

The Embeddedness of Networks: Institutions, Structural Holes, and Innovativeness in the Fuel Cell Industry

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Plentiful research suggests that embeddedness in alliance networks influences firms' innovativeness. This research, however, has mostly overlooked the fact that interorganizational ties are themselves embedded within larger institutional contexts that can shape the effects of networks on organizational outcomes. We address this gap in the literature by arguing that national institutions affect the extent to which specific network positions, such as brokerage, influence innovation. We explore this idea in the context of corporatism, which fosters an institutional logic of collaboration that influences the broker's ability to manage its partnerships and recombine the knowledge residing in its network as well as the extent of knowledge flows among network participants. We argue that differences in institutional logics lead brokerage positions to exert different effects on firm innovativeness. We propose that the firm spanning structural holes obtains the greatest innovation benefits when the firm (the broker) or its alliance partners are based in highly corporatist countries, or under certain combinations of broker and partner corporatism. We find support for these ideas through a longitudinal study of cross-border fuel cell technology alliance networks involving 109 firms from nine countries between 1981 and 2001.

Key words: national institutions; corporatism; alliance networks; structural holes; brokerage; knowledge flows; innovation

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Introduction

A large literature has focused on the relationship between firms' positions in alliance networks and outcomes such as market performance (Rowley et al. 2000, Shipilov and Li 2008), survival (Baum et al. 2000), and innovation (Ahuja 2000). Recent work has pointed to the salience of structural holes in influencing firm innovation but has shown mixed results in this regard. The core logic behind the benefits of structural holes is that firms in brokerage positions are exposed to a greater variety of nonoverlapping knowledge flows by being tied to disconnected partners (Burt 1992). Consistent with this mechanism, some studies report a positive relationship between brokerage and innovation (Reagans and Zuckerman 2001, Hansen 1999). However, others report the opposite effect, arguing instead that closure is necessary to allow for the "thick" transfer of tacit knowledge (Ahuja 2000, Obstfeld 2005). These mixed findings suggest that the effect of structural holes on innovation is likely to be contingent on the conditions affecting the behavior of network participants in the process of knowledge exchange (Tortoriello and Krackhardt 2010).

We propose that a major reason the literature has been inconclusive regarding the effects of structural holes (and networks more broadly) on firm innovation is the

noninclusion of the institutional context surrounding network members. The institutional embedding of networks must be considered because it can fundamentally define the nature of collaboration or competition among network members and, by extension, the efficacy of innovative outcomes for the broker. In fact, extant research broadly conveys the sense that network effects are conditioned by the collaborative versus competitive orientations of network participants. Scholars have demonstrated that such orientations derive from various factors such as structural equivalence (Burt 1997), family ownership of firms (Ingram and Lifschitz 2006), and the role of public organizations in fostering different models of information sharing (Owen-Smith and Powell 2004). We draw from this foundation and move research a step forward by pointing to the institutional context of the broker and its partners as a key factor explaining *when* structural holes enable or constrain innovation because of the collaborative or competitive logics engendered by the institutional setting in which the firms in the network are embedded.

To distinguish between collaborative and competitive institutions, we draw on prior literature that classifies countries by their level of corporatism—a sociopolitical institution that characterizes the nature of collaboration,

participation, and exchange among actors within a society in the process of achieving collective goals (Badie and Birnbaum 1983, Hicks and Kenworthy 1998, Jepperson 2002, Schmitter 1981). We argue and show that firms embedded in a technological alliance network spanning multiple countries, each with varying degrees of corporatism, will tend to differ in their approach to managing knowledge exchanges in the process of technological innovation. In countries with high degrees of corporatism, social objectives such as technological innovation are addressed in a more collaborative and coordinated manner than in less corporatist countries (Spencer et al. 2005, Vasudeva et al. 2012). Thus, the degree of corporatism of the broker's country and that of its partner's countries will, separately and jointly, affect the innovative output the broker achieves.

We focus this study on understanding how the institutional setting gets to the heart of the mechanisms driving the effects of structural holes on firm innovativeness. Our key insight is to point out that, in a technology alliance network spanning multiple countries, the corporatism of the countries in which the broker and its partners are situated creates significant variance both in the capability of the brokering firm to manage its alliance relationships and integrate knowledge from its disconnected partners and in the extent of knowledge flows from partners to the broker. The institutional logic of countries with high corporatism imprints brokers from highly corporatist countries with collaborative skills that enhance their integrative capacity and imbues in network participants norms of mutual problem solving that enhance knowledge flows to the broker. In contrast, the competitive norms prevalent in low corporatist settings constrain knowledge exchange because they foment opportunism and caution between the broker and its partners, which reduces the innovation value of spanning structural holes. Moreover, the corporatism of the broker and its partners creates unique contingent effects that make some combinations superior to others in generating innovation for the broker.

We test these ideas in the emergent fuel cell industry, which is dedicated to advancing hydrogen as a clean energy alternative to fossil fuels. Given the nascence of hydrogen power and the interest of multiple governments in developing sustainable energy, fuel cell development has required organizations to actively collaborate via alliances across multiple countries. This technological context represents an ideal setting to examine the joint effects of networks and corporatist institutions on innovation. We track the alliance networks of 109 firms located in nine countries over the period 1981–2001 and observe their innovativeness during five-year windows. Our data cover the bulk of fuel cell alliances with no left censoring. Our results show that the corporatism of the broker's country and that of the countries in which

its partners reside, and certain combinations of the two, enhance the innovativeness of the broker.

Our study makes at least three key contributions. First, we address the fundamental notion that the networks in which firms are embedded (Granovetter 1985) are themselves embedded within broader institutional contexts. Thus, it seems reasonable to argue that without considering the institutional settings within which different network actors are situated, we obtain at best a partial understanding of the influence of network structures on firm-level outcomes. Recognizing this broader issue, Powell et al. (2005, p. 1133) observe that “in the social sciences...analyses of [institutional] fields and networks have been oddly disconnected.” In this sense, connecting corporatism—and its associated institutional logic of collaboration—to the mechanisms by which brokerage impacts innovation is the core theoretical contribution. Second, we highlight the implications of the cross-national character of networks and show how this internationalization of relationships changes the benefits that firms obtain from a given network position. Our findings imply that although organizations have little control over national institutions, they are not deterministically bound by institutional norms because they can configure the structure and international scope of their networks to increase the benefits of spanning structural holes. This idea also contributes to institutional theory by demonstrating how institutional constraints can be overcome through the configuration of cross-national ties. Third, we address the conflicting results regarding the effects of structural holes on innovation by incorporating the firm's and its partners' institutional profiles to highlight a key contingency in this relationship.

Theory and Hypotheses

Institutions are defined as “the rules of the game in a society...the humanly devised constraints that shape human interaction” (North 1990, p. 3); they embody the norms, rules, and conventions that designate appropriate ways to pursue goals by societal actors (Scott 2001). Thus, they transmit information to actors regarding the broad parameters within which social action and behavior occurs. DiMaggio and Powell (1983) refer to the three specific mechanisms by which institutions legitimate the behavior of organizations located within the same institutional field through isomorphic pressures deriving from mimetic, coercive, and normative influences.

The link between networks and institutions stems from the fundamental idea that both are broadly concerned with social values and the structure of relations among societal actors (Granovetter 1985, Rowley et al. 2000, Westphal et al. 1997, White 1981). Stinchcombe (1968), for example, defines an institution as “a structure...committed to some value or interest” (p. 107). Because institutions denote both social

values (e.g., collaboration versus competition) and the structures that bring them about, social networks operating within the overall institutional setting are likely to be influenced by the underlying expectations of behavior defined by the institutional domain (Meyer and Rowan 1977). Networks of interfirm relationships can thus be viewed as embedded within the broader institutional field, subsumed within the larger social *zeitgeist* (Krippner and Alvarez 2007). Although recognizing that networks function within institutional settings, we are not suggesting that networks are in some fashion the deterministic outcomes of institutions. Rather, our primary purpose is to establish that networks and institutions mutually affect firm innovation by showing that the same network position can yield different outcomes depending on the institutional logic of collaboration governing exchange between partners embedded in those institutions.

The idea that the same network position can operate differently across contexts has an important precedent in research on brokers. Scholars suggest, for instance, that the role played by a broker organization can be classified into five distinct categories—liaison, representative, gatekeeper, itinerant, and coordinator—depending on the societal groups to which the broker or its partners belong (Fernandez and Gould 1994, Gould and Fernandez 1989). Consistent with Burt's (1997) key insight of the contingent advantage of brokerage, recent research has demonstrated that firms spanning structural holes enjoy varying degrees of advantage depending on the extent to which alternatives are available for the actors being brokered (Pollock et al. 2004, Ryall and Sorenson 2007). These studies highlight the idea that the brokerage advantages conferred by structural holes are constrained by the broader environment within which network members reside, and the extent to which network members operate within a more competitive versus collaborative framework importantly influences the broker's performance.

