	0.989***
	(0.062)	(0.061)	(0.061)	(0.061)	(0.061)
Overlap in strongly growing technologies	0.730***	0.731***	0.732***	0.730***	0.728***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Overlap in research	−0.038*	−0.094	−0.113	−0.097	−0.190*
	(0.077)	(0.082)	(0.093)	(0.081)	(0.095)
Patent quality focal firm	0.026	0.026*	0.026*	0.027*	0.026*
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Patent stocks	0.017***	0.016***	0.016***	0.016***	0.016***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
R&D location diversity	0.015***	0.015***	0.015***	0.014***	0.014***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Co-inventor linkages	0.106*	0.106*	0.108*	0.110*	0.119**
	(0.060)	(0.060)	(0.060)	(0.060)	(0.059)
Avg. IPR enforcement	−3.379***	−3.307***	−3.311***	−3.387***	−3.368***
	(0.623)	(0.619)	(0.618)	(0.615)	(0.610)
Same country	0.146***	0.141***	0.140***	0.142***	0.137***
	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
Focal employees	0.214***	0.210***	0.208***	0.212***	0.215***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.036)
Focal employees NA	0.432***	0.428***	0.428***	0.429***	0.431***
	(0.037)	(0.036)	(0.036)	(0.036)	(0.036)
Rival employees	0.379***	0.366***	0.363***	0.397***	0.400***
	(0.107)	(0.106)	(0.106)	(0.104)	(0.103)
Rival employees NA	0.935***	0.924***	0.925***	0.936***	0.942***
	(0.105)	(0.103)	(0.103)	(0.104)	(0.104)
firm fixed effects	<included>	<included>	<included>	<included>	<included>
rival fixed effects	<included>	<included	<included>	<included>	<included>
year fixed effects	<included>	<included>	<included>	<included	<included>
Observations	48,138	48,138	48,138	48,138	48,138
Log likelihood	−762,637.84	−762,220.93	−762,099.69	−760,694.04	−757,784.41
Wald	637,969.40	625,656.83	667,136.81	660,980.83	638,758.12
Wald p value	0.0	0.0	0.0	0.0	0.0

Notes: Results of Poisson models. Cluster-robust standard errors (at the level of 4036 dyads) in parentheses. *p < 0.10; **p < 0.05; ***p < 0.01. PRO is Public Research Organization (e.g., universities and research institutes).

insignificant for focal firms with a more aggressive patent litigation reputation – but only when the common partners are non-rival firms.

Studying knowledge leakage to indirectly connected rivals via common partners, and their encroaching onto a focal firm's technology space, is important, as such leakages and technology challenges 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 reputation between PROs and non-rival firms as common partners therefore lend credence to the claim that the attributes of the node, in network embeddedness parlance, connecting the focal firm with its rivals, matters for the consequences of such indirect ties. The lack of effectiveness of IP litigation reputation to combat knowledge leakage through collaboration with PROs 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 PROs. Universities and other PROs rarely employ patent attorneys in-house, and a lack of staff at technology transfer offices (Shane and Somaya, 2007) may make it difficult for universities to seek effective external counsel. This may make PROs reluctant to collaborate with firms with a tough reputation for IP enforcement. A focal firm's attractiveness as a collaboration partner for PROs may diminish, and it may be locked out from future access to scientific knowledge. Given the strategic benefits of collaborations with PROs, firms can neither easily avoid nor terminate ties with PROs to address the risk of spillovers (Hernandez et al., 2015). That would imply that firms need to systematically exclude PROs as a collaboration partner, at the expense of their 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

