TITLE: The evolution of cooperation in the face of conflict: Evidence from the innovation ecosystem for mobile telecom standards development

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ABSTRACT

***Research summary*:** How does interfirm cooperation in innovation ecosystems evolve in the face of conflict? We theorize that conflict propels firms to reconfigure cooperative relationships while maintaining and even increasing cooperation with aggressors because cooperation is the primary mechanism for value creation in such ecosystems. To empirically test our arguments, we study patent litigation and subsequent cooperation between mobile telecommunications firms within the 3GPP standards development organization. We find evidence of a dual cooperative strategy in the face of conflict: while cooperation increases between litigants, defendants also enhance cooperation with others to steer standards away from aggressors. We also highlight the contingent roles of technological complementarities and relational position underpinning cooperation after conflict. Our findings demonstrate that in innovation ecosystems, cooperation with adversaries persists despite conflict.

***Managerial summary*:** Firms in innovation-driven industries cooperate to develop interoperability standards and compatible technologies. Yet, cooperative firms may disagree about what constitutes fair, reasonable, and non-discriminatory terms for licensing intellectual property. Thus, conflict and patent litigation arise even as firms cooperate to build technologies and industry standards. We find that in innovation ecosystems, firms commonly increase cooperative efforts in response to conflict. Well-connected firms with a set of valuable complementary technologies are better positioned to address conflict than unconnected firms dependent on few cooperative partners. We suggest that defendant firms' managers can adopt a dual cooperative strategy: a) identify private and shared benefits from the joint development of complementary technologies with aggressors and b) invest in alternative technological partnerships to influence the direction of future standards development.

1 | INTRODUCTION

On August 13, 2020, Epic Games sued Apple and Google for anticompetitive behavior related to their mobile platforms. Epic Games had recently encouraged mobile players of its hugely popular Fortnite game to buy their in-game virtual goods directly from Epic's website, by-passing the mobile platforms and their payment systems that automatically result in a 30 percent commission for Apple and Google. Apple and Google, unsurprisingly, threw Fortnite out of their application stores as such off-platform sales are against their platform rules. The next day, Epic Games filed a thoroughly prepared 60-page document arguing the case for antitrust enforcement. How will the relationship of these long-time collaborators evolve going forward? Fortnite could be permanently blocked out of Apple's mobile devices. Alternatively, by lowering its platform commission for Epic Games, Apple and Google could potentially need to renegotiate fees with every major game developer, leading to a huge loss of revenue. Thus, for all parties, billions of dollars are at stake if they find no cooperative solution. We argue that there is a good chance that the parties will find a cooperative arrangement that allows Fortnite back into the application market and even expands the innovation opportunities for Epic Games on mobile platforms. We empirically test our arguments with data from a major standards-development organization.

As the foregoing example illustrates, innovating firms are often bound together in meta-organizations (Gulati, Puranam, & Tushman, 2012) involving cooperative activities for technological products (Adner & Kapoor, 2010; Jacobides, Knudsen, & Augier, 2006) and standards development (Farrell & Saloner, 1988; Rysman & Simcoe, 2008; Rosenkopf, Metiu and George, 2001). Although cooperation within such innovation ecosystems enables mutual gains through joint value creation, firms also face intense rivalry and tension over value appropriation (Casadesus-Masanell & Yoffie, 2007; Ansari, Garud, & Kumaraswamy, 2016; Ranganathan, Ghosh, & Rosenkopf, 2018). At times, firms' ecosystem interactions devolve into outright conflict, which can result in litigation (Somaya, 2003; Simcoe, Graham & Feldman, 2009). Yet, innovation ecosystems thrive on cooperation. In fact, many rapidly evolving ecosystems display both ample conflict and surprising amounts of cooperation. However, little is known about the impact of conflict on subsequent cooperation within innovation ecosystems.

In this study, we explore when interdependent firms in innovation ecosystems sustain cooperation in the face of conflict with rivals and complementors. In particular, we examine the cooperative development of technology when firms also engage in legal conflict. Our model of cooperation is informed by the prisoner's dilemma in evolutionary game theory (Axelrod & Hamilton, 1981; Axelrod, 1984) and distinguishes among public, private, and club benefits from cooperation (Buchanan, 1965; Ostrom, 2000). In repeated prisoner's dilemma games, it is in the long-term interest of adversaries that are likely to interact in the future to cooperate (Rapoport & Chammah, 1965), but cooperation can break down if the short-term benefits of defection exceed the discounted long-term benefits of cooperation (Axelrod, 1984). Based on these principles, we theorize about the impact of patent litigation—which reflects disagreements between firms about the value of the underlying technology—on subsequent cooperation, and we examine contingencies for such cooperation to prevail. We argue that technological and relational interdependence within an innovation ecosystem constrains strategic actions, making it costly to sever cooperation. As a result, the greater the expectation of future private and club benefits from cooperation, the more firms will sustain cooperation even after conflict.

Empirically, we document how patent litigation propels firms to reexamine their technical cooperation and how this type of litigation also affects cooperation by firms not directly involved in the lawsuit. We find that the defendants and plaintiffs of patent lawsuits typically increase their cooperation in specific technical areas following litigation filings related to those technical areas. Furthermore, when firms are more technologically distant, they can create mutually beneficial club benefits and increase their cooperation after conflict. In contrast, defendant firms that have abundant outside options for developing other technologies owing to their central position in the relational network do not increase their cooperation. Defendants also expand cooperation among themselves and with other parties unrelated to the conflict, suggesting an attempt to steer the standards development away from the technologies controlled by the plaintiff to attenuate interdependence and the risk of future conflict.

The innovation ecosystem we study is the standards development organization (SDO) called 3GPP, the Third Generation Partnership Project. It is recognized for developing global mobile telecom standards. Firms participate in SDOs like 3GPP to develop shared interoperable platform technologies and to increase the adoption of their own technological innovations (cf. Farrell & Saloner, 1988; Rysman & Simcoe, 2008; Bar & Leiponen, 2014; Vasudeva, Alexander & Jones, 2015). Cooperation between firms occurs because private benefits, such as capturing value by licensing standard essential patents, depend on the collective decisions concerning which technical features are included in the standards (Farrell & Simcoe, 2012). Some of the collaborative activities create club benefits in the form of complementary features that allow contributing firms to exclude others while enhancing their own market positions.

Many of the participating firms possess standard-essential patents (SEPs) upon which technical contributions are based. Legal conflicts arise when firms that own SEPs believe that other firms have failed to obtain the needed licenses or compensate them appropriately, thus infringing on their intellectual property (IP) (Layne-Farrar, Padilla, & Schmalensee, 2007; Simcoe et al., 2009). Alternatively, licensee firms may file lawsuits if they believe that the licensing arrangements are too onerous, violating the 3GPP norm that licensing terms be fair, reasonable, and non-discriminatory (FRAND). Such disagreements reveal the evolving “strategic stakes” for the concerned parties: the technologies embodied in SEPs are valuable to both the patent holders and those who use them for their own products and innovation (Somaya, 2003).

Conflict manifested in litigation can make continued technical cooperation between firms difficult (Lanjouw & Schankerman, 2001; Shane & Somaya, 2007; Sytch & Tatarynowicz, 2014). Yet, as our findings show, cooperation rather than defection can emerge as the optimal strategy between adversaries engaged in repeated interactions (Schelling, 1960; Axelrod & Hamilton, 1981; Axelrod, 1984; Hirshleifer, 1991) in innovation ecosystems.

Our study makes three main contributions to the literature on the evolution of cooperation in innovation ecosystems. First, our study identifies how interfirm cooperation changes due to conflict between ecosystem members. We propose that cooperation between parties is driven by the expectation of future private benefits and, in particular, club benefits that arise from complementarities between the contributors (Jacobides, Cennamo, & Gawer, 2018; Rothaermel & Boeker, 2012; Teece, 2018). Thus, distinct from static accounts of cooperation in strategic alliances (e.g., Parkhe, 1993; Khanna, Gulati, & Nohria, 1998; Arslan, 2018), our framework takes an evolutionary approach to model technological conflict and cooperation over time. In our study, litigation captures conflict over existing SEPs and related technologies, whereas cooperation in standards development influences how the technology will evolve in the future.

Second, we present conditions under which the affected firms are likely to increase or decrease cooperation with the aggressor. We highlight two contingencies—technological distance and relational position—that can alter the expectation of future payoffs under repeated interactions (cf. Ranganathan et al., 2018). In particular, within our tight-knit innovation ecosystem, technological distance creates conditions for technological complementarities and lower competitive pressure, enhancing potential club benefits from cooperation. A relationally central position, in contrast, lowers the cost of defection because it enhances the defendant's alternatives for cooperative development. Our theoretical framework sharpens our view of the mechanisms driving the impact of conflict on subsequent cooperation.

Third, while we are interested in observing cooperation between adversaries, the larger strategy question we address is how conflict between two parties triggers broader shifts in cooperative activity within the innovation ecosystem (Paik & Zhu, 2016). We find that defendants adopt a dual cooperative strategy which entails cooperation with the aggressor to build complementarities, while also forming new ties with other participants to potentially maneuver the technological development away from the aggressor.

Finally, our study is empirically novel because we are able to isolate instances of conflict using SEP litigation and tightly link these events to cooperative activities developing related technologies within 3GPP. We identify SEP lawsuits directly related to the technical specifications under development in a specific committee and observe the pattern of cooperation before and after the initiation of the lawsuit. These patterns include not only the plaintiff and the defendant but also those indirectly affected through the cooperative efforts of the defendant. Such a methodological approach that investigates how the litigation action of one firm affects the cooperative outcomes of the broader co-creation network is important for understanding the dynamic interplay of conflict and cooperation in innovation ecosystems.