Combining these perspectives from the networks literature with institutional theory, we propose that network positions vary in terms of their knowledge advantages according to the institutional context within which the broker firm and its alliance partners are situated. The dominant logic that mediates exchange across structural holes—or any other network position—therefore stems from the underlying competitive versus collaborative norms inherent in the institutional setting within which the firm or its partners reside. Recognizing the role of institutions in shaping the advantages (or disadvantages) conferred by network positions, Adler and Kwon (2002, p. 33) aptly note that “norms and beliefs figure in the analysis of social capital not only because they function as sources of social capital but also because the norms and beliefs in the surrounding environment influence the value of a given stock of social capital.”

Corporatism and the Logic of Collaboration

Corporatism is a sociopolitical, nonmarket institution concerned with the organization of interest groups in society, which can take varied forms based on communitarian principles at one extreme and individualism at the other. Corporatism varies across countries and ranges from low (e.g., the United States, United Kingdom) to high (e.g., Japan, Germany). Highly corporatist settings are characterized by hierarchically structured and functionally differentiated groups playing clearly specified roles (Schmitter 1981). According to Jepperson (2002), the distinctive assigned roles and responsibilities of groups in highly corporatist environments help overcome coordination failures, fostering collaborative relationships among industry members. Highly corporatist institutional environments are characterized by relationships that are often cemented through business confederations, industry associations, and other social structures that dominate the economic landscape and enhance connectivity among actors (Hicks and Kenworthy 1998). Even beyond these formal associations, however, corporatist systems encourage highly coordinated and collaborative business networks among independent firms (Windolf 2002).

In contrast, in low corporatism countries, industry groups tend to arise to address narrow issues of mutual interest, dissolving once those issues are less salient to members (Cawson 1985). Individualism and competitiveness lie at the core of low corporatist settings, making the classic problem of collective action more onerous (Olson 1971). The resulting policy bargains in such settings may reflect the preferences of less encompassing, but more dominant, groups in society. At the same time, the pluralist character of low corporatist models naturally allows for the emergence and coexistence of multiple preferences and interests that counterbalance the possible excesses of a single powerful actor. Thus, corporatism affects the way in which societal actors such as firms collaborate to achieve desired outcomes in sociopolitical or institutional settings (Spencer et al. 2005, Vasudeva et al. 2012).

Our purpose is to explicate how corporatism modifies the benefits that brokers obtain in innovation networks by influencing the behaviors of the firms involved in those networks. To do so, we must first explain in general how institutions, as higher-level entities, affect the behaviors of firms embedded within them and, subsequently, how corporatism in particular impacts the innovation benefits of brokerage. To make the first point, the notions of institutional logics and institutional imprinting are central. Institutional logics refer to a set of beliefs and related practices that constitute “recipes for action,” or blueprints guiding the behavior of organizations and other societal actors (Owen-Smith and Powell 2008). The concept of institutional imprinting is defined as the process by which firms adopt the

institutional logic of their organizational field by internalizing its coercive, normative, and cognitive dimensions (Stinchcombe 1965, Scott 2001). Such imprinting deeply influences the identity and fundamental nature of the firms embedded within a given institutional domain, thereby informing the default modes of behavior, the paradigms, and even the capabilities that they bring to interactions with other entities, both within their institutional contexts and beyond them (Holburn and Zelner 2010).

As suggested earlier, the particular institutional logic of corporatism is one of collaboration and mutual problem solving. While studies have not assessed the relationship between corporatism and brokerage, there has been some work demonstrating that corporatism leads firms to approach innovation in unique ways. Spencer et al. (2005, p. 324) explain that technological development by firms in corporatist settings follows a “bricolage” approach characterized by “a mutually adaptive, collective, and gradually emergent process in which many networked actors . . . create and then improve a technology” (see also Garud and Karnøe 2003). This is highly consistent with how innovation across countries differing in corporatism proceeded in our research context.

For example, in Germany—a highly corporatist country—the regional government of Baden-Württemberg assembled a group of automotive firms, led by Daimler-Benz, to collectively develop new chemical engineering capabilities required for fuel cell innovation. Within this group, composed of small and large entities, each firm was assigned responsibility for a specific domain of fuel cell technology, and each firm’s portion of responsibility converged into a consistent “whole” that met the technological policy agreed upon by various sociopolitical interest groups. In contrast, in the United States—a low corporatism setting—the federal government expressed and promoted its interest in fuel cell innovation by providing financial incentives to firms (e.g., tax breaks, grants), but no attempt was made to create groupings of firms with assigned technology domains. Instead, each firm was given freedom to pursue innovation as it deemed fit, and multiple firms often competed within the same technological space (Avadikyan et al. 2003). Thus, whereas collective interests and requirements are stressed under more corporatist systems, individual firms’ rights and choices are more prominent in less corporatist or pluralist systems (Crouch and Streeck 1997).

These examples suggest that differences in innovation stem from the different logics of collaboration of the institutions within each country. Importantly, the evidence from these cases suggests that firms are imprinted with the norms of corporatism (or the lack thereof) to the point that they adopt clearly different ways of going about innovation, and of working with other firms in the process. Although all firms—regardless of their

background—seek to achieve some measure of private gains as they collaborate for innovation, those from highly corporatist societies are more willing to allow a greater degree of common benefits than those from less corporatist countries. It is worth clarifying that firms from corporatist countries are not naïvely unaware of opportunism or private agendas in their partners, nor are they immune to their own private interests. Rather, such cooperation is bounded by well-defined networks and interest groups, and it operates within those boundaries. Corporatist actors may not be universally willing to share their knowledge in the absence of mutual interests and goals, but given these, they are more cooperative than actors from less corporatist institutional backgrounds (Spencer et al. 2005).

A final clarification is in order. There is a difference between corporatism as an institution and the mechanisms and processes that corporatism engenders or promotes (Schmitter 1981). Just as institutions are distinct from the institutional logics they promote, so too is corporatism distinct from collaboration. In addition, the collaborative institutional logic is manifested in more than one way. In what follows, we emphasize two of them: (1) integrative capabilities, which explain why the corporatism of the broker’s country enhances the benefits of brokerage; and (2) collaborative orientations, which explain why the corporatism of the broker’s partners increases knowledge transfer to the broker. We develop these ideas below.

Corporatism, Structural Holes, and Innovativeness

Within the networks literature, structural holes have been one of the most widely studied sources of positional advantage in general (e.g., Ryall and Sorenson 2007) and of firm innovation in particular (Ahuja 2000). Burt (1992) explains the value of structural holes as stemming from the ability of an actor to obtain and meld together diverse, nonredundant information from partners not directly connected to each other. Given that innovation is often defined as the recombination of existing knowledge for new applications (Schumpeter 1934), organizational scholars developed a keen interest in the informational benefits of brokerage as a possible explanation for firm innovativeness.

Despite this theoretical promise, however, the empirical literature seeking to link structural holes with firm innovation has produced mixed results. Although some studies find a positive main effect of brokerage on innovation (Reagans and Zuckerman 2001, Hansen 1999), others find negative effects (Ahuja 2000, Obstfeld 2005). We attempt to resolve such contradictions by explaining the contingencies that lead structural holes to foster or hinder innovation (Tortoriello and Krackhardt 2010), and we suggest that institutions are particularly important in this regard. However, to establish the importance of institutions—and corporatism in particular—as

a contingency, we believe it important to first outline the mechanisms behind Burt's (1992) arguments regarding the innovation benefits of structural holes.

Three important conditions (usually assumed to be in place in empirical work) must be met for structural holes to lead to innovation, of which the latter two are particularly germane to our study. In developing these conditions, we draw primarily from Burt's (2004) widely cited paper, "Structural Holes and Good Ideas," where the connection between brokerage and innovation is most explicitly developed.

First, the partners to which the broker is tied should each possess nonredundant knowledge. Burt (2004) makes this condition explicit with statements such as the following: "Behavior, opinion, and information, broadly conceived, are more homogeneous within than between groups. People focus on activities inside their own group, which creates holes in the information flow between groups, or more simply, structural holes" (p. 353).

Second, the broker must be capable of managing a diverse array of partners and drawing out, absorbing, and recombining the knowledge obtained from its partners in creative ways. For example, Burt (2004, p. 354, emphasis added) suggests that structural hole spanners are "able to see early, see more broadly, and translate information across groups" and that this "ability to learn" and "select" is important because integrating disparate ideas is "difficult"; thus, the skill of "synthesis" is an important dimension of brokerage (see pp. 354–357).

Third, knowledge flows occur from the partner to the broker, which in our setting is consistent with the purpose of a technology development alliance relationship. Returning to Burt (2004), this condition emerges in his recognition that, whereas mere observation of the problems or issues faced by disconnected partners is a basic form of brokerage, exchanging information is a "higher level of brokerage" (p. 355) essential for "learning and creativity" (p. 356). The stronger the presence of these conditions, the more likely brokerage will result in innovativeness. The latter two conditions are implicit in extant treatments of structural holes.

Our key insight is to point out that in a network spanning multiple countries, the institutional setting in which the broker and its partners are situated creates significant variance in the second and third conditions: the integrative ability of the broker and the extent of knowledge flows from partners to the broker, respectively. Thus, institutions directly affect the mechanisms by which brokers are able to translate their network position into innovation. We focus first on the institutional setting of the broker itself and then on that of its partners, followed by combinations of the institutional settings of both the broker and its partners.

