

Occasional Paper Series

**How Corporatist Institutions Influence Firms'
Knowledge-Building Alliance Strategies: Empirical
Evidence from Fuel Cell Technology Development**

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Flows of knowledge, technology and financial capital have become the cornerstone of the global economy. A wide variety of mechanisms such as trade, foreign direct investment and more recently alliances involving domestic and multinational enterprises (MNEs) have been regarded as instrumental for these flows (Kogut and Zander, 2003; Held, McGraw, Goldblatt and Pettigrew, 1999). Technology alliances are particularly interesting and important because they contribute to technological innovation and enable knowledge spillovers or “internalized” transfer of both tacit and codified knowledge across partners from diverse cultural, political, social and economic environments. In doing so, alliances can reduce the costs of transacting through the market (Grant and Baden-Fuller, 2002). Curiously, even large multinational enterprises that could transfer knowledge internally (Almeida, Song and Grant, 2002) or through acquisitions (Bersman, Birkinshaw and Nobel, 1999), at least as efficiently, prefer the alliance mechanism in several instances. This observation aligns well with Coase’s (1937) argument that there may be decreasing returns to the entrepreneurial function as the transaction costs of organizing increase with the size of the firm. Alternative explanations for why firms engage in alliances as opposed to transferring knowledge through other mechanisms are rooted in institutional explanations (Parkhe, 1993) and social relationships (Eisenhardt and Schoonhoven, 1996) that are not factored completely into standard transaction-cost theorizing.

In the early stages of technology development, alliances can be particularly beneficial as a mechanism for accessing a wide range of knowledge in the national and global innovation systems (Kogut, 1988; Hamel, 1991) as well as for sharing knowledge to improve innovatory performance (Appleyard, 1996; Spencer, 2003a). The alliance literature recognizes, however, that the benefits of technology cooperation are not without costs associated with managing the complexity of alliances. The possibility of premature dissolution and poor performance can impose heavy penalties on the alliance partners (Parkhe, 1993; Park and Russo, 1996; Park and Ungson, 1997).

Applying Williamson’s (1991) ‘shift parameter framework’ for example, Oxley (1999) found that changes in the national institutional environment elicit shifts in the governance structure of alliances. Oxley (1999) drew on differences in intellectual property regimes to postulate hypotheses concerning the structure of alliances, wherein the degree of hierarchical controls tilting towards the joint venture mode in alliances was inversely related to the strength of intellectual property regime in the country of the alliance partner.

Similarly, Oliver (1997) argued that the institutional environment has a profound influence on the firm’s ability to mobilize and access external resources for sustained competitive advantage. Therefore, given the importance and complexity of alliances, an integrative framework that combines firm-level resources with institutional effects to explain alliance formation and productivity of alliances, measured by knowledge spillovers, emerges as an area worthy of attention.

Alliances may be defined as cooperative systems that emerge in relation to a broader system of formal and informal codes. North (1991) described these codes as institutions constraining political, economic and social interaction. Since the present study is concerned with research and development (R&D) alliances in the early stages of fuel cell technology (FCT) development, the national institutional environment within which innovation occurs is expected to play an especially important role (Spencer, 2003b). This is because national institutions¹ shape the technology policies, capabilities and preferences of technological communities within the national innovation system (Nelson and Rosenberg, 1993). Consequently, the organizational capabilities and strategies of firms are at least partially contingent on the national institutional context within which innovation occurs (Lewin and Kim, 2004).

For the purpose of this study, the national institutional environment of relevance refers to the country² in which the firm carries out the bulk of its R&D activity, or the predominant *location of innovation* (Almeida, 1996). In

¹ In recent years, the sanctity of institutions at the level of the nation-state has stirred an active debate in the context of globalization (for a review see Guillen, 2001). Among the notable empirical studies on the subject, Garrett (1998) provided evidence on at least two divergent paths—one adhering to neoclassical economics, and the other to social democratic corporatism in industrialized countries. Even if the hypothesis of isomorphism of world societies (Meyer, Boli, Thomas and Ramirez, 1997) is to be regarded as an acceptable transformation, as Meyer and Hannan (1979) noted themselves, similarities of form do not automatically guarantee equalities of outcome or productivity. By accounting for institutional differences in technological innovation, this study expects to contribute to understanding a central issue for technology development and economic prosperity.