2 | THEORY AND HYPOTHESES

2.1 | Cooperation between litigants

Cooperative activities generate three types of benefits for firms participating in innovation ecosystems: public benefits, club benefits, and private benefits (Parkhe, 1993; Khanna et al., 1998; Vasudeva & Teegen, 2011; Arslan, 2018; Vasudeva, Leiponen, & Jones, 2020). Public benefits accrue to everyone in the industry, independent of their contributions to the shared platform. For example, any firm in the industry could adopt and apply the 3GPP technical specifications for mobile telecommunications. Club benefits (Buchanan, 1965; Olson, 1965) are available to a subgroup of firms that pool their technologies to create mutually complementary products and services. The profits from these innovations are shared with partners that contribute to commercializing the technologies. Private benefits are claimed by an individual technology holder. They might include royalty income from licensing SEPs and first-mover advantages in subsequent product markets. Private benefits and club benefits are obtained only when firms contribute to technology development because these contributions enable firms to shape the technological system in a direction that favors their own technology and market positions.

If firms cease to cooperate after conflict, they will only obtain public benefits subsequently, which could be an appealing option so long as the private and club benefits from cooperation are relatively small, and the costs of cooperation are high. Thus, the structure of the benefits and costs of cooperation is akin to a prisoner's dilemma scenario in which it is optimal for the participants to cooperate in repeated games. However, participants in such situations individually choose their actions based on expected profits and may or may not choose to cooperate (Axelrod, 1984). We illustrate these payoffs from cooperation when patent litigation conflict occurs with a prisoner's dilemma framework in an online appendix.

Patent litigation implies that the technology remains a critical strategic resource for the patent holders and defendants (Somaya, 2003; Ziedonis, 2004). As Lerner and Tirole (2015) note, *ex ante*—before adoption in a standard—technology owners may be willing to accept lower royalty arrangements to ensure that their technologies are incorporated, but *ex post* they have an incentive to exploit their expanded market power and increase their royalty rates. Yet, defendants would not infringe on the disputed technology and incur the costs of litigation if the expected returns from developing alternatives were higher than the expected returns from navigating current technological trajectory. Consequently, ceasing to license from the patent holder becomes an unappealing option, especially when the patented technology is essential for the standard. In such instances, we argue that a licensee will reconfigure its cooperative strategies to manage its technological dependence on the patent holder.

If the defendant must pay a higher licensing fee to implement the standards, then the higher fee will be required whether or not the defendant cooperates with the patent holder in further standards development. Since the defendant must pay higher royalties anyway, the firm might seek to appropriate more benefit from the disputed technology. We suggest that once a defendant is committed to the set of technologies covered by essential patents, it becomes lucrative for them to develop complementary technological features that enhance club benefits for both parties, as shown in the asymmetric prisoner's dilemma model[1] in the online appendix.

Apart from the club benefits, a cooperative approach may also confer private benefits on the defendant by allowing the firm to convert a one-way dependence on the plaintiff's technology to a two-way interdependence (Jacobides et al., 2018), such that the plaintiff also needs the defendant's technology in future generations of the product. When technological features are complementary (cf. Milgrom & Roberts, 1990; Topkis, 1998), one feature's increasing value enhances the returns to improving the other features (Gandal, Kende, & Rob,

[1] A prisoner's dilemma is symmetric if both parties receive the same payoffs for the same potential outcomes and is asymmetric if the payoffs differ.

2000). Such co-specialization fosters mutual forbearance and reduces the possibility of future hold-up since both parties become mutually dependent on each other's technological resources (Somaya, 2003; Ziedonis, 2004; Teece, 2018).

Cooperation also generates private and club benefits for the patent holder. As noted above, club benefits accrue from two-way complementarities. Private benefits accrue because cooperation prevents the defendant from entering into a "patent race" (Fudenberg, Gilbert, Stiglitz, & Tirole, 1983), thereby safeguarding the stream of licensing revenues. Building on the logic for managing relational conflict in repeated exchange settings (e.g., Li & Matouschek, 2013), the patent holder may even entice the defendant with particularly appealing cooperative projects to continue to cooperate and further enhance the value of the technological platform. Thus, the patent holder may alleviate conflict by offering compelling cooperative initiatives.

To summarize, cooperation may become the rational optimal response by firms that experience conflict over IP. They may see more benefits than costs in jointly developing further enhancements of the contested technology. If the underlying technologies hold strategic importance in the innovation ecosystem due to widespread adoption, technology users may look for opportunities to build complementary gains. Moreover, the patent holder will attempt to ensure continued use and licensing of the technology through cooperation. We thus hypothesize that SEP litigation sustains or increases subsequent cooperation between the litigating parties.

Hypothesis 1. *After a patent litigation event, a plaintiff and defendant will,* ceteris paribus, *sustain or increase cooperation related to the patented technology in an SDO.*

Consistent with the evolutionary perspective on cooperation (Axelrod, 1984), Hypothesis 1 implies that cooperation is likely to emerge when conflicting parties are bound together within a common technological space, such that the expectation of continuing interactions amplifies the importance of the future relative to the present. Two corollaries emerge. First, parties should cooperate more readily when they expect to create value in the future, not only through private benefits from potential technology licensing, but also through joint creation of complementarities resulting in club benefits. Second, there should be few outside options for the defendant, which increases the frequency of its interactions with the aggressor and fosters mutual dependence. Accordingly, in the hypotheses that follow, we develop arguments for two contingencies for cooperation to emerge: the technological distance between the plaintiff and defendant in the innovation ecosystem, and the defendant's relational position in the ecosystem network.

2.2 | The contingent role of technological distance between litigants

The preceding hypothesis assumes that conflicting firms can build technological complementarities. However, the firms' characteristics may make them more or less suited to do so, which will likely influence the cooperative response. If two firms are positioned for complementary technology development, then investments by one firm will enhance the returns for the other firm if it develops related technologies.

Building on Dussauge, Garrette, and Mitchell (2000), for firms to develop complementary resources and capabilities their resource endowments must differ and they must make distinct but related contributions to the standard. Accordingly, we expect that firms that are technologically more distant—that is, distinct in terms of their technology portfolios—are likely to be stronger complementors because they can combine their technologies to create mutually beneficial innovative features (Bar & Leiponen, 2014; Fleming, 2001). Such technological co-dependence reduces the threat of holdup (Oxley, 1997; Pisano, 1989).

In contrast, the potential for joint value creation is lower for firm dyads with a low technological distance. Firms that are very similar in terms of their technological portfolios perceive few opportunities for novel combinations. Although a minimal level of technological overlap that provides “absorptive capacity” is helpful for cooperation (cf. Mowery, Oxley, & Silverman, 1996; Diestre & Rajagopalan, 2012), a very high overlap (low technological distance) can prevent novel recombinations. In our context of study, since firms select into highly focused technology development groups, we do not expect absorptive capacity to be a major hurdle in the process of technology recombination (Fleming & Sorenson, 2001; Vasudeva & Anand, 2011).

Technologically distant firms are also more likely to cooperate after conflict because they are less likely to engage in direct competition. Because technological capabilities evolve in a gradual and path-dependent manner (Helfat, 1994; Stuart & Podolny, 1996), it is difficult for a technologically distant firm to make a sudden leap into another firm’s technological territory, thereby making knowledge-sharing less threatening. In contrast, firms within the same industry segment with overlapping technological or commercial domains are less likely to cooperate, especially when the potential for the expropriation of IP is high (Dushnitsky & Shaver, 2009). The resulting cooperation between technologically distant firms is akin to what Dussauge et al.

(2000: 104) call "link alliances" that combine complementary skills while allowing for private benefits in the form of licensing. Hence, if conflict signals the strategic value of the contested technology, firms that are technologically distant yet strategically interdependent should respond more cooperatively.

> **Hypothesis 2.** *After a litigation event, subsequent cooperation in an SDO between a plaintiff and a defendant will be amplified by their technological distance.*

2.3 | The contingent role of the defendant's relational position

The evolution of cooperation is determined by the calculation of expected payoffs in the form private and club benefits. These payoffs from cooperation can change depending on the surrounding market structure that determines how likely it is that the adversaries will interact with one another in the future (Axelrod, 1984). In particular, a defendant's relative cooperation payoffs with the plaintiff may depend on its access to other firms in the co-creation network. Conflict may reduce a defendant's continued cooperation with the plaintff when payoffs from developing new features with other firms exceeds those from cooperation with the plaintiff. Defendants with existing cooperative relationships with other firms in the ecosystem are more likely to have such opportunities. Consequently, the defendant's reliance on the plaintiff for mutual gains becomes proportionally smaller. Furthermore, a more central relational position connotes power and repute within the co-creation network (Gulati, 1995), to build a coalition or drive consensus in a direction that counterbalances the power of the plaintiff in standards development (Ranganathan & Rosenkopf, 2014; Ranganathan et al., 2018; Simcoe, 2012).

A more central relational position thus implies that the defendant has alternative co-development relationships as outside options that can overshadow opportunities for value creation from cooperation with the plaintiff. While there are always costs from ending and reconfiguring cooperative arrangements, the costs will be lower when there are already many alternatives to the focal relationship. Thus, the greater the number of outside options, the weaker will be the defendant's incentives to respond cooperatively to the changed technological opportunities vis-à-vis the plaintiff. Therefore, the cooperative response to conflict will become weaker for a defendant with a number of other cooperative ties within the co-creation network.