Broker Corporatism

Corporatism imprints organizations with a set of norms and values on how to manage the process of working

with multiple parties. When the broker is from a corporatist country, these norms and values endow the firm with a capacity to benefit from the process of integrating knowledge from disparate and otherwise disconnected alliance partner firms. This imprinting directly gets at the second mechanism referenced earlier, which explains variation in the ability of a firm spanning structural holes to integrate knowledge from its disconnected alters to enhance its innovativeness.

As mentioned previously, social goals in corporatist contexts are accomplished through norms of accommodation of the multiple actors involved in accomplishing these goals. Doing so requires a set of capabilities to understand and manage the diversity of goals and the potential contribution of the many interest groups in the corporatist context (Jepperson 2002). Brokers that originate from such environments are imprinted with this set of values, norms, and capabilities and are therefore better able to translate such capabilities into managing their alliance partners. Indeed, a body of literature has demonstrated the importance of the institutions in the country of origin in affecting the capabilities and strategic behaviors of firms. For example, Holburn and Zelner (2010) argue that the political environment of the country of origin imprints firms' capabilities to engage with actors in different political contexts and influences their overseas location choices. Similarly, we suggest that the collaborative norms present in the corporatist home country of the broker enable it to better manage the knowledge integration process so crucial for structural holes to deliver innovation.

Structural holes put the broker in a position in which it must manage diversity. In an ego network of research and development (R&D) alliances, such diversity manifests itself in the multiplicity of partners with different goals and objectives, in their differences in knowledge profiles, and in the relational qualities of each alliance. Managing such diversity requires both process- and knowledge-based capabilities. The process-related capabilities have to do with managing dyadic alliance relationships (Dyer and Singh 1998) as well as managing the entire set of portfolio partners, with their diverse interests and goals regarding technological development tasks. The knowledge-based capabilities are concerned with integrating multiple sources of technological knowledge through absorptive capacity (Cohen and Levinthal 1990). Corporatism affects both types, which are enhanced in terms of their innovation outcomes when the broker is from a highly corporatist setting. In terms of managing the interests and goals of multiple partners in the network, corporatism is important because the manner in which collective goals are addressed in corporatist countries involves the management of diverse interest groups with disparate goals. As social actors in corporatist settings, firms learn to manage and accommodate diversity through collaboration,

rather than competition, as collaborative approaches are fostered and legitimated by the institutional setting. We propose that the imprinting of these collaborative norms and capabilities becomes particularly useful when the firm spans structural holes because it finds itself in a position in which it encounters a similar imperative to manage diverse interests. Moreover, such imprinting also helps enhance the broker's dyadic alliance skills because the institutional logic of cooperation fostered by corporatism is consistent in many ways with the relational view proposed by Dyer and Singh (1998), which emphasizes the benefits of strong relational skills for alliance success.

In addition, corporatism facilitates absorptive capacity for similar reasons. In the process of engaging with and integrating the interests of multiple groups in corporatist settings to address collective technological objectives, firms are exposed to disparate and assorted knowledge and ideas. We see this process as parallel to the need for brokers to deal with diverse knowledge among their alliance partners. Inasmuch as corporatism imprints firms with skills to absorb such multifarious knowledge, firms from highly corporatist settings should be better able to benefit from brokerage. Importantly, these capabilities directly address the second assumed condition mentioned above regarding the necessary mechanisms for brokerage to lead to innovation. Merely occupying a brokerage position in the network is not sufficient; it is only when the broker is from a highly corporatist context will it derive superior innovation benefits from its integrative capabilities. Thus, it follows that

HYPOTHESIS 1 (H1). *The degree of corporatism in the focal firm's country positively moderates the effect of the focal firm's structural holes on its innovativeness.*

Partner Corporatism

We now turn to the institutional context in which the broker's partners are located, which gets at the third condition necessary for brokerage to produce innovation—the extent of knowledge flows from partners to the broker. When alliance partners are located in low corporatism countries, the logic of competition supersedes the logic of collaboration. Rather than facilitate positive-sum outcomes for the broker and its indirectly connected others, alliance partners assign greater priority to their self-interested objectives and are thus more oriented toward private rather than common benefits (Gulati et al. 2000, Khanna et al. 1998). At the same time, the process through which private benefits are obtained varies across more and less corporatist contexts. As such, whereas partners in competitive (low corporatism) settings form alliances, they are more prone to protect knowledge such as by placing safeguards to protect intellectual property (Oxley and Sampson 2004). This reduces knowledge flows to the broker.

In contrast, in the process of achieving their private innovation goals, partners from more corporatist settings will allow for a greater degree of common benefits to foster partner collaboration. This is because the institutional settings in which they are based have imprinted them with the logic that collaboration is a positive-sum game. Because of strong norms of collaboration and common benefits, highly corporatist partners will transmit more knowledge to the broker than less corporatist partners. It is important to note that we are not implying that such an attitude of stronger exchange on the part of highly corporatist partners is altruistic or based on a naïve assessment of firms' private agendas or goals. Rather, reflective of a feature of highly corporatist institutions, it implies an understanding and an approach whereby individual goals are viewed as better accomplished through accommodation and collaboration. Because of such imprinting, partners from corporatist settings display a willingness to share knowledge with the expectation that such sharing is valuable to accomplish the goals of the partnership and enhance innovation. Thus, we expect that¹

HYPOTHESIS 2 (H2). *The degree of corporatism in the countries of the focal firm's alliance partners positively moderates the effect of the focal firm's structural holes on its innovativeness.*

Partner and Broker Corporatism Combinations

In the following set of hypotheses, we go beyond the idea that firms (whether the broker or its partners) act only in accordance with the institutional scripts of their home countries; here, we argue that firms are also cognizant of their partners' institutional contexts. Consequently, we should expect that firms in a global network will adjust their own behavior according to the combinations of their own and their partners' institutional settings. Thus, in addition to the independent effects of the corporatism of the broker or its partners, we expect that certain combinations of the two will be more likely to enhance the innovation benefits of structural holes than others. The broker's capability to integrate disparate knowledge (the second condition specified previously), a function of its own institutional context, will become more or less valuable depending on the degree of corporatism of its partners' countries. Also, the flow of knowledge from partners to the broker (the third condition for brokerage to work, outlined previously) will vary not only based on their own corporatist contexts but also on that of the broker.

When the broker is based in a low corporatist setting and the partners are based in highly corporatist settings (referred to as the LH combination), the partners are likely to behave differently toward it than if the broker were from a more corporatist setting. This is because partners are more likely to view a broker in a

low corporatist setting with a greater degree of skepticism regarding its motives and incentives relative to a broker based in a highly corporatist setting. Specifically, a broker in a low corporatist setting is more likely to be viewed as an opportunistic actor, appropriating knowledge in a way that is inconsistent with the collaborative norms of knowledge building prevalent in a more corporatist environment. This perception may be well warranted because firms from low corporatist settings are likely to act according to a competitive institutional logic that prompts its partners to question its motives. Put another way, when the broker is from a low corporatism country and its partners are highly corporatist, the latter will be wary of exposing all their knowledge to a broker less interested in common gains. Importantly, we still expect highly corporatist partners to be, on average, more accepting of common benefits, as argued in our second hypothesis, but their propensity to do so would be higher still when the broker too is from a more corporatist setting. Thus, knowledge flows from the partners to the broker (the third assumed condition) may be constrained in the LH situation.

But when both the broker and its partners are based in highly corporatist settings (referred to as the HH combination), they share a common set of collaborative norms and ideals regarding the way in which innovation should be carried out collectively. This congruent combination of collaborative logics is especially germane to the process by which structural holes promote innovation because they enhance both the second and third conditions of the broker's ability to recombine knowledge and of greater knowledge flows from partners to the broker, respectively. This occurs because partners are now more confident in exchanging knowledge with a highly corporatist broker by keeping in mind the collective benefits that might accrue to the network participants. At the same time, the broker has been imprinted with the set of integrative capabilities that enhance its ability to manage its diverse partners and to recombine the knowledge obtained from them. Thus,

HYPOTHESIS 3A (H3A). *The effect of the focal firm's structural holes on its innovativeness will be more positive when the focal firm's and its partners' countries are both highly corporatist (HH) than when the focal firm's country is low on corporatism and its partners' countries are highly corporatist (LH).*

In contrast, when the broker's partners are from low corporatist countries and the broker itself also is based in a low corporatist country (referred to as the LL combination), competitive norms are reinforced. Although there is a congruence of norms in this case toward a more competitive orientation, those norms work against the underlying mechanisms through which structural holes lead to greater innovativeness. In particular, by virtue of being based in a low corporatist country, the broker

has a more limited ability to recombine the diversity in the knowledge held by its partners and to deal with the various interests and goals of those partners—which undermines the second condition. This occurs because less corporatist institutions foster logics of dealing with varied interests and stakeholders in a way that encourages a “go it alone” mentality rather than a collaborative and inclusive approach. In addition, these competitive dynamics limit the flow of knowledge from the partners to the broker—which limits the third condition—because partners are more focused on private gains and place greater emphasis on protecting their intellectual property. In contrast, when the partners reside in a low corporatist environment but the broker resides in a high corporatist country (referred to as the HL combination), the broker is at least more capable of dealing with disparate partners, knowledge, and collaborative approaches in the face of low corporatist partners who compete among each other and have conflicting interests. Therefore,

HYPOTHESIS 3B (H3B). *The effect of the focal firm's structural holes on its innovativeness will be more positive when the focal firm's country is highly corporatist and its partners' countries are low on corporatism (HL) than when the focal firm and its partners' countries are both low on corporatism (LL).*

Data and Methods

We test our hypotheses in the context of the global fuel cell technology network. Fuel cells are electrochemical devices that combine hydrogen and oxygen to produce electricity. This technology arose in the early 1980s as a promising alternative to fossil fuels and has been promoted by governments, environmental groups, and media interested in renewable energy across many industrialized nations. Firms and other organizations responded to these demands by conducting R&D to enhance the ability of fuel cells to power cars, homes, and electronic devices. In this emerging industry, new knowledge creation and diffusion are critical for firms that seek leadership positions (Avadikyan et al. 2003, Teece et al. 1997). Given the newness of this technology, firms conduct the bulk of their fuel cell R&D within their home country, as observed in the context of other technologies such as semiconductors (Macher 2006), and therefore they can be seen as being embedded in their home country's national institutional context. However, alliances with both domestic and foreign partners constitute a key strategy for most fuel cell firms. Thus, the process of innovation in this industry is affected by both national institutions and interfirm relationships, which provides an ideal setting to explore our research questions.