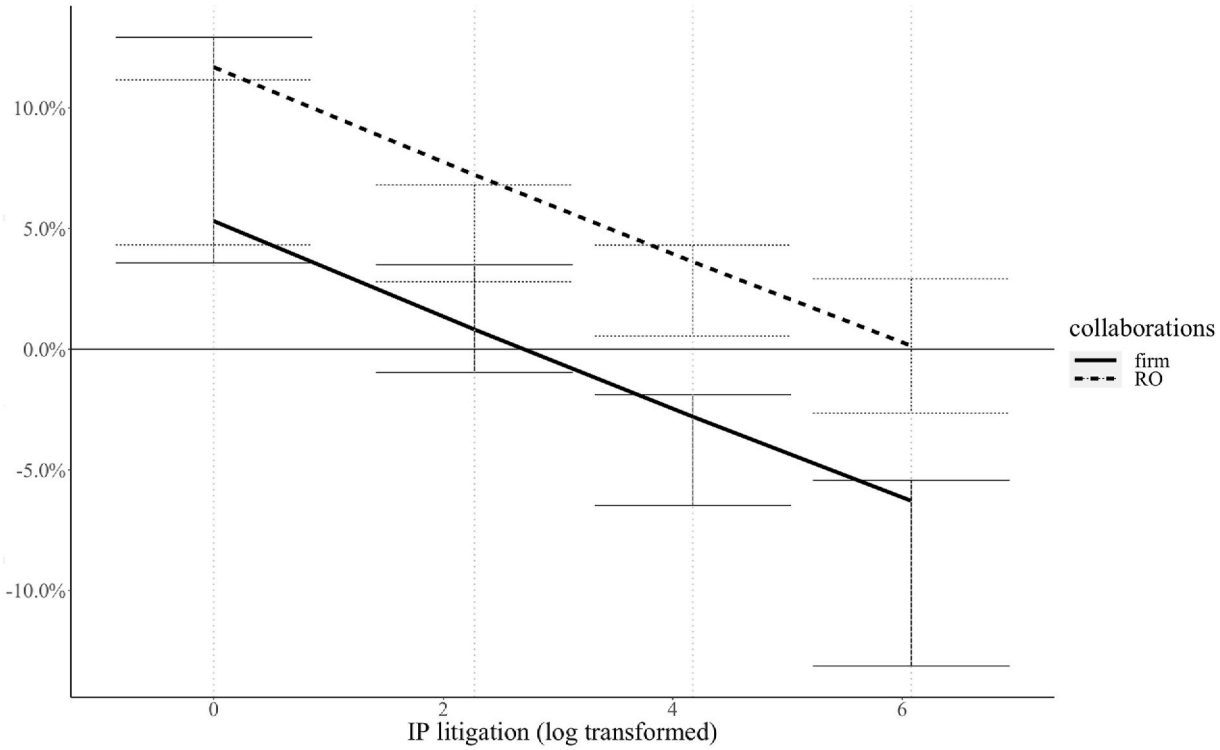

Fig. 2. Effects of common partner collaboration on firms' patent similarity: the moderating effect of IP litigation reputation
Notes: Effects of a standard deviation increase in common partner collaboration (with non-rival firms or PROs) in terms of a percentage increase in patent similarity due to common partner collaborations. The solid vertical lines indicate the 95% confidence interval.

collaboration with firms and PROs.

Our paper makes several contributions. We contribute to the literature on KBV that has emphasized the need for appropriation of newly created knowledge by the firm, but has paid less attention to the mechanisms on when and how to do this effectively (Belderbos et al., 2021a,b). Here, we contribute by arguing and showing that the risk of knowledge leakage to indirect rivals occurs, and more so when the common partner is a PRO rather than non-rival firm. Moreover, we show how the effectiveness of IP litigation reputation also affects intermediaries that serve as the common partner between a firm and its rivals, and demonstrate that this decreases when the common partner is a PRO instead of a non-rival firm.

We complement the network embeddedness 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. We show that whether the common node is a PRO, as a public partner, or a firm, as a private firm, has a differential effect on both the risk of knowledge spillovers and on the effectiveness of litigation as a mechanism to address this risk. We argue that in case the common partner is a PRO, this risk not only becomes stronger but also more difficult to address through litigation. While the network embeddedness literature 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 and 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 addressing these risks. Our paper shows that legal IP strategies and reputation 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 PRO or a firm.

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 PRO, 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 role of PROs and firms as (common) collaboration partners.

Our study is not without limitations. First, we did not examine detailed heterogeneous traits of individual common partners – as we were interested in the distinction between PROs and non-rival firms. Second, our study was restricted to the 55 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 PRO as well as firm collaborations, but our findings will 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, as long as litigation is also observed there. Third, 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, although we used a careful research design including a range of control variables to represent influences on patent similarity and although models with patent citations as an alternative dependent variable gave consistent results, we cannot completely rule out omitted variable bias. It is also conceivable that firms that are targeting overlapping technology domains also choose

Table 3
Common partners and patent similarity of rival firms: alternative specifications.