> **Hypothesis 3.** *After a litigation event, subsequent cooperation between a plaintiff and a defendant in an SDO will be diminished by a defendant's more central relational position.*

2.4 | The defendant's cooperation strategy with other participants

The preceding arguments concerning the advantages of a strong relational position imply that litigation by one party in an innovation ecosystem may propel defendants to expand their cooperation with other parties as a buffer. In our context, a legal challenge by a plaintiff might induce cooperation between co-defendants and between defendants and other parties in the standards development arena. Thus, conflict may alter not only the cooperative dynamics between adversaries, but also influence their actions within the broader ecosystem.

The goal of patent litigation is to appropriate value from a specific technological asset. As the patent holder attempts to appropriate a larger share of the returns to innovation through licensing fees, the defendant may be encouraged to safeguard itself by circumventing the patented technology in question. Accordingly, the defendant may expand its efforts and pursue other cooperative relationships, as illustrated by the symmetric prisoner's dilemma model in the online appendix. Its cooperative efforts with others broaden its opportunities for developing complementary innovations, thus reducing the possibility of getting "fenced in" by the plaintiff (Ziedonis, 2004). The less the defendant depends on the plaintiff's technologies for innovation opportunities, the better its bargaining position with respect to the plaintiff. By building coalitions (Davis, 2016), the defendant could also reduce the possibility of delays and hold-up that can determine success in standards development and in downstream product markets (Farrell & Simcoe, 2012; Ranganathan et al., 2018; Simcoe, 2012). Thus, cooperation among co-defendants or among defendants and other parties may increase following litigation in an effort to move technological standards away from the contested territory.

Consequently, a defendant may adopt a dual strategy: while cooperating more with the plaintiff to appropriate returns from complements to the disputed technology, a defendant may also build stronger cooperative relationships with others to strengthen its relational position or to further differentiate to counteract future contests with the plaintiff.

> **Hypothesis 4a-b.** *Patent litigation will increase subsequent cooperation in an SDO (a) between co-defendants and (b) between defendants and other parties.*

3 | DATA AND METHOD

3.1 | Empirical context

*3GPP technical contributions***.** We examine collaboration among firms in 3GPP, the key SDO in the global mobile telecommunications sector. From 1999 through 2008, 3GPP developed the 3G standard Universal Mobile Telecommunications System (UMTS). It then developed the 4G standard Long-Term Evolution (LTE), with its first release in 2009 (Baron & Gupta, 2018). 3GPP began planning its 5G standard in 2016 (3GPP, 2018). Hundreds of telecom firms such as carriers, handset manufacturers, and chipset manufacturers are 3GPP members. Some actively contribute to standards development, whereas others observe the standards process to keep abreast of new advancements. We focus only on active contributors.

Contributing to standards development involves a substantial cost. Participating firms' standards development efforts are closely connected with their product and innovation strategies, so they bear the risk of revealing their IP strategies (Rosenkopf et al., 2001). They also pay SDO membership fees, allocate engineering time and talent to develop technical solutions, and support the effort of engineers and managers to influence the trajectory of standards development.

Working groups (WGs) in which the majority of standards development takes place roll up into three technical specifications groups (TSGs): Radio-Access Network (RAN) maintains specifications for how mobile phones connect to the wireless network; Core Network and Terminals (CT) maintains specifications for the core network and its interfaces, protocols for mobile phones, and specifications for SIM cards; and Service and System Aspects (SA) maintains specifications for the overall system architecture. Table 1 describes the technical domain, contributors, and litigation activity of each WG.

--- Insert Table 1 about here ---

New specifications begin when WG members propose new features as work items. To address new requirements, members submit technical contributions to the WGs for consideration. These contributions are approved through consensus or voting at WG meetings (Baron & Gupta, 2018). Contributions are submitted by individual firms or groups of firms. Hundreds of contributions are required to create one technical specification, and each WG maintains 30 to 100 technical specifications. In our analysis, we focus on these technical contributions because they are the finest-grained unit that captures technical cooperation between firms. We focus on contributions jointly authored by two or more firms.

*Standard-essential patent licensing and litigation***.** In technical contexts, litigation usually involves a plaintiff enforcing their IP rights that the defendant has arguably infringed. A lawsuit often follows a “cease and desist” letter informing the potential infringer that unless certain behavior (e.g., marketing a product that contains the allegedly infringing technology) is discontinued, it will be sued. This legal challenge initiates a negotiation to discover the basis of the challenge and determines whether the parties can agree to a settlement. A settlement implies that the parties agree on the value and infringement of the underlying IP. However, if the parties disagree, they will go to court. Such situations can arise because a firm has not licensed from a patent holder or because an existing license has expired and the firms could not reach a new licensing agreement. For example, Motorola filed a suit against Research in Motion (RIM) in 2010, claiming that RIM infringed on Motorola’s patents concerning encrypted data packet transfer.[2] The parties settled without going to trial.

[2] Case reference 1:10-cv-00457, Northern Illinois District Court

Patent litigation can also occur when plaintiffs believe defendants are demanding unreasonable and unfair licensing terms. 3GPP requires firms to license patents under FRAND terms. However, the nature of FRAND is loosely defined in SDO bylaws, and the litigants may disagree about the value of the licensed SEPs. For example, Samsung filed a complaint in 2007 against Interdigital alleging anticompetitive licensing of its 3G technology, claiming Interdigital was violating FRAND terms.[3]

In either situation, patent litigation highlights disagreement about the validity and value of IP rights. The payoff to the owners of standard-essential patents is substantial because firms throughout the industry need licenses to make products under the standard. The FRAND licensing terms permit SDOs to set standards while mitigating the threat of hold-up over the proprietary technology. Thus, a member firm trades away its right to refuse licensing to anyone willing to pay FRAND royalties so that its patented technology can be included in the worldwide standard. However, despite that FRAND terms generate broad public benefits as well as private benefits to patent holders, determining the value of the IP can be contentious.

Table 2 lists the 3GPP firms that were most often involved in SEP litigation during the sample period. Most litigation was settled out of court, but some went to trial. A number of suits also spurred countersuits. SEPs being litigated often affected more than one WG because the technology underlying an SEP can touch specifications across WGs.

--- Insert Table 2 about here ---

[3] Case reference 1:07-cv-00167, Delaware District Court

3.2 | Sample

Data sources. Our sample comprises data from four sources. First, our sample of technical contributions was provided by the Searle Center on Law, Regulation, and Economic Growth at Northwestern University (Baron & Spulber, 2018). The Searle Center collected this data from 3GPP.org. Second, we collected a sample of all known SEPs from ETSI.org. The European Telecommunications Standards Institute (ETSI) works closely with 3GPP to publish globally applicable telecommunications standards. Using ETSI, firms declare their patents that they deem essential to specific technical specifications. Third, we collected SEP and non-SEP litigation data between 3GPP firms from Lex Machina, which mines and aggregates litigation data in the U.S. (Most case filings dealing with telecommunications patent disputes are litigated in the U.S.) Fourth, we downloaded patent citation data from Thompson Reuters for declared SEPs and alliance data for firms in our dataset.

The 3GPP contribution data spans from 2005-Q2 through 2012-Q3. This time window covers late contributions to the 3G standard and early to middle contributions to the 4G standard (Release 7 through 11). The contribution data were extracted from contribution documents and included (a) the assigned WG, (b) the submission date to a WG meeting for consideration and approval, and (c) the firms that authored the contribution. For each WG and quarter, we counted the number of documents coauthored by each dyad. The total number of dyadic coauthoring observations was 1.4 million.

We connected 3GPP contributions and SEPs through the technical specification number and firm name published in the ETSI data. Thus, we can link SEPs to specific working groups. Further, we added SEP litigation from Lex Machina using the patent publication number (which matches to SEPs in the ETSI data) and firm names documented in the case filing. Non-SEP litigation was matched by firm name. Finally, we added patent forward-citations from Thompson Reuters using the patent publication number, and matched alliance data collected from SDC Platinum by firm name.

Panel creation. To test our hypotheses, we used a subset of the data. In H1 through H3, we are interested in plaintiff-defendant dyads; in H4, we focus on co-defendant and defendant-other dyads. The plaintiff-defendant and co-defendant dyads include firms named in the litigation. The defendant-other dyads include an ego who was a defendant and an alter who was not party to the case. While other dyad combinations are possible, we focus only on defendant dyads where our arguments and hypotheses are the most apposite. These observations constitute the set of treated dyads. We matched the treated dyads with similar untreated dyads. We detail our matching process in the Model Specification subsection.

Each dyad is observed for nine WG-quarters: four quarters before filing, the filing period, and four quarters after filing. The panel included 287 unique firms; 8,377 unique dyads; 17 quarters with filings; 14 WGs; and 217,296 observations. For H1 through H3, we focused only on plaintiff-defendant dyads, which were a small subset of the panel including 148 unique dyads and 2,304 observations. (Most observations in the panel are defendant-other dyads.)

3.3 | Variables

Dependent variable. Our variable of interest is the number of contribution documents coauthored by a dyad within a quarter. It is calculated as a simple count of documents by a dyad in a given WG at a given quarter. There are different types of contribution documents (Baron & Gupta, 2018); we include technical reports and proposals and discussion documents because they best capture new technical collaborations. They represent the forefront of new standards development and are often produced as technical specifications are emerging. Firms gain value from producing these documents because they establish a technical trajectory for the standards and bolster the value of the IP on which they are built. We omit change request documents because they are primarily backward looking and reflect prior cooperative efforts. Coauthored change requests often represent past rather than new cooperative strategies.