We included in our sampling frame all entities with at least one fuel cell patent application filed with the

U.S. Patents and Trademarks Office (USPTO). Based on expert opinion from a fuel cell patent examiner² and an analysis of patent subclasses identified from the filings of leading fuel cell firms (UTC Power and Ballard Power Systems), we ascertained that fuel cell patents are filed under patent class 429, with subclasses 12–46 categorizing different technological domains. From 4,087 fuel cell patents filed with the USPTO during 1971–2006, we initially identified 138 firms from 11 countries. The unit of analysis for this study is the firm, for which we observed the alliance ego network and innovativeness over time.

Alliance Networks. For each of the 138 firms initially identified from fuel cell patents, we gathered information regarding alliances by searching for corporate press releases of alliance formation as compiled by LexisNexis from public archives of news reports, industry journals, and trade magazines in over 650 titles, including foreign language publications (Hagedoorn and Narula 1996, Ahuja 2000, Rosenkopf and Almeida 2003). We began by using “fuel cell” as a keyword to be as broad as possible. We then narrowed down the articles to the most relevant reports based on an examination of the text. Importantly, we were also able to validate a subsample of these alliances by directly contacting the firms and having them verify the accuracy of our data. The rate of alliance formation increased from only one partnership in Japan in 1981 to 55 new alliances in 2004 spanning many countries.

We tracked each firm’s alliance ego network from the year it formed its first partnership until the year in which it no longer participated in alliances. Although ties typically last for more than one year, alliance termination dates are rarely reported. To skirt this problem, we followed prior research and assumed a five-year productive life span (Gulati 1995, Lavie and Miller 2008). Thus, the network of any given firm increased or decreased in size from year to year depending on whether new alliances were formed or old alliances reached the five-year expiration date. In this manner, we account for how each firm’s network evolved over time. We used 2001 as the cutoff year to observe the alliance networks to allow for a five-year period following the observation of the network to capture innovative output (the last year for which patent data were available was 2006). Thus, for example, for an alliance network observed in 2001 we observed the resulting innovation for the firm between 2002 and 2006. After some loss of data, our final usable alliance sample comprises 626 firm-year ego networks, including 1,728 dyads, spanning the period 1981–2001, for 109 firms located in nine countries.

Variables

Innovativeness. We measured firm innovativeness as the logged value of Trajtenberg’s (1990) citation-weighted patent count formula, $\sum_i (p_i + c_i)$, where p_i is

the number of patents granted to firm i , and c_i represents the number of citations to firm i ’s patents. Citation-weighted counts of patents have the benefit of capturing both the rate (p_i) and impact (c_i) of innovation simultaneously and are widely used in empirical research on organizational innovativeness (Ahuja 2000, Sampson 2007). Jaffe et al. (1993) have shown that most patent applications occur within five years of the R&D investment, which justifies our choice of a five-year postalliance window to observe citation-weighted counts. We note that we only used fuel cell-related patents (USPTO class 429) to measure innovativeness, consistent with our focus on fuel cell technology alliance networks.

The use of patent-based measures to capture innovativeness has substantial precedent in the literature (Gomes-Casseres et al. 2006, Jaffe et al. 1993, Rosenkopf and Almeida 2003). Whereas the limitations of such measures have been highlighted by recent scholars (Alcácer and Gittelman 2006), they remain one of the primary ways to capture innovation because of the systematic, rigorous, and uniform nature of the patenting process. Of course, patents are only proxies for innovation, because they do not capture the success of firms in commercializing technological inventions. However, extant research reveals that in high-technology sectors, there is a strong correlation between patents and R&D investments (Cohen et al. 2002, Pakes and Griliches 1984). Moreover, patents are especially appropriate indicators of innovation in a nascent industry such as fuel cells, where technology is still in the discovery stages and not widely commercialized.

Structural Holes. We used Burt’s (1992) network efficiency variable, calculated based on the equation $[\sum_j (1 - \sum_q p_{iq} m_{jq})] / C_j$.

In this formula, p_{iq} is the proportion of firm i ’s total ties invested in partner q , m_{jq} is the marginal strength of the relationship between firm j and firm q (who are both partners of i), and C_j is the total number of partners in firm i ’s ego network.³ This measure captures the extent of nonredundancy in a firm’s network, where higher values of efficiency (which ranges from 0 to 1) signify a network high in structural holes (Borgatti 1997).

Corporatism. Adopted from Hicks and Kenworthy (1998) and Kenworthy (2003), our measure of national corporatism represents the most comprehensive continuous corporatism score available and aggregates macro- and microlevel dimensions of collaboration (Beramendi and Rueda 2007, Lee 2007, Swank 2008). This measure ranges from 0 to 1 and is highly correlated with alternative noncontinuous variables used in other strands of research in management, sociology, and political science (Jepperson 2002, Murtha and Lenway 1994, Schofer and Fourcade-Gourinchas 2001). The most corporatist countries represented in our data set include Sweden, Denmark, Germany, and Japan; the least corporatist are

the United States, United Kingdom, and Canada. France and Italy lie in the middle.

We measured the degree of corporatism of the focal firm or its alliance partners based on the country in which each firm carried out the bulk of innovative activity as indicated by the location of the majority of its patents' inventors. To aggregate partner corporatism as an ego-network variable, we calculated the average country-level corporatism for the portfolio of each focal firm's alliance partners. We classified the country in which each firm carried out the bulk of its innovative activity based on the location of the inventors in the firm's patents, to ensure that the home country truly represented the institutional environment in which the firm conducted its innovation. This allows us to capture the relevant institutional setting in which a partner firm is actually carrying out innovation. Following this approach, we verified that all firms conducted the vast majority of their innovation in their home countries.

To test H3A and H3B, we split broker and partner corporatism at the median and created four categories capturing the different combinations of focal firm and partner corporatism—both high (HH), both low (LL), high focal firm and low partners' corporatism (HL), and low focal firm and high partners' corporatism (LH). We then interacted each of these categories with the continuous measure of structural holes. In the interest of robustness, we tested for whether the findings are sensitive to splitting corporatism at the mean instead of the median. The results remained unchanged. There are no confounding effects from countries switching categories because countries remain in the "low" or "high" categories during the entire observation period. Although testing a three-way interaction between structural holes, focal firm corporatism, and partner corporatism would be another way to test H3A and H3B, the approach we follow eliminates the challenges of interpreting a complex three-way interaction by reducing it to a series of straightforward two-way comparisons consistent with the hypothesis statements.

Control Variables. We controlled for several additional factors influencing innovativeness. The fixed effects specification in all our models—described in detail below—accounts for all time-invariant factors at the firm, industry, or country level. These fixed effects are especially helpful in ruling out sources of endogeneity based on stable but unobserved capabilities that are likely to explain firm innovativeness (Henderson and Cockburn 1994). To account for variation in innovation related to specific time periods, we also included year fixed effects. In addition, we also controlled for many time-varying factors at the firm, alliance network, and country levels that have been shown to affect innovation.

The focal firm's technological base, which is a proxy for accumulated R&D and absorptive capacity, was calculated as the logged cumulative number of patents up

to the year in which its alliance network was observed. The technological concentration of the focal firm captures the scope of the firm's prior innovations and was calculated using the formula $\sum (n_i/N)^2$, where n_i is the number of patents filed in one of the 35 fuel cell-related subclasses, and N is the total number of patents filed by the firm. Technological age captures the focal firm's experience in the fuel cell domain and was calculated as the number of years since the firm filed its first patent application. We included Freeman's (1979) degree centrality, which captures the prominence of each firm in the overall network of fuel cell innovators and the volume of knowledge that flows to the organization. Characteristics of the focal firm's home country also affect its innovativeness. We thus controlled for the number of voluntary fuel cell industry associations in the focal firm's country. These associations are manifestations of industry-level institutional mechanisms that often provide networking and learning opportunities that may be functionally similar to alliance networks, and thus they may influence the relationship between network structures and innovativeness in those countries. Furthermore, we controlled for the strength of the intellectual property regime in the focal firm's country using Park's (2008) well-known measure.