² In most cases, firms undertake the bulk of their R&D effort in their home country (Vernon, 1966; Porter, 1990). Dunning and Narula (1995), for example, found no support for the hypothesis that foreign multinationals concentrate their R&D effort in sectors of the host country’s comparative advantage. Contingency based

fuel cell technology development, however, in less than 2% of a sample of about 10,000 patents, one or more of the inventors are located outside the home country of the assignee firm. The small proportion of inventive activity carried out overseas lends support to the proposition that both domestic and multinational firms prefer to carry out the bulk their innovative activity in the home country (Wade, 1996; Held, McGrew, Goldblatt and Perraton, 1999). However, there are instances when a firm may be headquartered in one country but prefers to carry out bulk of the R&D effort in another country—the most notable examples, in the case of fuel cell technology development are Siemens-Westinghouse and Daimler-Chrysler. Both firms are headquartered in Germany, but carry out sizeable fuel cell technology related R&D effort in the U.S. In such instances, the national institutional environment of the country in which innovation occurs could exercise a decisive influence on the innovatory strategies of the firm.

This paper therefore addresses the following research questions: To what extent does the propensity to form technology development alliances vary according to degree of corporatism in the firm's national institutional environment? To what extent does the propensity for knowledge spillovers within a technology development alliance vary according to the degree of corporatism in the firm's national institutional environment?

The character of national institutions is described according to the degree of corporatism-- or the extent to which interest groups and elements of society are organized in dense and enduring partnerships legitimated by the state (Schmitter, 1974; Badie and Birnbaum, 1983; Katzenstein, 1985; Wiarda, 2003). In a recent study, Spencer, Murtha and Lenway (2005), for example, mapped the corporatist dimension of a country's polity type to its technology policy and entrepreneurship orientation. Thus, they argued that the social and political milieu within which innovation occurs has implications for technology development, industry emergence and firms' strategies. The motivation for using the corporatist dimension of the national institutional environment in the present study, therefore, is based on its utility for explaining both *innovation* and *collaboration*.

New technologies such as fuel cells require extensive knowledge building to allow for the transition to a hydrogen-based economy that is expected to make existing energy technologies obsolete in a variety of applications. Such an effort requires knowledge transfer through participation and involvement of a variety of firm and non-firm actors that are involved with producing and using FCTs. The structure of relationships, therefore, can play a crucial role for addressing issues concerning technological hurdles and social acceptance that are perceived as deterrents to the successful diffusion of FCTs. The corporatist dimension helps better understand the proclivity of society to engage with different elements that constitute it and the social and political drivers for such engagement.

Theoretical Literature

Knowledge-based strategies have emerged as an important area of research in international management (Kogut and Zander, 2003; Almeida, Song and Grant, 2002; Bresman, Birkinshaw and Nobel, 1999). Indeed, as Murtha, Lenway and Hart (2001) noted, firms in emerging high technology industries increasingly depend on knowledge creation and acquisition processes more than ownership of physical assets.

The knowledge-based perspective in strategy recognizes alliances as important mechanisms for knowledge flows (Simonin, 1999; Mowery, Oxley and Silverman, 1996). The role of knowledge in strategy as applied to networks recognizes that knowledge that is critical to a firm's performance resides within a network rather than in individual firms or nodes (Kogut, 2000).

A variety of theoretical perspectives including the resource-dependence (Pfeffer and Salancik, 1978), transaction costs (Williamson, 1985), and institutional approaches (Baum and Oliver, 1991; Garcia-Pont and Nohria, 2002) have been utilized to explain the rationale for alliance formation. Osborn and Hagedoorn (1997) provided an extensive review of the various theoretical perspectives underlying alliances, calling for an integrative theory encompassing views in economic, sociological and political institutions. The present paper, therefore, attempts to contribute to such an integrative approach for explaining strategic technology alliances and associated knowledge spillovers.