*Independent variables***.** Our independent variables include the litigation filing treatment, dyad type (plaintiff-defendant, co-defendant, and defendant-other), and year pre- and post-filing. Treated dyads are coded as 1; matched untreated observations are coded as 0. Post-filing is set to 1 for quarters +1 to +4; 0 otherwise.

Moderators. The *technological distance* variable was calculated as the Euclidean distance between the dyad members' technological profiles within a WG. A firm's technological profile within a WG was a vector of cumulative document counts. Each vector element held the cumulative number of documents authored by a firm in a technical specification assigned to the WG up to the given quarter. A dyad's technological distance could vary from one WG to another. *Defendant's relational position* was calculated as the defendant's degree centrality within a WG which was calculated as the sum of coauthoring ties with other firms in a WG, excluding the plaintiff. For this measure, a coauthoring tie had a value of 1 if the defendant had coauthored with the firm within the prior year; 0 otherwise. Because control observations do not have litigation attributes, defendant's relational position was not calculated for them. This second moderator only applies to treated observations.

*Control variables***.** We included working group dummies and quarter dummies to account for differences in levels of coauthoring in different technological areas and over time. We included an off-quarter filing control to adjust for multiple treatments over time. For instance, if a dyad was affected by litigation +4 quarters after the focal treatment (because another case was filed), then the dyad off-quarter filing variable was set to 1 at the +4 quarters observation. This isolated the focal treatment from the effect of filings in other observation quarters.

We controlled for attributes of WG dyads. We included third-party closure to account for the constraints third parties imposed on the focal dyads. We calculated it as the geometric mean of coauthoring counts for the prior year for ties between dyad members and a third-party; these means were then summed for all third parties.[4] We included the combined citation-weighted patents within a dyad and the standard deviation of citation-weighted patents to account for the total technological strength of the firms and the difference in their technological strength,

[4] For instance, let A and B be the firms in a focal dyad and let C and D be other firms in the network. If C coauthored 1 document with A in a given WG-quarter and 0 documents with B, then C would not provide third party closure ($\sqrt{0 \cdot 1} = 0$). If D coauthored 9 documents with A and 1 document with B, then closure by D would be $\sqrt{9 \cdot 1} = 3$. The total third-party closure for the A-B dyad would be $0 + 3 = 3$ for the given WG-quarter.

respectively. Citation-weighted patents were calculated as the 5-year forward citations for SEPs associated with the WG and owned by the firms in the dyad. We included a dummy for no authoring by a dyad member, which was coded as 1 if either firm in the dyad had not authored documents in the WG up to the given quarter. This dummy isolated instances of no defined technological distance. Finally, we included the number of alliances between dyad members and the number of non-SEP-related cases where dyad members were co-litigants (i.e., co-defendants or co-plaintiffs) or opposing litigants. These variables account for ways in which interactions outside the context of 3GPP might affect litigation and coauthoring. Note that we observed no publicly reported alliances between plaintiffs and defendants over the observation window, but there were alliances between defendants and other WG members; thus, the effect of alliances only appears in our models that include defendant-other dyads.

We also controlled for attributes of the SEP-related litigation. We included the number of 3GPP firms that were listed as litigants in open cases and the number of SEPs listed in open cases within a WG-quarter. This accounted for changes in the overall level of litigation within a WG. We also included a dummy for whether the litigation was part of a suit-countersuit. A willingness to counter litigation may indicate particular value in the underlying technologies being litigated, which may change the way in which firms respond when litigation is filed.

3.4 | Model Specification

We used a difference-in-differences approach to test our hypotheses. The treatment we observed was a plaintiff filling a lawsuit against defendants' alleged SEPs infringement or unfair licensing terms. This litigation treatment is not purely exogenous to the system because the treatment occurs only after negotiations or other remedies break down. Thus, there can be selection effects into the treatment group. To mitigate this concern, we matched litigating dyads with a comparable set of non-litigating dyads through the quarter in which a suit was filed. We then used the paired treatment and control observations to estimate the effect of SEP litigation on subsequent coauthoring. Because we only included lawsuits containing SEPs (and excluded unrelated suits such as those related to products), we isolated the effect of litigation directly related to standards development. Thus, we can be more confident that the change in cooperation post filing is directly related to the IP conflict.

Our observed response was the coauthoring of dyad d in working group g at filing quarter f and pre- or post-filing t ($t \in \{-4, \dots, 4\}$). To simplify the notation, we represent the combined dgf index simply as index i. We modeled coauthoring between plaintiffs and defendants as a negative binomial distribution with mean and variance, $y_{it} \sim NegBin(\mu_{it}, \mu_{it} + \omega\mu_{it}^2)$, where ω is the dispersion parameter that allows the variance to be greater than the mean. We used a negative binomial model instead of a linear or Poisson model because our response was a non-negative count variable with over-dispersion. The mean μ_{it} was modeled as:

$$\ln \mu_{it} = \alpha_q + \beta_1 L_i + \beta_2 D_{it} + X_{it}\theta + \varepsilon_{it},$$

where: α_q are year-quarter dummies, β_1 estimates the difference in coauthoring between treated and untreated dyads ($L_i = 1$ when i is a treated dyad); β_2 estimates the coauthoring difference-in-differences ($D_{it} = 1$ when i is a treated dyad and $t > 0$); θ is a column vector of parameter estimates for the control variables in row vector X_{it} (including dummy variables for working group); and ε_{it} is the error term.

Unlike a linear model where each term is added to the model, the terms in a negative binomial model enter multiplicatively. This can be seen when we exponentiate the function:

$$\mu_{it} = e^{\alpha_q} \cdot e^{\beta_1 L_i} \cdot e^{\beta_2 D_{it}} \cdot e^{\boldsymbol{X}_{it}\boldsymbol{\theta}} \cdot e^{\varepsilon_{it}}.$$

For a model such as ours, the average treatment effect of the treated (ATT) would normally be the statistic of interest. The ATT would be appropriate if the average was indicative of the treatment effect across the various dyads. However, the level of participation in coauthoring across the sample of dyads varies widely, and it is likely that the treatment effect will differ based on the level of participation. More-active firms will experience a larger effect of litigation, whereas less-active firms will experience a smaller effect of litigation. Thus, we focus on the average treatment *rate* on the treated instead of the average absolute effect on the treated. The rate estimate better reflects the effect of the treatment than the absolute value because of the heterogeneous activity in the sample. Assuming a constant rate for the sample allows less-active firms to have smaller absolute treatments and more-active firms to have greater absolute treatments. We define the average treatment rate for the treated (τ) as:

$$\tau = \frac{E\left[Y^1 \middle| D_{it} = 1, L_i = 1, X\right]}{E\left[Y^0 \middle| D_{it} = 1, L_i = 1, X\right]},$$

where Y^1 and Y^0 are the potential outcomes with and without the treatment, respectively. The average treatment rate for the treated is estimated as e^{β_2}.[5]

*Causal inference***.** Our interest is the effect of a litigation filing (the treatment) on a dyad's subsequent coauthoring. Accurately estimating the causal effect is complicated by the observational nature and complexity of the data. First, litigating dyads are not independent of other dyads, and the effect of litigation may spill over within the network. We addressed the problem of non-independent treatments by explicitly modeling the dyad types of interest affected by litigation and by removing other dyad types from the treatment group. Specifically, we demarcate plaintiff-defendant, co-defendant, and defendant-other dyads as treated observations. Other dyads within the network for a given WG-quarter that could be affected by the treatment were excluded from estimation.

Second, litigants are not randomly distributed within the sample. It is often the more active participants in a WG who contribute frequently that are litigants. Furthermore, there may be time-variant reasons for plaintiffs to both litigate and co-author with defendants. We

[5] When a litigating dyad is treated, then $E[Y^1|D_{it} = 1, L_i = 1, X] = e^{\alpha_q} \cdot e^{\beta_1} \cdot e^{\beta_2} \cdot e^{\boldsymbol{X}_{it}\boldsymbol{\theta}}$; counterfactually, if a litigating dyad were not treated, then $E[Y^0|D_{it} = 1, L_i = 1, X] = e^{\alpha_q} \cdot e^{\beta_1} \cdot e^{\boldsymbol{X}_{it}\boldsymbol{\theta}}$. Thus, the average treatment rate on the treated is simply e raised to the β_2 power: $\tau = \frac{e^{\alpha_q} \cdot e^{\beta_1} \cdot e^{\beta_2} \cdot e^{\boldsymbol{X}_{it}\boldsymbol{\theta}}}{e^{\alpha_q} \cdot e^{\beta_1} \cdot e^{\boldsymbol{X}_{it}\boldsymbol{\theta}}} = e^{\beta_2}$. When the moderators (technological distance and relational position) are added to the model, the treatment rate is multiplied by $e^{M_1\beta_3} \cdot e^{M_2\beta_4}$, where M_1 and M_2 are the values of two moderators and β_3 and β_4 are the parameters for the M_1D_{it} and M_2D_{it} interactions, respectively. The moderators possess only nonnegative values. Thus, when M_1 is zero the treatment rate is $e^{\beta_2} \cdot e^{M_2\beta_4}$, holding M_2 constant; when M_1 is greater than zero, then the treatment rate is $e^{\beta_2} \cdot e^{M_1\beta_3} \cdot e^{M_2\beta_4}$ (again holding M_2 constant), such that the treatment rate will rise or fall depending on whether β_3 is positive or negative, respectively. The effect of M_2 is similarly calculated, holding M_1 constant.

addressed the problem of sample selection using a matching procedure. We chose a matching procedure over a two-step selection model because we have many informative covariates but lack an appropriate instrument. The matching procedure allowed us to match treated dyads with untreated dyads that were similar on observable characteristics. The standard assumption for a matching model such as ours is that the treatment assignment is independent of the potential outcome given the observable covariates (Stuart, 2010).