At the alliance network level, we included many controls. The average age of alliances in the firm's portfolio accounts for the experience firms have in working together in the process of innovation. The ratio of foreign partners accounted for the extent to which the firm's alliances were international or domestic—an especially important control given our emphasis on differences across national institutions. The proportion of equity and multiparty alliances in the portfolio captured the partners' governance and organizational arrangements. To account for the possibility that partners possessing technologically valuable inventions may contribute more to the innovativeness of the firm than partners with less valuable patents, we included the partners' technological value as the ratio of citations to partners' patents relative to all fuel cell patent citations up to the observation year. Also, partners working on the same technologies may be more likely to limit the scope of knowledge sharing for competitive reasons. To account for this, the technological diversity of all partners' patents was calculated in a manner analogous to our measure of focal firm technological concentration, but subtracted from 1 to capture the portfolio's diversity.

We also calculated the geographical concentration of the firm's partners to ensure that our findings were not simply driven by the national configuration of alliance partners. Because we suggest that the willingness to share knowledge is a crucial mechanism affecting firm innovativeness arising from the institutions in which partners are embedded, controlling for alternative explanations based on repeated ties and technological overlap between the firm and its partners becomes

important, especially in light of arguments regarding partner-specific learning (Dyer and Singh 1998). The proportion of repeated ties was calculated as the number of partners with which the focal firm had established at least one alliance prior to the currently observed portfolio (Gulati 1995). Technological distance between the focal firm and its alliance partners was calculated as the square root of $\sum (x_i - y_i)^2$, where $x_i - y_i$ is the difference in the percentage of patents belonging to subclass i between the firm and its partners up until the period of observation.

In addition to characteristics of firm's partners, attributes of partners' countries should also matter. To account for the innovative breadth of partners' countries, we included a measure of the average fuel cell technological diversity (based on a Herfindahl index) of the countries represented in each focal firm's alliance network. To account for the intellectual property regimes within which the partners operated, we included the average strength of the intellectual property laws of each country in the firm's portfolio (Park 2008), weighted by the frequency with which a country appeared in the portfolio. We also controlled for the dispersion in corporatism across the partner's countries by including the standard deviation of partners' corporatism scores.

Additionally, we controlled for several variables that captured the distance between the firm and its partners' country characteristics. To ensure that the effects of partners' corporatism can be distinguished from national cultural characteristics, we calculated the cultural distance between the firm and its partners (Kogut and Singh 1988). This variable is a composite of differences along Hofstede's (1980) four cultural dimensions of uncertainty avoidance, masculinity–femininity, collectivism, and power distance. We averaged the cultural distance between the focal firm and each individual partner to obtain a measure at the ego-network level (Lavie and Miller 2008). In addition, we included several variables to account for the possibility that the countries of the focal firm and its partners may exhibit different degrees of global connectedness (Rangan and Sengul 2009) in the political and economic realms. Our measure of inter-governmental organization (IGO) distance captures the difference between the number of IGOs to which the focal firm's country and the countries of its partners belong. Similarly, we included two measures capturing the differences in inward foreign direct investment (FDI) and in gross national income (GNI) per capita, respectively, to capture the economic distance between the firm's country and those of its partners.

Estimation

Based on the nature of the dependent variable and on the panel structure of the data, we employed a linear fixed effects specification to estimate the impact of structural holes and corporatism on firm innovativeness. As

mentioned earlier, the fixed effects model allows us to account for time-invariant but unobserved sources of heterogeneity that could bias the results if correlated with the error term (Wooldridge 2002). We compared the results of the fixed and random effects specification based on Hausman's test, which clearly favored the former ($p < 0.01$).

Given the need to employ a fixed effects model based on the Hausman test, a comment regarding our measures of corporatism is in order. Like all institutional variables, corporatism is highly stable over time within countries. Thus, our measure of focal firm corporatism is time-invariant, and its main effect cannot be captured in a coefficient through a fixed effects specification because it is averaged out of the equation. In contrast, the measure of partner corporatism changes meaningfully over time because alliance portfolios are modified as partners from various countries are added or removed, and thus its main effect can be estimated through a coefficient. Because we are interested in the interaction of the focal firm and partner corporatism with structural holes rather than in the main effect of focal firm corporatism, we were still able to test our hypotheses.

Specifically, we created an indicator variable coded as 1 if a focal firm hailed from a highly corporatist country (above the sample median) and 0 otherwise. We can then interact this indicator with our measure of network efficiency to compare how structural holes affect innovation for focal firms from high versus low corporatist countries, as per H1 (see Shaver and Flyer 2000 or Alcácer and Chung 2007 for a precedent to this approach). We note that although the main effect of focal firm corporatism is not shown in a coefficient estimate, it is accounted for directly by the fixed effects specification. Also, we found robust results whether we categorized high corporatism as above the mean or median degree of focal firm corporatism in our sample. In addition, to interpret the significance of all interaction effects, we follow the procedure suggested by Zelner (2009) and King et al. (2000) by graphing the interactions and showing the range over which they are significant within our sample. This methodology has the advantage of providing information not only on whether the average interaction effect is significant but also on the points along the whole range of observation in which our two variables of interest may (or may not) meaningfully interact.

Results

Tables 1 and 2 display the descriptive statistics and correlations, respectively. Model 1 in Table 3 includes the control variables plus the main effects of the focal firm's structural holes and its partners' corporatism. Although we did not explicitly provide a hypothesis regarding the main effect of structural holes, we found that it

Table 1 Descriptive Statistics

Variable	Mean	S.D.	Min	Max
<i>Innovativeness</i> (log)	1.03	2.92	−2.30	6.81
<i>Technological base</i>	0.76	2.03	−2.30	4.84
<i>Technological concentration</i>	0.35	0.36	0	1
<i>Technological age</i>	9.49	8.10	0	30
<i>Degree centrality</i>	6.42	9.05	0.97	100
<i>Multiparty alliances</i>	0.55	0.44	0	1
<i>Equity alliances</i>	0.27	0.39	0	1
<i>Repeated alliances</i>	0.27	0.98	0	10
<i>Age of alliances</i>	2.55	1.23	1	5
<i>Technological value</i> (portfolio)	0.01	0.02	0	0.09
<i>Technological distance</i>	0.63	0.34	0	1.41
<i>Technological diversity</i> (portfolio)	0.76	0.30	0	1
<i>Foreign alliances</i>	0.39	0.43	0	1
<i>Intellectual property strength</i>	4.49	0.42	3.28	4.88
<i>Cultural distance</i>	0.65	1.05	0	5.22
<i>Fuel cell associations</i>	0.09	0.12	0	1
<i>IGO distance</i>	1.61	5.19	0	46.95
<i>FDI distance</i>	1.22	3.53	0	27.60
<i>GNI distance</i>	0.72	1.82	0	17.66
<i>Number of countries</i> (portfolio)	1.57	1.10	1	7
<i>Intellectual property strength</i> (portfolio)	4.48	0.40	3.28	4.88
<i>Geographic concentration</i> (portfolio)	0.79	0.35	0	1
<i>Country tech. diversity</i> (portfolio)	0.93	0.05	0.5	0.96
<i>Partner corporatism variation</i>	0.13	0.17	0	0.42
<i>Partner corporatism</i>	0.36	0.30	0.01	0.92
<i>Structural holes</i>	0.89	0.19	0.33	1

had a marginally positive effect on firm innovativeness ($p < 0.10$)—consistent with prior theories that suggest firms can obtain creativity benefits from this network position. Our primary interest lies in how corporatism modifies this effect. We added the interaction between structural holes and focal firm corporatism in Models 2 and 4. In support of H1, we found that structural holes have a more positive effect when the focal firm hails from a country with a high degree of corporatism than when it originates from a low corporatism country ($p < 0.05$). We also found support for H2 in Models 3 and 4, which demonstrate that focal firms benefit more from spanning structural holes when their partners originate in highly corporatist countries than in low corporatist countries ($p < 0.05$).

To aid in the interpretation of these effects, Figures 1 and 2 depict the interactions called for in H1 and H2, respectively. Figure 1 shows that as structural holes increase, focal firms from highly corporatist countries (above the sample median) increase in innovativeness. This contrasts clearly with firms from low corporatism countries, whose innovativeness declines slightly as structural holes increase. The differences across low and high corporatism remain significant at $p < 0.05$ throughout the entire range for which structural holes are observed, clearly supporting H1. Figure 2 demonstrates the interaction for partner corporatism. The depiction

generally supports H2 but is more nuanced than that for H1. As expected, the slope of the innovativeness line increases significantly more steeply when the focal firm's partners tend to come from highly corporatist countries than from less corporatist countries. The overall level of innovation, however, is higher for brokers with less corporatist partners. This difference is significant until efficiency—the measure of structural holes—reaches 0.7, after which the two lines are not statistically distinguishable. Thus, corporatism combines with structural holes to increase the rate of innovativeness for firms up to a moderately high degree of structural holes.