An important aspect of current perspectives explaining alliances is that they tend to overlook the ex-ante conditions leading to alliance formation, by focusing on the benefits that alliances create once they are formed.

arguments, on the other, hand propose that 1) organization of R&D activities (Nobel and Birkinshaw, 1998) and, 2) search for knowledge (Frost, 2001) from the host country's innovation system are highly conditional on the characteristics of the firm.

This literature has argued that alliances improve the strategic position of the firms in competitive markets by providing resources that enable them to share costs and risks. Such resources give firms a cushion to weather downturns in the business cycle and to ensure predictable resource flows (Baum and Oliver, 1991). Moreover, alliances improve the market power of the firm by allowing firms to cooperate with competitors, and gaining access to knowledge-based resources (Burgers, Hill and Kim, 1993). Alliances also serve as a primary means of gaining significant presence in new markets, enabling faster entry and achieving greater market penetration (Glaister and Buckley, 1996). Finally, alliances can benefit firms through legitimization, greater visibility and status in competitive markets (Garcia-Pont and Nohria, 2002).

It is only recently that studies have begun to investigate the conditions that either perpetuate or restrain alliance formation. From a social capital perspective (Koka and Prescott, 2002; Chung, Singh and Lee, 2000), firms in strong and complementary social positions by virtue of previous alliance history and trust developed therein often capitalize their relation-based assets to create new alliance opportunities (Das and Teng, 2002; Das and Teng, 1998). Inherent in the social capital and strategic resource perspectives is the view that firms must *have* resources to *get* resources (Eisenhardt and Schoonhoven, 1996).

Advances have also been made to incorporate a broader societal view of the firm's environment into strategic decision making such that both resource dependence and the institutional environment shape alliance formation (Rowley, 1997). The roles of exogenous interdependencies that prompt organizations to seek alliances and endogenous factors such as embeddedness as a result of prior relationships (Gulati and Gargiulo, 1999) are increasingly viewed to explain the formation of alliances and the choice of partners based on social network positions. Acknowledging the dynamic influence of both exogenous and endogenous forces shaping the evolution of alliances, Madhavan, Koka and Prescott (1998) showed that the regulatory and technological environment both shaped the configuration of alliances and networks over time.

From a risk and opportunism perspective, inter-firm alliances are a preferred choice under conditions when the transaction-cost involved in an exchange are too high for using the market mechanism but not high enough to form a hierarchy (Hennart, 1988; Williamson, 1991; Ring and Van de Ven, 1992). Applying this logic, transaction-cost theorists posit that the governance *structure* of an inter-firm alliance is determined by the transaction costs of the deal.

While the logic of transaction-cost minimization is helpful, it does not capture the role of technological change, learning and legitimacy that are important aspects of alliances (Englander, 1988; Eisenhardt and Schoonhoven, 1996). Further, Ghoshal and Moran (1995) observed that transaction-cost theory is most relevant to static efficiency and routine situations. Arguments in support of knowledge-based and trust-based deterrence that lower the problems of moral hazard also emphasize the inadequacy of the transaction-cost approach in explaining alliances and networks. As Barney and Hansen (1994) noted, the presence of trust and confidence, which develop dynamically, will themselves act as a deterrent to opportunistic behavior among the members of an alliance or network.

Recent theorizing however, has recognized these deficiencies, and efforts have been made to examine transaction costs in the context of repeated games such that future strategies cast a shadow on present actions, shaped in large measure by the institutional environment rather than purely transaction-cost considerations (Parkhe, 1993). Similarly, Bradach and Eccles (1989) and Gulati (1995a) have drawn on both transaction-cost economics and sociological theory, thereby taking into account the role of trust, personal relationships and other behavioral characteristics of firms' relationships over time.