We matched exactly the quarter in which the litigation occurred and then used nearest neighbor matching. We chose nearest neighbor matching because it is easy to understand and execute, supports exact matching, and has been shown to be effective among alternatives choices (Austin, 2014). We used the shortest Mahalanobis distance to find comparable observations. We chose Mahalanobis distance matching because it is shown to approximate a fully blocked experimental design (Iacus, King, and Porro, 2011) and recent work has questioned the effectiveness of propensity score matching (King and Nielsen, 2019). We matched without replacement and selected one untreated observation for every treated observation. The pool of untreated observations included dyads that were untreated and were in untreated WG-quarters. We excluded all dyads within a treated WG-quarter and firm pairs in untreated WGs that were treated in a different WG. We excluded these observations from the untreated pool because spillovers could affect such dyads, making them undesirable matches. For purposes of matching, the pre-treatment period was the four quarters prior to a filing and the filing quarter.

We used the following covariates in the matching procedure: pre-treatment coauthoring in each of the 5 quarters; third-party closure (calculated based on the pretreatment period); dyad members' combined citation-weighted patents; standard deviation of citation-weighted patents; technological distance; no authoring by a dyad member; number of alliances between dyad members; number of non-SEP-related cases where dyad members were co-litigants; and the number of non-SEP-related cases where dyad members were opposing litigants. Other control variables were not included because they only applied to treated dyads (e.g., litigation attributes).

24,783 treated dyads were matched to dyads in a pool of 739,121 untreated observations. Diagnostics showed that the standardized difference (Stuart, 2010) between treated and untreated observations improved (i.e., decreased) due to matching. The standardized difference (a heuristic for matching sufficiency) for all matched attributes was less than 0.25. Thus, the matching procedure substantially improved the similarity of the non-litigation dyads to the litigation dyads.

3.5 | Descriptive Analysis

To understand why firms litigated and coauthored, we conducted preliminary descriptive analysis by aggregating the data to the WG-firm-quarter level (32,550 observations with 287 unique firms). We used logit models to predict (a) the odds of suing another firm in the WG, (b) the odds of being sued by a WG firm, and (c) the odds of coauthoring with another firm. We examined attributes of firms and WGs in quarter t to predict the response variables in $t + 1$.

The litigation analysis revealed that firms were more likely to file a lawsuit (i.e., be a plaintiff) if they owned substantial IP related to the WG and if they were already plaintiffs in non-SEP-related suits. On average, a firm's odds of filing a lawsuit increased 15 percent for every one thousand citations to the firm's WG-related patents. (Firms with patents averaged 1,742 citations in a WG.) Additionally, a firm's odds of filing increased 4 percent for every additional non-SEP-related suit in which they were a plaintiff. (Firms averaged 2 suits.) This suggests that firms are apt to assert IP rights if they own substantial IP and have a capability to employ litigation as a means of assertion.

The two predictors also predicted a firm's likelihood of being sued (i.e., being a defendant). This is not surprising with the substantial number of countersuits within this context. However, firms were less likely to be sued if they had a higher percentage of their technical activity in the WG or if the overall number of SEPs being litigated in a WG increased. On average, the odds of being sued *decreased* 10 percent with a 10 percent rise in a firm's share of its total contributions belonging to the WG. (Firms averaged 11% of their total contributions in a given WG.) This may suggest a liability of newness: firms that are building out their contributions in a WG may become targets of litigation. Additionally, the odds of being sued *decreased* 6 percent for every additional SEP being litigated in the WG. (WGs averaged 5 SEPs being litigated per quarter.) This suggests that firms in a WG may become more cautious after SEPs become entangled in litigation.

The coauthoring analysis revealed that firms were more likely to coauthor with other firms in a WG if they owned IP in the WG, if a larger percentage of their technical activity was in the WG, and if they had a history of coauthoring and a more central relational position. On average, the odds of a firm coauthoring increased 33 percent for every one thousand patent citations. The odds increased 6 percent with a 10 percent rise in a firm's share of its total contributions belonging to the WG. The odds increased 19 percent for every 100 additional cumulative documents. (Firms averaged 86 cumulative documents.) And the odds increased 16 percent for each additional coauthoring partner (i.e., expansion of relational position; firms averaged 5 partners). Overall, the coauthoring analysis suggests that activity in the WG—whether measured by cumulative documents, relational position, IP, or firms' share of technical activity—is related to higher coauthoring. Interestingly, IP was related to litigation and coauthoring; however, cumulative coauthoring and relational position were not related to litigation, and firms' share of technical activity in the WG was related in the opposite direction. This suggests litigation and coauthoring have different underlying drivers, although both are connected to the presence of IP.

Note, this analysis is merely descriptive and intended to elucidate the data we examine. We also present descriptive statistics—means, standard deviations, and correlations—in Table 3.

--- Insert Table 3 about here ---

4 | RESULTS

Figure 1 illustrates the difference-in-differences effect for litigating dyads. The solid lines depict the quarter-to-quarter coauthoring for litigating and matched non-litigating dyads. The dashed lines depict the average coauthoring pre- and post-filing for these same dyads. An inspection of the pre-filing trends in the figure suggests they do not violate the parallel trends assumption.

Further, we tested whether the level of coauthoring for any pre-filing quarters differed. The t-values ranged from −0.95 to 1.50, suggesting that the parallel trends assumption was appropriate. Figure 1 shows that after a litigation event, coauthoring in non-litigating dyads fell slightly while coauthoring in litigating dyads increased substantially. Thus, consonant with H1, Figure 1 suggests that filings had a positive effect on coauthoring between defendants and plaintiffs.

--- Figure 1 about here ---

The models in Table 4 test the differences illustrated in Figure 1. Model 1 presents a simple difference-in-differences model with no controls. The results show that a case filing increased coauthoring between defendants and plaintiffs, which supports H1. The average treatment rate for the litigating dyads was 3.1 (β_2 = 1.12; p = .001); that is, the average rate of coauthoring increased three-fold after a case filing. Model 2 adds the controls, which adjusts the treatment rate lower to 2.1 (β_2 = 0.72; p = .01). Prior to litigation, a defendant and plaintiff averaged about one document per year. The treatment rate in Model 2 indicates that litigation increased coauthoring to about two documents per year, on average.

--- Insert Table 4 about here ---

The moderating effect of technological distance and relational position is presented in Model 3 and illustrated in Figure 2. Dyads with greater technological distance increased coauthoring more after a filing than those that were less distant (β_2 = 1.97; p = 0.002), which supports H2. Panel A in Figure 2 illustrates the predicted mean response and the lower bound of the 95% confidence interval, which was calculated using nonparametric paired (treatment with control) bootstrapping with 10,000 iterations. When technological distance was low (M_1 = 0.00) and defendant relational position was held constant (M_2 = 14), the average treatment rate was 2.2; when technological distance was high (M_1 = 0.30), the treatment rate rose to 4.1. Thus, the coauthoring response to litigation increased with greater technological distance. When technological distance was greater than 0.07, the lower bound of the 95% confidence interval was above 1. (Coauthoring increases post-filing when the rate is above 1.)

--- Insert Figure 2 about here ---

When the defendant's relational position was on the periphery of the network (meaning the defendant coauthored with few other firms), then the defendant coauthored more with the plaintiff post-filing. Plaintiff-defendant coauthoring post-filing decreased when a defendant was more central (β_4 = −.05, p = .002), which supports H3. Panel B in Figure 2 illustrates the predicted response. When relational position was low (M_2 = 0) and technological distance was held constant (M_1 = 0.14), then the treatment rate was 5.5; when relational position was high (M_2 = 30), then the treatment rate dropped precipitously to 1.4. Thus, the coauthoring response for defendants with many other coauthoring ties was lower.

The treatment rate for plaintiff-defendant, co-defendant, and defendant-other dyads was estimated by Model 4. The average treatment rate for plaintiff-defendant dyads was 3.7 (est. = 1.31, p < .001), which was somewhat higher than the Model 2 estimate. The average treatment rate was 2.1 for co-defendant dyads (est. = 0.73, p = .001) and 2.5 for defendant-other dyads (est. = 0.91, p < .001), which supports H4a and H4b. Co-defendants averaged about two coauthored documents per year prior to a case filing; a filing increased coauthoring with another defendant to about four documents per year, on average. A defendant coauthored an average of just less than one document per year with another member of the working group prior to a case filing; a filing increased coauthoring to two to three documents per year. On average, a defendant would coauthor with 75 other WG members. By multiplying the dyadic annual average pre-filing rate by the average number of defendant-other dyads, we found that a defendant was, on average, co-authoring about 70 documents per year pre-filing and 175 documents per year post-filing.

The average treatment rates did not differ for the three types of dyads. In Model 4, the estimated rate for defendant-plaintiff dyads was greater than the rate for defendant-other dyads, which was greater than the rate for co-defendant dyads. However, a likelihood ratio test revealed that the coefficients did not differ statistically ($\chi^2 = 2.90$; d.f. = 2; $p = 0.23$).

4.1 | Supplemental analyses

Learning as a competing argument. One competing argument posits that learning opportunities may cause increased cooperation after litigation. According to this argument, the dispute arises because the litigants lack understanding of one another, which would compel them to cooperate to learn more about one another, and hence improve the process of standard development in the working group. In this scenario, litigants without a history of cooperation should cooperate more after a conflict event than litigants with a history of cooperation. To test this possibility, we reran Model 2 with the cumulative count of coauthored documents (which captures repeated cooperation) as a moderator. If the coefficient for the moderation effect was negative, then it would support this argument. However, the cumulative count moderation was positive (est. = 0.03; $p = 0.28$). This is counter to what we would expect if learning was driving the results.