Models 5 and 6 show the interaction of structural holes with different combinations of focal firm and partner corporatism. Each model conveys the same information, but the combination used as the base category to which the other three combinations are compared changes. To test H3A, Model 5 uses the LH combination as the comparison. Consistent with our expectations, the HH combination interacts more positively with structural holes than the LH combination ($p < 0.05$). Model 6 uses the LL combination as a baseline to test H3B. The results show that the HL combination interacts more positively with structural holes than the LL combination ($p < 0.05$). The two strongest combinations are the HH and HL, and the two weakest are the LH and LL. These interactions are depicted in Figures 3(a) and 3(b).

Robustness Checks. Although the fixed effects specification we employed accounts for time-invariant sources of endogeneity, unobserved factors that vary throughout the time frame of our study could also be problematic. Corporatism is clearly an exogenous variable beyond the control of firms, but structural holes could be subject to this source of endogeneity. To account for this possibility, we ran additional models using instrumental variables in place of structural holes. We instrumented network efficiency following the approach of Zaheer and Soda (2009), who utilized past (expired) network characteristics to instrument current structural holes. In our case, we utilized three lags of efficiency ($t - 1$, $t - 2$, and $t - 3$), as well as past status based on a lagged measure of power centrality (Bonacich 1987). We ensured that these instruments met the necessary criteria for relevance, exogeneity, and overidentification (Bascle 2008). The results (tables not shown, but available from the authors upon request) were estimated through two-stage least squares (2SLS) and limited information maximum likelihood (LIML) models to ensure robustness. Through this approach, we found strong support for H1, H2, and H3A. H3B was not supported. Overall, however, the findings were highly consistent with those reported in the main analysis. Another benefit of 2SLS or LIML was that they allowed us to test for the possibility of mediation (Shaver 2005). Whereas our interest is in how corporatism moderates the relationship between structural

Table 2 Correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1 Innovativeness (log)																									
2 Technological base	0.32																								
3 Technological concentration	−0.32	0.01																							
4 Technological age	0.14	0.73	−0.03																						
5 Degree centrality	0.25	0.11	−0.04	−0.02																					
6 Multiparty alliances	−0.01	−0.02	0.16	−0.03	0.25																				
7 Equity alliances	−0.21	−0.17	−0.04	−0.15	−0.06	−0.10																			
8 Repeated alliances	0.05	0.11	−0.07	0.07	0.18	0.07	0.08																		
9 Age of alliances	−0.03	0.12	−0.06	0.12	−0.05	0.07	0.01	0.04																	
10 Technological value (portfolio)	0.11	0.08	−0.05	0.03	−0.03	−0.06	−0.10	−0.08	−0.02																
11 Technological distance	−0.27	−0.17	0.73	−0.14	−0.06	0.07	−0.02	−0.14	−0.04	−0.20															
12 Technological diversity (portfolio)	0.09	0.23	−0.03	0.14	0.04	0.02	0.01	0.08	−0.01	0.30	−0.65														
13 Foreign alliances	−0.02	−0.07	0.00	−0.11	−0.10	−0.13	0.10	0.07	−0.09	0.16	−0.05	0.05													
14 Intellectual property strength	−0.11	0.14	0.05	0.22	−0.43	−0.19	0.06	0.02	−0.09	0.08	−0.04	0.15	0.03												
15 Cultural distance	−0.06	−0.12	−0.10	−0.17	−0.10	−0.07	0.24	−0.06	−0.02	0.10	−0.15	0.12	0.73	0.02											
16 Fuel cell associations	−0.11	0.03	0.18	0.04	−0.15	0.03	0.00	0.05	−0.02	0.02	0.10	0.03	0.07	0.31	−0.03										
17 IGO distance	−0.06	−0.17	−0.11	−0.14	−0.08	−0.15	0.23	−0.04	−0.02	0.07	−0.12	0.08	0.36	−0.01	0.35	0.09									
18 FDI distance	−0.05	−0.01	−0.02	0.01	−0.10	0.00	0.00	−0.01	−0.20	0.06	−0.04	0.01	0.28	0.14	0.17	0.20	0.01								
19 GNI distance	−0.08	−0.11	0.05	−0.12	−0.11	0.02	0.04	−0.01	−0.09	0.09	−0.01	0.07	0.35	0.08	0.34	0.03	0.10	0.36							
20 Number of countries (portfolio)	0.07	0.16	−0.01	0.08	0.24	0.11	−0.03	0.59	−0.04	−0.10	−0.14	0.14	0.30	0.09	0.12	0.05	−0.05	0.06	0.07						
21 Intellectual property	−0.10	0.11	0.07	0.11	−0.30	−0.12	0.02	0.04	−0.11	0.14	−0.03	0.14	0.03	0.64	0.08	0.27	0.00	0.20	0.13	0.15					
22 Strength (portfolio)																									
23 Geographic concentration (portfolio)	−0.02	0.00	0.03	−0.01	−0.01	−0.01	−0.09	−0.19	0.03	0.29	0.30	−0.40	−0.16	0.01	−0.19	−0.03	−0.04	−0.05	−0.11	−0.27	0.09				
24 Country tech. diversity (portfolio)	0.08	0.20	−0.09	0.12	−0.04	0.03	−0.20	0.06	0.04	0.11	−0.15	0.10	−0.21	0.10	−0.18	0.07	−0.08	0.02	−0.05	0.14	0.36	0.19			
25 Partner corporatism variation	0.07	0.10	0.04	−0.01	0.16	0.11	−0.04	0.25	0.02	−0.07	−0.07	0.13	0.05	0.05	−0.01	0.00	−0.11	−0.02	−0.05	0.51	0.13	0.01	0.18		
26 Structural holes	0.06	−0.09	−0.03	−0.16	0.24	0.10	0.03	−0.05	0.03	0.04	−0.05	0.04	0.00	−0.26	0.03	−0.15	0.12	−0.10	−0.04	−0.04	−0.19	−0.04	−0.15	0.01	
	−0.02	−0.11	−0.10	−0.09	−0.13	−0.30	0.10	−0.04	0.04	−0.03	0.01	−0.14	0.09	0.02	0.09	−0.02	0.09	0.01	−0.02	−0.12	−0.02	−0.11	−0.12	−0.33	0.04

Table 3 Fixed Effects Estimation Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Firm, country, industry, and year FE	Y	Y	Y	Y	Y	Y
Focal firm controls						
<i>Technological base</i>	−0.4362*** (0.1267)	−0.4538*** (0.1307)	−0.4283*** (0.1271)	−0.446*** (0.1309)	−0.4481*** (0.1307)	−0.4481*** (0.1307)
<i>Technological concentration</i>	0.3864 (1.0419)	0.2144 (1.0555)	0.4397 (1.0452)	0.2602 (1.0565)	0.2406 (1.0619)	0.2406 (1.0619)
<i>Technological age</i>	−0.6023*** (0.1138)	−0.5944*** (0.1121)	−0.6063*** (0.1145)	−0.5987*** (0.1127)	−0.5996*** (0.1141)	−0.5996*** (0.1141)
<i>Degree centrality</i>	0.046** (0.0211)	0.0494** (0.0219)	0.0465** (0.0207)	0.05** (0.0214)	0.0494** (0.0218)	0.0494** (0.0218)
<i>Intellectual property strength</i>	1.6527* (0.9811)	1.6148* (0.9713)	1.681* (0.9792)	1.6415* (0.9683)	1.5833 (0.9724)	1.5833 (0.9724)
<i>Fuel cell associations</i>	0.856 (1.3139)	0.8906 (1.2876)	0.7365 (1.3069)	0.7594 (1.2790)	0.8796 (1.2960)	0.8796 (1.2960)
Alliance portfolio controls						
<i>Multiparty alliances</i>	0.4352 (0.4071)	0.4599 (0.3987)	0.4244 (0.4060)	0.4494 (0.3975)	0.4729 (0.4019)	0.4729 (0.4019)
<i>Equity alliances</i>	0.0804 (0.5442)	0.1568 (0.5239)	0.0513 (0.5493)	0.1256 (0.5286)	0.1693 (0.5260)	0.1693 (0.5260)
<i>Repeated alliances</i>	0.033 (0.1170)	0.0392 (0.1165)	0.0357 (0.1165)	0.0417 (0.1155)	0.0500 (0.1154)	0.0500 (0.1154)
<i>Age of alliances</i>	−0.059 (0.0813)	−0.0571 (0.0801)	−0.0484 (0.0834)	−0.0457 (0.0823)	−0.0549 (0.0805)	−0.0549 (0.0805)
<i>Technological value</i>	6.896 (13.4069)	5.5081 (13.5639)	6.5724 (13.3840)	5.1534 (13.5697)	5.5146 (13.5322)	5.5146 (13.5322)
<i>Technological diversity</i>	−0.7324 (1.1121)	−0.499 (1.1195)	−0.8103 (1.1294)	−0.5755 (1.1368)	−0.5059 (1.1322)	−0.5059 (1.1322)
<i>Foreign alliances</i>	1.0156 (0.6889)	1.1726* (0.6438)	1.0766 (0.7036)	1.2362* (0.6532)	1.1844* (0.6422)	1.1844* (0.6422)
<i>Number of countries</i>	0.1657 (0.1556)	0.1402 (0.1553)	0.1444 (0.1597)	0.1171 (0.1585)	0.1448 (0.1567)	0.1448 (0.1567)
<i>Intellectual property strength</i>	−0.3113 (0.5508)	−0.3546 (0.5530)	−0.298 (0.5428)	−0.3417 (0.5461)	−0.3410 (0.5526)	−0.3410 (0.5526)
<i>Geographic concentration</i>	0.3957 (0.6069)	0.4901 (0.6203)	0.3354 (0.6164)	0.4267 (0.6303)	0.4835 (0.6182)	0.4835 (0.6182)
<i>Country technological diversity</i>	4.6475* (2.5431)	4.3728* (2.5116)	4.668* (2.5628)	4.3907* (2.5266)	4.1308* (2.4736)	4.1308* (2.4736)
<i>Partner corporatism variation</i>	0.2826 (0.6030)	0.2176 (0.5991)	0.4391 (0.6081)	0.3871 (0.6047)	0.1157 (0.6157)	0.1157 (0.6157)
Firm–portfolio distance controls						
<i>Technological distance</i>	−1.0938 (1.5297)	−0.9257 (1.5196)	−1.16 (1.5303)	−0.9907 (1.5171)	−0.9312 (1.5267)	−0.9312 (1.5267)
<i>Cultural distance</i>	−0.4777 (0.3550)	−0.5233 (0.3391)	−0.4873 (0.3602)	−0.5346 (0.3428)	−0.5290 (0.3406)	−0.5290 (0.3406)
<i>IGO distance</i>	−0.0537 (0.0552)	−0.0533 (0.0553)	−0.0562 (0.0561)	−0.0556 (0.0562)	−0.0576 (0.0552)	−0.0576 (0.0552)
<i>FDI distance</i>	−0.0194 (0.0364)	−0.0231 (0.0370)	−0.0197 (0.0358)	−0.0227 (0.0364)	−0.0254 (0.0358)	−0.0254 (0.0358)
<i>GNI distance</i>	−0.1268 (0.0924)	−0.1349 (0.0947)	−0.1263 (0.0910)	−0.1331 (0.0933)	−0.1322 (0.0946)	−0.1322 (0.0946)