As evidenced from the preceding discussion, different theoretical lenses have been used to explain the rationale for alliance formation. These perspectives based on resource-dependence, social capital and transaction costs, when juxtaposed with the cultural and societal context, pave the way for examining firms' alliance activity in entrepreneurial activity and new technology development across countries (Steensma, Marino, Weaver and Dickson, 2000).

The Concept of Institutions

Following Jepperson, I adopt the polity³ as the primary locus of institutionalization giving rise to variation in inter-organizational structures. These institutional models have enormous potential explanatory power to inform

³ Polities as conceptualized here include both the state, and also civil society, and are defined as systems of rules conferring societal authority in pursuit of collective goals such as progress and justice, and establishing agents

cross-national variations in patterns of formal organization, collective participation and policy formation that constitute the subject of interest in this paper.

Corporatist theory for explaining organization of society is primarily concerned with the relationship between organized interests and public authorities – often referred to as intermediation. According to Schmitter (1974), corporatism can be defined as a system of interest representation in which the constituent units are organized into a limited number of singular, compulsory, noncompetitive, hierarchically ordered and functionally differentiated categories, recognized or licensed by the state. These interest groups are granted a deliberate representational monopoly within their respective categories in exchange for observing certain controls on their selection of leaders and articulation of demands and supports. In more corporatist models, society remains envisioned as a communal order with subsidiary elements--often collectivities themselves--carrying out explicitly imagined and differentiated roles or functions. In corporatist polities, sub-elements of society are viewed as representing different socially defined functions. The elements are typically groupings or orders with group rights accorded to them.

Therefore, in more corporatist systems one might expect to see interest organizations such that: (i) through the attribution of public status to interest organizations, the state establishes the basis upon which to license the behavior of interest organizations, (ii) power within interest organizations is hierarchical and the leadership enjoys some position of authority over members to ensure compliance with the bargains they reach with the state, (iii) members of interest associations cannot escape the confines of state-dependent hierarchical associations, because access to other associations is curtailed through monopolization, and (iv) membership for a substantial portion of the constituency is made compulsory (Wiarda, 1974; Schmitter, 1974; Badie and Birnbaum, 1983).

Associationalism, which lies at the other end of the continuum characterizing organization of society is defined as a system of interest representation in which the constituent units are organized into an unspecified number of multiple, voluntary, competitive, non-hierarchically ordered and self-determined categories. This system of interest representation is not specifically licensed, recognized, subsidized, created or controlled by the state and does not exercise a monopoly over the representation activity within specific categories. In more pluralist or associational ideologies--society is envisioned as natural and emergent rather than rational and planned -- more as a fellowship of members initiating lines of public action (Jepperson, 2000).

Associational systems, therefore, embody ideologies about the commitment and capacities of public actors that are primordial subunits of society rather than about functions and roles. Whereas collective requirements and duties are stressed under corporatist systems, rights and choices are more prominent in associational systems. In pluralist or associational systems of societies of which the U.S. and U.K. are cited as examples, multiple and widely dispersed interests create competition but also cleavages and conflicts over policy preferences (Schmitter, 1974). The main criticism of the associational system stems from the underlying assumptions of a highly competitive market and individualism in interests (Cawson, 1985).

Both associational and corporatist models, however, recognize, accept and attempt to cope with growing structural differentiation and interest diversity within the modern polity, but they offer divergent images of the institutional forms such modern systems of interest representation will take. The former suggest spontaneous formation, proliferation, lateral extension and competitive interaction; the latter advocates controlled emergence, limitation in numbers, vertical stratification, and complementary interdependence.

Institutionalism in Firm Strategy

Two explanations--isomorphism and legitimacy-- are commonly espoused to explain why firms “structurally reflect the socially constructed reality” inherent in the environment (Berger and Luckman, 1967, p.15) manifested in their strategic decision-making. Institutional isomorphism occurs through three mechanisms (DiMaggio and Powell, 1991): (i) *coercive isomorphism* stems from formal and informal pressures exerted on organizations by other organizations on which they are dependent and by cultural expectations in the society within which organizations function, (ii) *mimetic processes* create a tendency for firms to model themselves after similar organizations in the field that they perceive to be more successful, and (iii) *normative pressures* stem primarily from professionalization – defined as the collective struggle of members of an occupation to

of collective regulation and intervention. Society refers to citizens, professions and sciences that develop around the polity's goals.

define the conditions and methods of their work to establish the cognitive base and legitimation for their occupational autonomy.