Identification and threats to exogeneity. To account for the non-randomness of the litigation treatment, we used a difference-in-differences approach with a matching procedure and various controls as described above. However, there may still be time-varying unobserved characteristics that affect litigation and coauthoring. (Such characteristics are more likely to bias the plaintiff-defendant dyads than the defendant-other dyads because the "other" firms are not party to the conflict that culminates in a lawsuit.) In searching for a valid instrument, we discovered two U.S. Supreme Court cases[6] within our time window that would likely affect the propensity to litigate but not co-authorship. However, when we used the court cases as instruments, we found that they only weakly predicted litigation. We did not use them because weak instruments could lead to a more severe bias.

To address the concern of bias, we turned to proxies that could account for the most likely and problematic unobserved confounder. Our primary concern in the context of 3GPP is that a change in the value of the technology within the WG (which we do not observe) could lead to litigation as well as greater cooperation. In this scenario, not accounting for a change in value could lead to overstatement of the effect of litigation. To account for this possibility, we constructed two proxies that captured the change in value of the underlying IP. First, we calculated the total number of documents authored within a WG-quarter. This not only included

[6] KSR International Co. v. Teleflex Inc., 2007, and Ebay v. MercExchange, 2006.

technical reports and discussion documents, but all types of contributions and change requests. We use this as a proxy because authoring of all types is apt to increase if the value of IP is increasing. Moreover, an increase in value is likely to attract new firms to the WG. Thus, we created a count of new firms entering each WG. We reran model 2 with the proxies. Both total WG authoring (β = 0.06; p = .02) and new entrants (β = 0.12; p = .003) positively predicted coauthoring. Still, the litigation effect remained consistent: β_2 in the model with the proxies was 0.76 vs. 0.72 originally. These results enhanced confidence in our models.

The role of plaintiff attributes. A defendant's reaction to litigation within the plaintiff-defendant dyad may not only be based on the attributes of the defendant (e.g., relational position) or the dyad (e.g., technological distance), but also on the attributes of the plaintiff. It is plausible that coauthoring after litigation is more likely when a plaintiff has greater IP to protect and a stronger litigation capability, which could make the club benefits more appealing to the defendant. To explore this possibility, we considered the moderating effects of: (a) a plaintiff's IP, measured as the plaintiff's citation-weighted patents, and (b) its litigating ability, proxied by the number of non-SEP-related cases initiated by the plaintiff. We added these moderators to Model 2 and found that a plaintiff's IP led to higher coauthoring post litigation, but general litigating ability did not. However, upon including the technological distance and defendant's relational position moderators in Model 3, the effect of the plaintiff's IP disappeared.

We further considered the effect of plaintiffs and defendants being entwined in other litigation not related to SEPs. Thus, we added to Model 3 a moderator for the number of non-

SEP-related cases where the plaintiff and defendant were opposing litigants as well as the proxy for plaintiff's general litigating ability. This model revealed two opposite effects. First, dyads coauthored more post-litigation when plaintiffs possessed a demonstrated litigation ability. The average treatment rate for plaintiff-defendant dyads was 1.3 when the plaintiff had no non-SEP-related litigation, whereas the treatment rate was 3.5 when the plaintiff had three open non-SEP-related cases (holding the other moderators constant). In contrast, the post-filing coauthoring rate lowered when plaintiff-defendant dyads were engaged in litigation unrelated to SEPs. When the dyad had no non-SEP-related litigation, then the average treatment rate was 5.7. However, when the dyad was engaged in two non-SEP-related cases, the average treatment rate was 0.2. This model with the additional moderators fit the data better than Model 3 (χ^2 = 12.85; d.f. = 5; p = 0.02). Overall, the first moderator reinforces our arguments: plaintiffs with a litigation capability will use it to enforce patent rights and push defendants toward greater cooperation. The second moderator suggests a boundary condition: when a plaintiff and defendant are litigating technology unrelated to 3GPP SEPs, they may not choose to cooperate more within 3GPP.

Plaintiff versus defendant ownership of SEPs. A plaintiff may own SEPs and sue a defendant for patent infringement or a defendant may own SEPs and get sued by a plaintiff for unreasonable or discriminatory licensing terms. While both types of suits suggest disagreement about the value of the underlying technology, one may drive the observed results more than the other. In our dataset, plaintiffs held the SEPs in 75 percent of the cases, and defendants held the SEPs in 25 percent of the cases. We reran Model 2 and split our results by whether the plaintiff or the defendant possessed the SEPs. We found the treatment rate was 4.0 when defendants held SEPs (β = 1.39; *p* = .004) and the rate was 2.0 when plaintiffs held SEPs (β = 0.67; *p* < .02). However, a likelihood ratio test revealed that this alternative model did not fit better than Model 2 (χ^2 = 2.04; d.f. = 2; *p* = 0.36). This suggests that cooperation will increase whether the defendant or plaintiff holds patents.

Persistence of the litigation effect. We examined whether the effect of litigation is temporary or persists over time. To test this, we added four more quarters of data so that we had eight quarters of coauthoring post-filing. We then added a variable to Model 4 that was 1 for treated dyads in the second-year post-filing ($t \in \{5,\ldots,8\}$); 0 otherwise. The existing treatment × post-filing variable, D_{it}, was also coded as 1 for all eight post-filing quarters. A near-zero estimate for the new parameter would suggest a persistent effect from year 1 to 2, whereas a negative or positive coefficient would indicate a diminishing or growing effect, respectively. For defendant-plaintiff dyads, the rate of coauthoring dropped 34 percent from the first-year to the second-year post-filing (est. = −0.42; *p* = .44); for co-defendant dyads, the rate of coauthoring dropped 68 percent (est. = −2.16; p = .06); and for defendant-other dyads, the rate of coauthoring rose 16 percent (est. = 0.15; *p* = .41). Only the co-defendant change in coauthoring from year 1 to 2 was notable. Further analysis showed that by the second year, co-defendant rates of coauthoring were similar to pre-treatment, but plaintiff-defendant dyads remained 2.2 times higher than pre-treatment and defendant-other dyads remained 2.5 times higher. Thus, except for co-defendants, litigation's influence on coauthoring continued to persist.

5 | DISCUSSION AND CONCLUSIONS

Our study examines the evolution of cooperation in the face of conflict about valuable intellectual property. In innovation ecosystems, cooperation occurs frequently. In 3GPP, firms participate in standards development to jointly create technical specifications for mobile telecommunications. However, conflict is also frequent, and patent litigation regularly hampers firms' ability to derive value from their IP or products. In light of this phenomenon, we asked how firms respond to conflict within an interdependent technological landscape.

Similar to how cooperation might evolve in economic, political, or biological ecosystems (Axelrod & Hamilton, 1981; Axelrod, 1984), we find that firms bound together in an innovation ecosystem continue to cooperate—and even increase their cooperation—following a conflict. We argue that this occurs because essential IP (the source of conflict) cannot be bypassed without significant technology development, a costly and unappealing option. Since defecting is a poor alternative, adversarial firms engage in cooperation after conflict to enhance private and club benefits derived from complementary assets (Teece, 2018; Jacobides et al., 2018). Such a cooperative approach also reduces the risk of future hold up and prevents technological substitution by rivals (Arora, Fosfuri, & Gambardella, 2001; Polidoro & Toh, 2011).

The extent to which contesting firms benefit from cooperation depends on whether their technological profiles are complementary. If litigating firms are more technologically similar or less distant, they have fewer joint opportunities and pose greater competitive threats to one another. In contrast, more technologically distant firms (within the ecosystem) have greater potential for complementarities that generate club benefits. Also, the cooperative benefits for litigants is relative to other opportunities in the co-creation network. If a defendant holds a central network position, it enjoys more outside options and becomes less inclined to cooperate with the aggressor. Further, while a firm may choose to cooperate with an aggressor, it may in tandem cooperate with others to move the technological trajectory away from the contested IP and safeguard against future attacks (Ziedonis, 2004).

5.1 | Contributions

Our study contributes to four conversations in the strategic management literature. First, our study is among the first within strategic management to focus on outright conflict between firms and its subsequent implications for cooperation. This omission probably owes to the fact that while interfirm conflict is frequent, it is rarely well-documented, making it difficult to examine. As a result, conflict is viewed as a perpetual state of disagreement (cf. Sytch & Tatarynowicz, 2014). In contrast, we trace a more nuanced set of strategic actions that present conflict as an evolutionary aspect of competition. Our key insight is that the effect of conflict on subsequent cooperation in innovation ecosystems is more complex than the extant literature on interfirm cooperation would lead us to believe. Conflict does not simply lead to firms severing cooperative ties (Baker Faulkner, & Fisher, 1998; Greve, Baum, Mitsuhashi, & Rowley, 2010; Polidoro, Ahuja, & Mitchell, 2011). Depending on their technological and relational positions in the ecosystem, parties in conflict can use cooperative arrangements to build complementarities or redirect technological development to their advantage. Moreover, we address the question of how conflict between two firms triggers broader shifts in the technological landscape. Our finding that firms reconfigure their interactions with third parties post-conflict offers insights on the dynamic ramifications of conflict within innovation ecosystems (Helfat & Raubitschek, 2018).