holes and innovativeness, it is conceivable that structural holes may mediate the effect of corporatism on innovativeness. We found no evidence of mediation.

Norms fostered by institutions serve as one of the key mechanisms we propose as driving the observed effects. As in all studies of institutions based on secondary

data, direct observation of the operation of norms is challenging. Inasmuch as norms vary across low and high corporatism, the contingent effects we have reported so far are consistent with the notion of norms driving the effects. As a further way to ascertain this, we ran an additional test to specifically assess whether norms of

Table 3 (cont'd)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Independent variables						
Partner corporatism	−0.1175 (0.2358)	−0.1363 (0.2378)	−2.2729* (1.3428)	−2.4492* (1.3178)	−0.4816 (0.4165)	−0.4816 (0.4165)
Structural holes	1.2272* (0.7831)	−0.3164 (0.8062)	0.3541 (0.9173)	−1.2746 (0.9733)	−0.197 (0.8147)	−0.5427 (0.8539)
Structural holes × Partner corp.			2.2625** (1.3523)	2.4242** (1.3221)		
Structural holes × High firm corporatism		2.2355** (1.1302)		2.2696** (1.0857)		
Structural holes × (High firm corp. & High partner corp.)					2.2060** (1.1338)	2.5517** (1.2170)
Structural holes × (Low firm corp. & High partner corp.)						0.3457 (0.3317)
Structural holes × (High firm corp. & Low partner corp.)					2.0606** (1.1046)	2.4063** (1.1585)
Structural holes × (Low firm corp. & Low partner corp.)					−0.3457 (0.3317)	
Sample size	626	623	626	623	626	626
R-squared	0.4614	0.4666	0.4647	0.4703	0.4672	0.4672
Log likelihood	−970.8079***	−964.6231***	−968.8645***	−962.4154***	−967.3878***	−967.3878***

Note. FE, fixed effects.

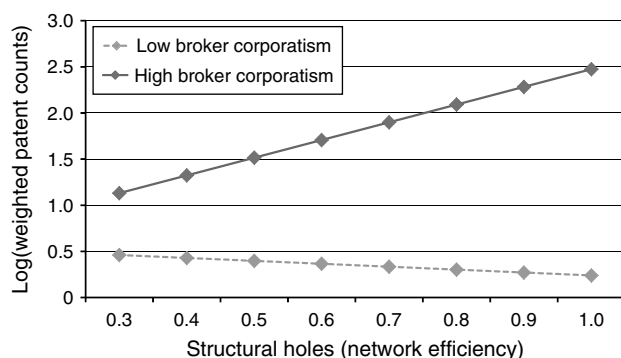
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (one-tailed tests of hypotheses).

collaboration are behind the positive moderating effect of partner corporatism (per H2). Specifically, we should observe that partner corporatism interacts more positively with structural holes as the focal firm's ego network is composed of partners residing in the same country instead of partners dispersed across multiple institutional environments. This should be so because geographic collocation is associated with a strengthening of collaborative norms if partners are in a single corporatist setting, whereas geographic dispersion inherently relates to a multiplicity of norms as partners hail from various backgrounds. Consistent with this logic, we found that the interaction of structural holes with partner corporatism

has a more positive effect on innovation when partners are concentrated in the same country than when partners are fully dispersed across different countries—a difference that was statistically significant.

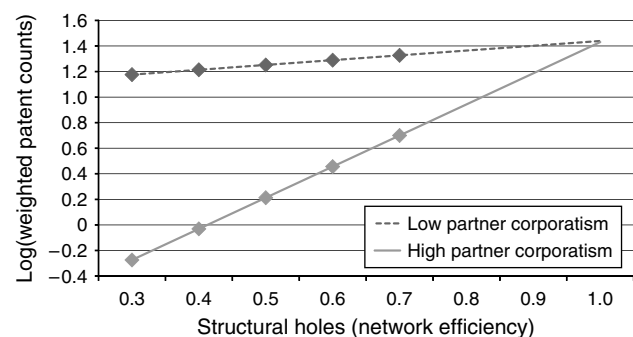
One factor that could counter the effect of home country corporatism is the extent to which a firm has R&D activities in foreign countries. A firm with high levels of foreign R&D may not act based on the norms of its home country corporatism, but rather based on those of the places where its technological development is conducted. This is partly countered by the fact that, as we looked at the data, we found that the vast majority of fuel cell R&D is conducted in the firm's home country. However, to make sure this alternative factor did not bias

Figure 1 Interaction of Structural Holes and Broker Corporatism (Hypothesis 1)



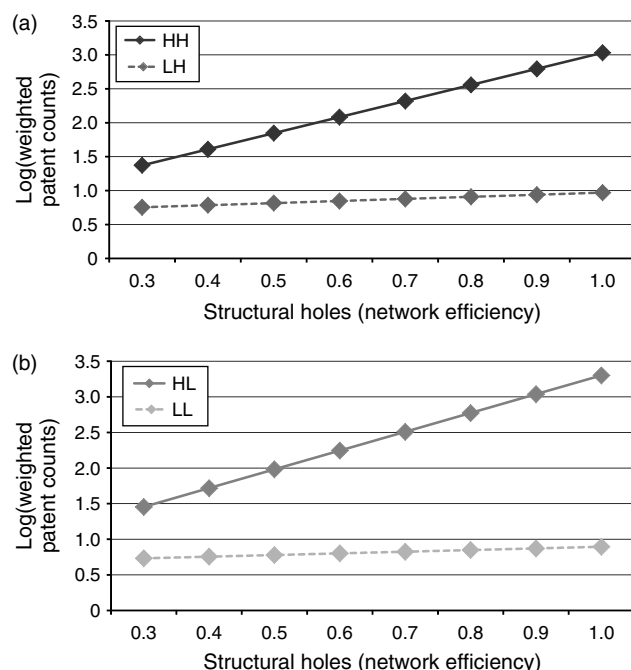
Note. A diamond marking a point indicates that the corresponding estimates in each line are significantly different from each other ($p < 0.05$), based on the approach recommended by Zelner (2009) to assess interaction effects.

Figure 2 Interaction of Structural Holes and Partner Corporatism (Hypothesis 2)



Note. A diamond marking a point indicates that the corresponding estimates in each line are significantly different from each other ($p < 0.05$), based on the approach recommended by Zelner (2009) to assess interaction effects.

Figure 3 Interaction of Structural Holes and Various Combinations of Focal Firm and Partner Corporatism (Hypotheses H3A and H3B)



Note. A diamond marking a point indicates that the corresponding estimates in each line are significantly different from each other ($p < 0.05$), based on the approach recommended by Zelter (2009) to assess interaction effects.

our results, we created a variable counting the number of inventors of each firm residing in a foreign country. We reasoned that the more foreign inventors in a firm's patent portfolio, the more likely a firm was to have foreign R&D facilities participating in fuel cell alliances. After including this measure, our findings remained as already reported. As fuel cell R&D becomes more globalized within firms, however, it would be interesting to assess if and when the home country institutional context diminishes in importance.