	(1) citations	(2) smaller sample of rival firms	(3) common partner collaboration weighted	(4) higher similarity threshold
PRO CP	1.789*	0.742***	0.542***	0.821***
	(1.063)	(0.212)	(0.141)	(0.323)
Firm CP	3.111**	1.125***	0.893***	1.253***
	(1.391)	(0.361)	(0.226)	(0.522)
*PRO CP * focal litigation*	−0.335*	−0.138***	−0.087***	−0.162**
	(0.194)	(0.055)	(0.035)	(0.079)
*Firm CP * focal litigation*	−0.738*	−0.422***	−0.335***	−0.397***
	(0.412)	(0.100)	(0.066)	(0.143)
Focal litigation	−0.070**	−0.068***	−0.071***	−0.118***
	(0.034)	(0.014)	(0.012)	(0.027)
Rival litigation	−0.108***	−0.091***	−0.069***	−0.098***
	(0.028)	(0.014)	(0.012)	(0.017)
Focal-rival collaboration	0.518	−0.014	0.054	−0.027
	(0.334)	(0.133)	(0.119)	(0.243)
R&D co-location with rival	0.643***	0.644***	0.663***	0.811***
	(0.158)	(0.050)	(0.046)	(0.079)
Overlap in technologies	0.864**	0.888***	0.988***	0.967***
	(0.404)	(0.063)	(0.060)	(0.128)
Overlap in growing technologies	0.713***	0.707***	0.726***	0.662***
	(0.071)	(0.027)	(0.024)	(0.040)
Overlap in research	−0.258	−0.216**	−0.241***	−0.045
	(0.445)	(0.093)	(0.093)	(0.143)
Patent quality focal firm	0.112***	0.021	0.025	−0.005
	(0.034)	(0.018)	(0.016)	(0.028)
Patent stocks	0.075***	0.020***	0.016***	0.014**
	(0.014)	(0.004)	(0.004)	(0.006)
R&D location diversity	0.006	0.014***	0.014***	0.000
	(0.009)	(0.005)	(0.005)	(0.008)
Co-inventor linkages	−0.201	0.142**	0.115**	0.203**
	(0.209)	(0.064)	(0.059)	(0.093)
Avg. IPR enforcement	−9.010***	−1.912**	−3.369***	−3.273***
	(3.129)	(0.637)	(0.605)	(0.923)
Same country	0.083	0.138***	0.136***	0.217***
	(0.156)	(0.038)	(0.036)	(0.059)
Focal employees	−0.056	0.215***	0.213***	0.204***
	(0.074)	(0.039)	(0.036)	(0.052)
Focal employees NA	0.574***	0.470***	0.427***	0.425***
	(0.077)	(0.035)	(0.036)	(0.051)
Rival employees	0.080	0.448***	0.395***	0.443**
	(0.252)	(0.113)	(0.103)	(0.155)
Rival employees NA	0.772***	1.201***	0.928***	0.843***
	(0.205)	(0.094)	(0.104)	(0.155)
firm fixed effects	<included>	<included>	<included>	<included>
rival fixed effects	<included>	<included>	<included>	<included>
year fixed effects	<included>	<included>	<included>	<included>
Observations	48,138	38,676	48,138	48,138
Log likelihood	−147,538.83	−632,514.71	−756,758.25	−280,083.76
Wald	105,940.56	572,373.63	649,211.49	499,587.61
Wald p value	0.000	0.000	0.000	0.000

Notes: Results of Poisson models. Cluster-robust standard errors at the dyad level in parentheses. *p < 0.10; **p < 0.05; ***p < 0.01.

common partners to pursue their R&D objectives. We interpret our results therefore in terms of associations, while noting that the complex relationships uncovered related to common partner types and IP litigation are less likely to be influenced by such alternative explanations.

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) PRO or firm partners, learning and incoming knowledge are key considerations as well, and there will be tradeoffs between the two (Laursen and Salter, 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 PROs while these induce a risk of spillovers to rivals. Greater insights gained from PRO 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 PRO partner. Not litigating against knowledge leakage involving PROs 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.