Second, patent litigation is a special kind of strategic conflict where one party demands concessions from another party via the legal system. According to Somaya (2003), such demands may arise from disputes about asset valuations and the expected evolution of technologies and markets. The parties may also hold asymmetric information and divergent stakes in terms of their technological or market positions. As a result, the parties may use the legal process to sort out disagreements. Our study builds on this view of litigation as a strategic process. We conceptualize the filing of a lawsuit as indication of changes in the parties' strategic stakes and describe the implications for their cooperation. Prior literature has viewed litigation as a socially acrimonious process (e.g., Sytch & Tatarynovicz, 2014). In contrast, we view litigation through a strategic lens as an element of high-technology competition that illustrates the parties' attempts to capture value from the complex and rapidly evolving innovation ecosystem.

Third, litigation in high-technology ecosystems is often the result of interdependencies created by complementary technologies (cf. Adner & Kapoor, 2010; Jacobides et al., 2006; Teece, 2018). Jacobides et al. (2018) highlight the importance of understanding the direction and strength of complementarities in order to design robust ecosystem governance that enables collaboration and value capture while incentivizing participation. We extend their framework by demonstrating the influence of technological and relational interdependence on cooperative outcomes after conflict. Our study generates novel insights about the relationships between complementarities, cooperation, and value capture in innovation ecosystems: under strong complementarities, strategies to create joint value entice cooperation, but outside options can weaken the cooperative response and keep future attempts at appropriation in check.

Fourth, while we build on prior studies in cooperative strategy and game theory (e.g., Parkhe, 1993; Brandenburger & Stuart, 1996; Casadesus-Masanell & Yoffie, 2007; Arslan, 2018), our conceptual framework introduces the central role of club goods in innovation ecosystems. Extant research focuses on public and private benefits only, and conflates public and club benefits under the notion of common benefits (Arslan 2018). We argue that when technological inputs are complementary requiring continuous investment, club benefits provide major incentives for cooperation. By solely focusing on private benefits as the driver of cooperation, one may miss the importance of club benefits to sustain broader collective action.

Finally, from an empirical standpoint, our study examines repeated interaction in an interdependent setting. Repeated interaction is an important aspect of competitive strategy (Gulati, 1995), but we are not aware of studies with long panels of cooperative activity interspersed with disagreement and potential cooperative failure (cf. Johnston & Waldfogel, 2002). Further, our setting allows us to match firms operating in similar circumstances, except for the litigation disturbance. Our study is unique in tracing the impact of conflict on closely related cooperative activities. Few studies have achieved such a close correspondence between the conflict domain and strategic actions associated with it. We can generate exceptionally specific insights compared to studies with firm-level and annual observations of firm behavior and outcomes where the list of possible confounding factors is excessive.

5.2 | Limitations and future research

Patent litigation is primarily about licensing negotiations for using existing IP, which is backward-looking. However, with repeated interactions, litigation can also involve forward-looking strategic behavior (e.g., Macchiavello & Morjaria, 2015). That means a plaintiff's litigation strategies can be tied to its subsequent cooperation, confounding our efforts to isolate the litigation effect. Nonetheless, to our knowledge, the trigger to initiate litigation stems from the evolving value of the underlying technology. Thus, we believe that our research design of matching highly similar dyads around the quarter of a lawsuit filing is able to reasonably identify the impact of litigation on cooperation, even though the broader technology market may influence both litigation and cooperation decisions. In particular, the quarterly difference-in-differences design is able to isolate the immediate impact of filing from the general, gradual appreciation of SEPs. Furthermore, including additional proxies for demand for the technology in the marketplace does not substantially change our results.

The effect of litigation on cooperation between a defendant and other parties including co-defendants is relatively less confounded by the plaintiff's strategies. If a defendant cooperates with other parties after being sued, the defendant's is more likely responding to the litigation and not the plaintiff's pre-existing strategy. Nevertheless, as with all empirical strategy research, the decisions of individual firms are influenced by developments in the marketplace, and ideally, we would like to test the robustness of our results with an instrument that affects the cost of litigation but is unaffected by the market or other unobservable factors.

Relatedly, our study of cooperation after conflict hinges on the assumption that adversaries can calculate with some certainty the expectation of future payoffs—be they private or club benefits. However, uncertainty about the evolution of the technology, supporting industries and dominant players can undermine such calculations. Technological and commercial uncertainty is high in the telecommunications industry owing to the evolving generations of technology which could usher in unforeseen new players and radical innovations. Moreover, conflict over technology in standards development could be compounded by conflict in other political and economic domains. In particular, international conflicts can arise in strategic industries and cast a shadow on expected benefits from cooperation between private actors.

5.3 | Managerial implications

This study provides insights for managers of high-technology firms innovating and competing in innovation ecosystems. Conflict drains resources, and firms need to be cognizant of when to engage in it and when to tolerate or even accommodate aggression. For example, engaging in patent wars or standards wars can be extremely costly. However, when in conflict, firms that have cultivated cooperative alternatives are better positioned to strategically respond by diverting the technological development away from the aggressor and towards less contested territory. Overall, such conflict need not be viewed as devastating incidents of cooperative failure but as instances of competition where expectations about future payoffs have changed and where firms can renegotiate their relationships to refashion the technological trajectory. Occasionally those negotiations fail and firms end up in court. However, a swift reaction to cut off cooperative activity may be misplaced. Instead, it is more beneficial to assess whether it is advantageous in the long term to continue the existing arrangement or to divert investments into new cooperative arrangements.

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Figure 1. Technical document coauthoring pre- and post-filing for defendant-plaintiff dyads. Solid lines depict quarter-by-quarter coauthoring; dashed lines depict average coauthoring pre- and post-filing.

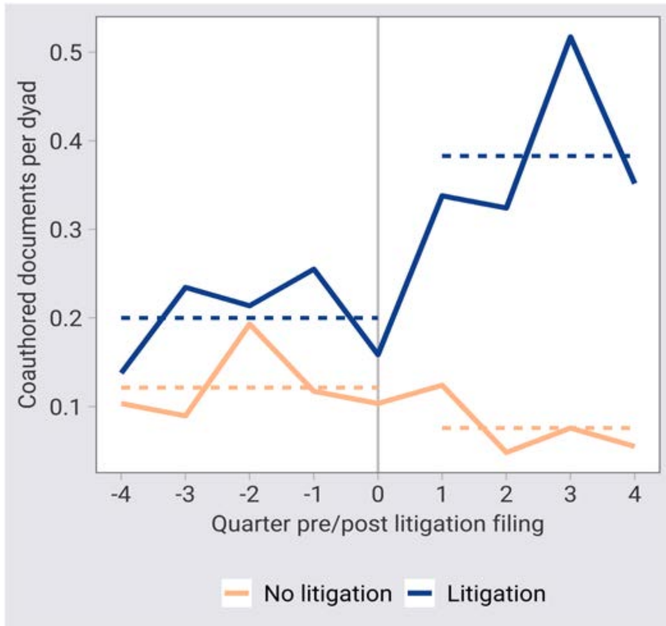

Figure 2. Predicted effect of litigation on plaintiff-defendant coauthoring moderated by (A) technological distance and (B) defendant relational position. Predicted effects are based on Model 3. The litigation effect is measured as a rate, so values above 1 increase coauthoring, whereas values below 1 decrease coauthoring. C.I. = confidence interval.

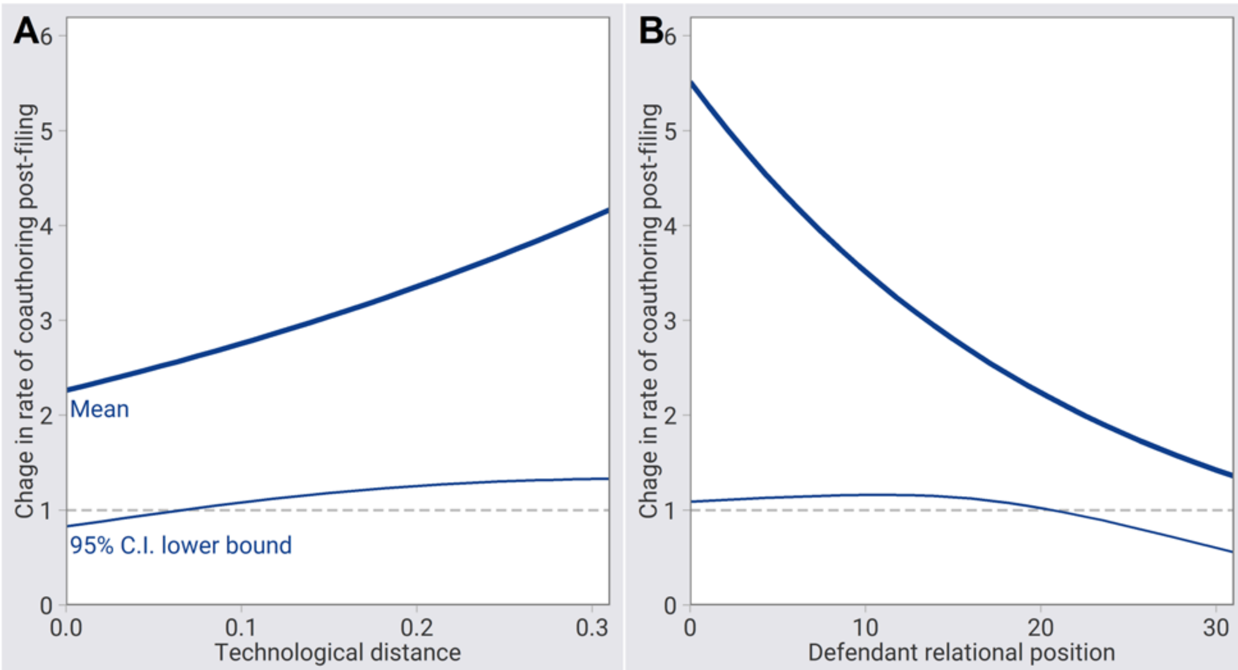
A
B
Chage in rate of coauthoring post-filing
Mean
95% C.I. lower bound
Technological distance
Defendant relational position
0
1
2
3
4
5
6
0.0
0.1
0.2
0.3
10
20
30