The imperative for adjusting firms' strategies in conformity with the institutional environment is necessitated by the need for "social fitness". Relatedly, the concept of legitimacy propounded by Parsons (1990) emphasized the consistency of organizational goals with societal functions. Legitimation may incur costs, but as DiMaggio and Powell (1991) noted, organizational structures that fit well with the institutional environment also enjoy more material benefits, in addition to ceremonial gains. Further, legitimacy improves the confidence of key stakeholders such as investors, buyers and suppliers of the firm (Deepphouse, 1996).

Non-conformity to the institutional environment can cost a firm its survival; as population ecologists (Hannan and Freeman, 1977; 1989) argue, isomorphism results because non-optimal structures are selected out of the population. Scott (2000) noted, however, that structural isomorphism cannot be regarded as the litmus test for detecting institutional processes; varying, competing and multiple institutional forces are often at work and institutional forces often combine with other factors to shape organizational structure and action. Scott and Meyer (1983) proposed for example that organizations confronting more complex, fragmented environments such as multiple regulatory authorities and funding sources are likely to develop complex and elaborate internal structures, in consonance with the complexity of their environment.

Firms' responses to the institutional environment are also expected to vary across time, such that firms' needs and choices co-shape the institutional environment in the early stages, but in later stages of institutionalization, the logic of action shifts from instrumentality to appropriateness guided by normative and cultural pressures (Westphal, Gulati and Shortell, 1997). Analogously, new firms and emergent industries are more likely to adhere to the established norms and practices of their institutional environment.

Relevance to FCTs

Fuel cell technologies (FCTs) are often described as a class of "transformational" energy technologies leading a new technological paradigm labeled as the "hydrogen era" (Avadikyan, Cohendet and Heraud, 2003). Current developments in FCTs are aimed at transportation, stationary power generation and portable device applications. The radical nature of the innovation is characterized by Schumpeterian *creative destruction*, such that new knowledge would need to be developed, replacing long-standing bodies of knowledge. As an illustration of the Schumpeterian dynamic, FCTs could replace the internal combustion engine (ICE) that has been dominant in the automotive sector for nearly 100 years. The choice of fuel cells as the chosen technological sector, therefore, ensured that given the radical nature of the technology, imperatives for knowledge building and patenting were especially salient.

The first applications of fuel cells, however, are likely to emerge in niche areas where their non-standard performance attributes compensate for high costs (Mima and Criqui, 2003). As an example, the emergence of the 3G technology in cellular phones could play an important role in the adoption of fuel cells because it is widely believed that existing battery technologies will not be able to serve the power density requirements for 3G enabled phones (IFC, 2001; BTI, 2003b). Therefore, countries that become early adopters of FCTs will also most likely be leaders in other complementary technologies. As one of the early adopters of 3G enabled phones, Japan, may lead the adoption of FCT applications in the cellular phone segment.

In recent years, active involvement of public authorities through public-private partnerships and increasing investments in R&D provide evidence of a triadic race for achieving market shares and establishing national superiority in FCTs. The drivers for active engagement of the public sector in FCT development range from national security considerations in the U.S., to environmental targets in Europe. In Japan, prospects for economic power and market dominance together with environmental goals have played an increasingly important role in garnering public support for the development of FCTs.

A comparison of national public policies for FCT development reveal stark variations in at least five areas—public versus private funding, mechanisms for allocating public resources, public-private partnerships, public support for international participation and technological choices. These five areas are regarded as important determinants of national leadership in FCT development. Such a cross-national perspective is intended to offer a better understanding of the extent to which national innovatory approaches are grounded in the institutional environment characterizing the organization of society or the degree of corporatism.