To rule out the possibility that our hypothesized relationships are driven by the window of time during which firms' innovation outcomes are observed, we estimated the hypothesized relationships for a window of 10 instead of 5 years. Our findings were generally consistent across both windows of time. We also attempted to validate the underlying mechanism of heterogeneity in knowledge flows emanating from the different logics of collaboration underpinning our hypothesized relationships. To do this, we estimated the joint effect of corporatism and structural holes on citations to the partners' patents, reasoning that exchange of knowledge should be enhanced by certain combinations of structural holes with focal firm or partner corporatism. Our findings were supportive of our theory and findings, and they revealed that high partners' corporatism enhanced the relationships between structural holes and knowledge flows between partners and the focal firm.

Discussion

Our overarching goal was to address a fundamental disconnect in the literature, which has tended to treat interfirm networks—even those that cross national borders—as acontextual. We argued that, given the likely effect of the underlying institutional setting on the fundamental exchange processes that occur within interfirm networks, to ignore the institutional contexts in which networks are embedded implies that most research examining network effects on firm-level outcomes is underspecified. Such issues become even more salient when cross-border networks span multiple institutional fields. Recent research has begun to recognize such a connection between institutions and networks (Xiao and Tsui 2007, Luo and Chung 2005, Powell et al. 2005), and we advance this nascent area of inquiry by showing that important firm outcomes depend on institutional as well as network factors. Our theoretical argument turns on the crucial idea that network positions are likely to operate differently across institutional settings of high and low corporatism. Our study is important for understanding the link between institutions and networks in explaining organizational outcomes, specifically innovation arising from firms' positions in cross-border alliance networks.

Overall, our work suggests that network and institutional research—two of the most prominent areas of study in organizational research—cannot be considered independent of each other. Moreover, both bodies of literature can be greatly enriched by taking into account the fact that, with the rise of globalization, organizations and networks now span multiple national, cultural, and institutional contexts. Given that national institutional contexts vary substantially, the consequences of the configuration of firms' cross-border networks across different institutional contexts becomes an important area of inquiry. More generally, although research has examined the network outcomes of globalization, or how firms are driven by network antecedents to become more global (Guler et al. 2002, Whittington et al. 2009), it has not yet assessed the implications of the interorganizational network itself being globalized. Examining institutional influences on such globalized networks, and their outcomes for firms, presents an important new angle for a deeper understanding of the consequences of networks.

Our results showed that structural holes have a more positive impact on innovation when the brokering firm or its network partners are located in countries with higher levels of corporatism. This implies that firms must not only match their network structures to the outcomes they wish to obtain in the knowledge-gathering and knowledge-transferring process, but they must also consider whether their partners will behave collaboratively based on the institutional norms with which they have been imprinted. Interestingly, even though the marginal effect of partners' corporatism is found to improve the

innovativeness achieved from spanning structural holes, having less corporatist partners results in higher absolute innovation performance for firms (Vasudeva et al. 2012). This finding suggests that when considered by themselves, institutions and network structures may lead to very different conclusions about their effects on firms' innovation, thereby underscoring the importance of considering their joint effects. These results imply that firms with partners from highly corporatist countries could overcome their lower baseline innovativeness, as found in a recent study by Vasudeva et al. (2012), by increasing the degree to which they span structural holes.

Perhaps even more provocatively, the arguments we present suggest that brokers hailing from a highly corporatist context are more capable of managing the inherent diversity with which firms must deal when spanning structural holes. Although we have suggested that these capabilities could be both knowledge related (i.e., absorptive capacity) or relationally and process focused (e.g., managing multiple interests, enhancing dyadic relations), further research is needed to directly observe these capabilities, which we have argued theoretically and inferred empirically.

Beyond the main effects of broker and partner corporatism, some combinations of the two—specifically, cases in which both firms hail from high corporatism countries (HH) or when the broker's country is highly corporatist but its partners' countries are less corporatist (HL)—enhance the effects of structural holes on innovation most. These findings get at the possibility that firms not only behave according to the institutional logics to which they are accustomed but also adjust their behaviors depending on the institutional background of the firm with which they are interacting. For example, we suggested in our arguments for H3A that highly corporatist firms limit the extent of knowledge flows with brokers from low corporatism countries because they may be wary of exchanging too much with a firm imbued with a logic of fostering competition and private gains. Another interesting implication of H3A and H3B is that high broker corporatism is necessary and sufficient on its own for structural holes to enhance innovation, whereas partner corporatism is insufficient by itself. Rather, having highly corporatist partners enhances brokerage only when partners feel “safe” in exchanging knowledge with highly corporatist brokers who have a shared appreciation for collaboration, mutual problem solving, and the pursuit of common gains as a means to achieving private benefits.

More generally, our arguments and results provide an institutionally based explanation for the constraints and opportunities that networks create for organizations. Although classic structuralist arguments provide a framework to understand why social capital accrues to actors within networks, they have limits in explaining the underlying mechanisms behind the effects of network

positions on organizations. For example, Salancik (1995) wonders why structural holes work in organizational settings if disconnected partners observe the benefits accruing to the broker and goes as far as calling for “a good network theory of organization” capable of explaining the motivations behind firms' willingness to participate in networks. We respond to this call by suggesting that institutional logics of collaboration or competition provide a powerful theoretical explanation for the conditions under which the broker will be able to integrate nonredundant knowledge from its partners and under which knowledge will flow from partners to the broker. More broadly, observing that the same structural position can lead to different innovative outcomes contingent on the institutional logic raises a strong case for additional research on the process dimensions of how network advantages are related to specific configurations of ties.

Another implication of our work is that firms may have latitude in overcoming institutional constraints through the configuration of their networks. Although we do not model the network formation process, the issue of cross-national dispersion in networks raises the possibility that firms can span multiple institutional fields through the global configuration of alliances. Prior research has noted that multinational corporations (MNCs) are embedded in multiple institutional fields (Westney 1993) and has conceptualized the MNC as a global network of subsidiaries (Ghoshal and Bartlett 1990). Our study raises a related point, but instead of the organization directly spanning multiple fields through its subsidiaries, it may need to deal with many different national institutions because of the global nature of its portfolio of network partners (Zaheer and Hernandez 2011). This area of research is only beginning to be explored (Lavie and Miller 2008) and represents a promising direction for further inquiry.

Limitations and Directions for Future Research

Although we are careful to detail the characteristics of corporatism to theoretically explain how such a national institution affects networks, we do not directly observe the micro behaviors of brokers and their partners across the different institutional contexts central to our arguments. Our approach has been to assess moderating effects that are consistent with changes in the underlying mechanism we propose, but further work using direct observation is necessary. Furthermore, we recognize that patents represent only one type of innovative output, and that innovation may be measured through other indicators. Patents are a good indicator of innovation in the nascent fuel cell industry, where new technologies are still being developed and commercialization is still developing. Yet this raises the possibility that, in contexts in which commercialization is more advanced, the

relationships between institutions, networks, and innovation might be different than in our setting.

In addition, competition among alliance partners arises from sources not captured directly by low versus high corporatism. We address this limitation by including relevant controls such as partners' technological relatedness and diversity, and geographical collocation, which could serve as proxies for other indicators of competition among partners. At the same time, many organizational-level controls are unavailable for the privately held firms in our sample. We address this potential issue empirically by using firm fixed effects, yet this does not address the omission of time-variant firm characteristics. Our use of instrumental variables mitigates this problem, but it does not fully eliminate it. Finally, we assessed the effects of only one type of institution that operates at the national level. Our understanding of the embeddedness of networks in larger institutional contexts can be enriched by focusing on different types of institutions operating at different levels of analysis (e.g., industries) to determine whether they moderate the effect of network structures on innovation in different ways.

Concluding Remarks

The vast literature on the outcomes of interfirm networks has focused on the effects of brokerage, or spanning structural holes, on firm performance, but it has neglected the context in which the networks themselves are embedded. We suggest that the institutional setting in which network participants reside has an important influence on their orientations and knowledge integration capabilities because of the norms and values that these institutions imprint on the societal actors comprising the network. Arguing that corporatism is an important institutional construct embodying propensities for collaboration versus competition, we propose that the innovativeness of firms spanning structural holes in their alliance networks is contingent on the degree of corporatism of the countries in which they and their alliance partners are based. We find that the degree of corporatism in the home countries of the broker and its alliance partners—both separately and jointly—enhances the innovativeness of the broker, suggesting that incorporating institutional effects is crucial for a more complete understanding of how interorganizational networks affect innovation. In sum, network embeddedness is itself embedded in the institutional context that shapes the outcomes firms obtain from their brokerage positions.

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Endnotes

¹It is important to note that our arguments do not depend on the broker's partners being aware that they are being brokered. Corporatism affects the norms of exchange between the firm and its partner, and those norms are separate from a given structural position or awareness of that position. The structural position occupied by the broker interacts with firms' institutional backgrounds to determine whether or not structural holes accomplish their innovative potential.

²Stephen J. Kalafut (P/1745, Group Art Unit 1745, USPTO).

³ m_{jq} captures the ratio between the interaction of firm j with firm q divided by the strongest of j 's relations with any other team. Put mathematically, $m_{jq} = (Z_{jq} + Z_{qj}) / \max(Z_{jk} + Z_{kj})$.

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