Table 1. Summary of 3GPP data

Working Group	Technology Domain	Contributors: Firms	Contributors: Documents	Litigation: Filings	Litigation: Litigants	Litigation: SEPs
Core Network & Terminals (CT)						
CT1	Specifications for interfaces between Radio Access Network and Core Network (Iu-CS, Iu-PS)	69	2,761	4	8	8
CT3	Specifications for interfaces between Core Network and external networks	43	948	0	0	0
CT4	Specifications for Core Network	51	2,234	2	6	2
CT6	Smart card applications	45	208	0	0	0
Radio Access Network (RAN)						
RAN1	Specifications for interface between User Equipment and Node B (Uu)	89	10,273	35	38	54
RAN2	Architecture for User Equipment to Node B interface	95	12,488	26	33	40
RAN3	Specifications for interfaces between Node B and Radio Network Controller (RNC) and between RNCs (IuB, IuR)	72	6,218	10	14	12
RAN4	Radio frequency aspects, repeaters, and radio performance	114	13,084	4	7	6
RAN5	Specifications for conformance testing of the User Equipment interface	79	8,696	0	0	0
Service and System Aspects (SA)						
SA1	Requirements for services and features of the system	98	2,808	9	12	10
SA2	System architecture (except for RAN)	103	3,777	11	16	14
SA3	Requirements and architecture for system security	60	1,248	6	9	5
SA4	Specifications for audio and video codecs	56	604	8	16	18
SA5	Requirements and architecture for overall system management	40	1,884	1	4	1

Notes. Observation window is 2005-Q2 to 2012-Q3. Technical reports and discussion documents are included in the document count; change requests, liaison requests, and withdrawn or unknown documents are excluded. SEPs = standard essential patents.

Table 2. Standard essential patent litigation: Most litigious firms

Firm	Litigant role: Plaintiff	Litigant role: Defendant	Case outcome: Went to trial	Case outcome: Settled or dismissed	Case outcome: Unknown	Suits with countersuits	WGs affected
Apple	4	9	1	8	4	6	10
Motorola	1	6	0	6	1	2	7
Samsung Electronics	3	4	0	4	3	4	6
Motorola Mobility	3	3	0	6	0	4	5
Nokia	1	5	0	6	0	0	8
Cisco Systems	3	1	0	1	3	0	8
Interdigital	3	1	0	4	0	2	6
Motorola Solutions	3	1	0	2	2	0	1
Qualcomm	2	2	1	2	1	2	8
SPH America	3	1	0	4	0	2	1

Broadcom	2	1	1	2	0	2	5
Hewlett-Packard	2	1	0	2	1	0	1
Research In Motion	1	2	0	3	0	0	7
Sony-Ericsson	1	2	0	3	0	1	3
Other firms (38 total)	17	33	9	33	8	4	11

Notes. Table lists firms involved in 3 or more cases filed between 2005-Q2 and 2012-Q3.

Table 3. Descriptive statistics

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Coauthored documents	0.18	1.25								
(2) Plaintiff-defendant dyad	0.01	0.10	0.00							
(3) Co-defendant dyad	0.01	0.12	0.04	-0.01						
(4) Defendant-other dyad	0.98	0.15	-0.03	-0.66	-0.74					
(5) Post-filing	0.44	0.50	0.01	0.00	0.00	0.00				
(6) Litigating dyad	0.50	0.50	0.07	0.00	0.00	0.00	0.00			
(7) Technological distance	0.17	0.51	0.05	-0.01	-0.01	0.01	0.00	-0.02		
(8) Defendant relational position	0.08	1.61	0.02	0.43	-0.01	-0.29	0.00	0.05	0.00	
(9) No authoring by dyad member	0.69	0.46	-0.18	-0.01	-0.01	0.02	0.00	0.01	-0.51	-0.03
(10) Dyad members' citation-weighted patents	1.51	3.37	0.07	0.02	0.00	-0.01	0.00	0.14	0.00	0.03
(11) Std. dev. of citation-weighted patents	1.02	2.29	0.05	0.01	-0.01	0.00	0.00	0.14	0.01	0.02
(12) Dyad third-party closure	1.74	6.85	0.49	0.01	0.04	-0.04	0.00	0.13	0.10	0.05
(13) Dyad alliances	0.01	0.13	0.01	-0.01	-0.01	0.01	0.00	0.01	-0.01	0.00
(14) Dyad non-SEP cases, co-litigants	1.40	7.67	0.04	0.00	0.03	-0.03	0.02	0.03	-0.01	0.00
(15) Dyad non-SEP cases, opposing litigants	0.06	0.33	0.03	0.14	0.03	-0.12	0.02	0.02	0.00	0.08
(16) WG litigants in open cases	10.11	10.32	0.09	0.00	0.02	-0.01	0.12	0.48	-0.09	0.04
(17) WG SEPs in open cases	6.87	6.35	0.07	0.00	0.01	0.00	0.06	0.52	-0.09	0.03
(18) Off-quarter filing	0.04	0.20	0.00	0.01	0.00	-0.01	0.08	0.10	-0.03	0.01
(19) Suit-countersuit	0.12	0.32	0.00	-0.01	-0.03	0.03	0.00	0.37	-0.08	0.00

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(10) Dyad members' citation-weighted patents	-0.03									
(11) Std. dev. of citation-weighted patents	-0.02	0.98								
(12) Dyad third-party closure	-0.30	0.10	0.08							
(13) Dyad alliances	-0.02	0.02	0.02	0.01						
(14) Dyad non-SEP cases, co-litigants	-0.04	-0.02	-0.03	0.06	0.18					
(15) Dyad non-SEP cases, opposing litigants	-0.04	0.02	0.00	0.07	0.02	0.18				
(16) WG litigants in open cases	0.09	0.15	0.15	0.22	0.00	0.03	0.03			
(17) WG SEPs in open cases	0.10	0.16	0.16	0.18	0.00	0.02	0.02	0.90		
(18) Off-quarter filing	0.06	0.07	0.07	0.03	0.01	0.02	0.02	0.20	0.18	
(19) Suit-countersuit	0.12	-0.03	-0.03	0.04	0.01	0.04	0.01	0.18	0.23	0.17

Notes. Total observations = 217,296; defendant-plaintiff dyads = 2,304; Co-defendant dyads = 2,934; defendant-other dyads = 212,058.

Table 4. Negative binomial difference-in-differences models

	Model 1		Model 2		Model 3		Model 4	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
Baseline	-2.09	(0.36)						
Post filing	-0.46	(0.31)						
Litigating dyad (β_1)	0.51	(0.58)	-0.27	(0.33)	-1.04	(0.41)	-0.33	(0.33)
Litigating dyad post-filing (β_2)	1.12	(0.35)	0.72	(0.29)	1.43	(0.64)	1.31	(0.29)
Technological distance moderator (M_1)								
Tech. distance * Post-filing					-0.80	(0.48)		
Tech. distance * Litigating dyad					-1.59	(0.18)		
Tech. distance * Litigating dyad post-filing (β_3)					1.97	(0.62)		
Defendant relational position moderator (M_2)								
Relational position * Litigating dyad					0.05	(0.01)		
Relational position * Litigating dyad post-filing (β_4)					-0.05	(0.01)		
Co-defendant dyad								
Relative baseline							0.71	(0.20)
Co-defendant dyad							-0.81	(0.41)
Co-defendant dyad post-filing							0.73	(0.23)
Defendant-other dyad								
Relative baseline							0.09	(0.23)
Defendant-other dyad							-0.30	(0.15)
Defendant-other dyad post-filing							0.91	(0.10)
Controls								
Technological distance			0.45	(0.17)	0.69	(0.22)	-0.10	(0.11)
No authoring by dyad member			-3.81	(0.70)	-3.95	(0.68)	-2.01	(0.16)
Dyad members' citation-weighted patents			0.11	(0.02)	0.11	(0.03)	0.08	(0.03)
Std. dev. of citation-weighted patents			-0.06	(0.04)	-0.09	(0.04)	-0.08	(0.04)
Dyad third-party closure			0.08	(0.02)	0.05	(0.02)	0.12	(0.01)
Dyad alliances							0.39	(0.15)
Dyad non-SEP cases, co-litigants			0.09	(0.03)	0.10	(0.03)	0.00	(0.00)
Dyad non-SEP cases, opposing litigants			-0.24	(0.21)	-0.30	(0.20)	-0.01	(0.08)
WG litigants in open cases			-0.10	(0.04)	-0.10	(0.04)	0.00	(0.02)
WG SEPs in open cases			0.16	(0.07)	0.18	(0.08)	-0.05	(0.03)
Off-quarter filing			-0.03	(0.46)	-0.17	(0.50)	0.11	(0.09)
Suit-countersuit			0.05	(0.31)	0.03	(0.33)	-0.44	(0.26)
WG dummies			Included		Included		Included	
Quarter dummies			Included		Included		Included	
Dispersion parameter	18.4		2.8		2.6		6.9	
Akaike information criterion (AIC)	1,811		1,413		1,407		109,444	
Observations	2,304		2,304		2,304		217,296	

Notes. Cluster robust standard errors (clustered on firm and partner) in parentheses. The effects of the moderators are similar whether they are modeled separately or together, so Model 3 presents the moderators together.

Defendant relational position only applies to treated dyads, so there is no ‘relational position x post filing’ interaction.