CRediT authorship contribution statement

Sarah Edris: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **René Belderbos:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Victor Gilsing:** Conceptualization, Writing – original draft, Writing – review & editing.

Data availability

The authors do not have permission to share data.

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Appendix. firms in the sample and their merged units

Company	Home	Focal/Rival	Company (continued)	Home (continued)	Focal/Rival (contrinued)
.Abbott Labs	.US	Focal/Rival	.Hoffman-La Roche	.CH	Focal/Rival
… St Jude Medical	… US	Rival	… Chugai	… JP	Rival
.Abbvie inc.	.US	Rival	.Syngenta	.CH	Rival
.Amgen	.US	Focal/Rival	.Bayer	.DE	Rival
.Biogen	.US	Focal/Rival	… Monsanto	… US	Rival
.Bristol-Myers-Squibb	.US	Focal/Rival	… Schering AG	… DE	Focal/Rival
.Celgene corp.	.US	Focal/Rival	.C.H. Boehringer Sohn AG&Co.	.DE	Rival
.Eli Lilly	.US	Focal/Rival	… Boehringer Ingelheim	… DE	Rival
.Gilead Sciences	.US	Focal/Rival	… Dr. Karl Thomae GmbH	… DE	Rival
.Immunomedics	.US	Focal/Rival	.Merck Group	.DE	Focal/Rival
.Incyte	.US	Focal/Rival	.Gruenenthal Gmbh	.DE	Focal/Rival
.Ionis	.US	Focal/Rival	.Novo Nordisk	.DK	Focal/Rival
.Johnson & Johnson	.US	Focal/Rival	.Novozymes	.DK	Focal/Rival
… Janssen	… BE	Focal/Rival	.AkzoNobel	.NL	Rival
.Merck & Co.	.US	Focal/Rival	… Imperial Chemical Industries	… UK	Rival
… Schering-Plough	… US	Focal/Rival	.Astellas	.JP	Focal/Rival
.Pfizer	.US	Focal/Rival	… Fujisawa	… JP	Focal/Rival
… Pharmacia AB	… SE	Focal/Rival	… Yamanouchi	… JP	Focal/Rival
… Upjohn	… US	Rival	.Eisai co.	.JP	Focal/Rival
… Warner-Lambert	… US	Rival	.Ono	.JP	Focal/Rival
… Wyeth	… US	Focal/Rival	.Otsuka	.JP	Focal/Rival
… G.D. Searle	… US	Rival	.Daiichi Sankyo Co. Ltd.	.JP	Focal/Rival
.Promega	.US	Focal/Rival	… Daiichi	… JP	Focal/Rival
.Regeneron	.US	Focal/Rival	… Sankyo company	… JP	Focal/Rival
.Rigel	.US	Focal/Rival	.Shionogi	.JP	Focal/Rival
.Vertex	.US	Focal/Rival	.Takeda Chemical Industries	.JP	Focal/Rival
.Valeant	.CA	Focal/Rival	… Millennium	… JP	Focal/Rival
.AstraZeneca	.UK	Focal/Rival	.Teva	.IL	Focal/Rival
… Astra	… UK	Focal/Rival			
… Zeneca	… SE	Focal/Rival			
.GlaxoSmithKline	.UK	Focal/Rival			
… Glaxo	… UK	Focal/Rival			
… SmithKline	… UK	Focal/Rival			
… Burroughs Wellcome	… UK	Rival			
… Beecham	… UK	Rival			
… Chiron	… US	Rival			
.Reckitt Benckiser	.UK	Rival			
.Allergan	.IE	Focal/Rival			
.Perrigo	.IE	Focal/Rival			
.Sanofi-Aventis	.FR	Focal/Rival			
… Sanofi	… FR	Focal/Rival			
… Aventis	… FR	Focal/Rival			
… Hoechst-Rhone	… DE/FR	Rival			
… Hoechst	… DE	Rival			
… Rhone Poulenc	… FE	Rival			
.Novartis	.CH	Focal/Rival			
… Ciba-Geigy	… CH	Focal/Rival			
… Sandoz	… CH	Focal/Rival			

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