A comparative analysis of policies and technological choices in the U.S. and Japan is particularly instructive for understanding why countries that lie at the opposite ends of the corporatist dimension have maintained a

consistent technological lead in fuel cells and related technologies. More recently, efforts in Europe at the level of both the E.U., as well as individual countries such as Germany and France, have posed an important challenge for U.S. firms.

The prospects for the success of fuel cells in the U.S. are to a large extent dependent on the competing needs of diverse stakeholders, regulatory agencies, utilities, non-governmental organizations and consumers' choices and preferences. In Japan, on the other hand, given the state-centric approach to innovation, these factors do not emerge as decisive in the diffusion and adoption of the technology. Therefore, even though a large potential market is seen to exist in the U.S., the market is viewed as being less predictable compared to that in Japan and Europe.

In a related vein, a recent report points out that given that a number of competing product designs and markets for application still persist in the U.S., it remains uncertain if the U.S. would lead the commercialization phase of the technology (BTI, 2003a). As one government official observed, the approach for new technology development in the U.S. has often been guided by short-term interests rather than by long-term gains in both the public and private sectors. Therefore, even as increased public sector funding is made available to large firms (often at the expense of small entrepreneurs), it is difficult to assess if these investments are motivated by a genuine commitment to FCTs or are intended primarily to ward off environmental groups that lobby for cleaner fuels (BTI, 2003b).

Drawing upon the variations in country experiences, and the theoretical literature discussed in the preceding section, I develop a set of empirically testable hypotheses that posit a relationship between the corporatist dimension of the national institutional environment and firms' innovatory strategies. Although, the research framework is developed in the context of FCTs, findings from this study may be applicable to other technology areas that are characterized by competing technological designs and applications, such that the success of knowledge building strategies would depend on firms' ability to leapfrog other firms in rapid moves and countermoves. In such technological domains, the extent to which the institutional environment enables such competitive maneuvers would influence the technological choices and resultant success of firms. Relatedly, the relevance of applying the current findings to analysis of variations in the effectiveness of the alliance mechanism as a strategy for knowledge building may hold only in technological sectors such as FCTs where an increase in the alliance activity involving both firm and non-firm actors has been observed over a period of time.

Hypotheses

The Relationship Between Corporatism and Alliance Formation

According to Schmitter (1974) and Jepperson (1991, 2000), in corporatist polities such as Germany and Japan, society is characterized as an integrated partnership, a "national social community" usually organized along communitarian principles and functional sectors representing inclusive, interdependent and dense organizational blocs. Networks in such polities are characterized by a high degree of group cohesion or "knittedness" (Blau, 1977). In contrast, associational models of society prevalent in the U.S., Canada and U.K. are more individualistic and atomistic comprising actors rather than groupings.

Juxtaposing Jepperson's institutional archetypes with different technology policy and entrepreneurship orientations, Spencer, Murtha and Lenway (2005) argued that corporatist systems are associated with what Garud and Karnøe (2003) described as the *bricolage* approach to technology entrepreneurship. Bricolage approaches are consistent with the cooperative, consensual and networked aspects of corporatism, leading to technological development in a gradual and incremental fashion. *Breakthrough* approaches characterized by a highly competitive and turbulent process in the U.S. on the other hand, aim at establishing superiority in the high end of technologies through less collaboration and greater protection of intellectual property. Breakthrough approaches are observed to inhere in associational polities characterizing the U.S., Canada and UK.

Despite its emphasis on extensive cooperation, corporatism does not imply a lack of inter-firm competition. In Japan for instance, the government has brought together the largest automotive firms to cooperate and share knowledge in fuel cell technologies under the ACE⁴ and World Energy Network (WE-NET) coordinated by the Japan Automobile Vehicle Association (JAVA) and Engineering Advancement Association of Japan (ENAA), respectively. Large automotive firms that are members of these consortia however, tend to form dense clusters with suppliers of components, energy producers and small firms with whom they have prior relationships. In many instances, clusters led by a large firm pursue a specific technology, such that direct competitors are rarely

⁴ACE is an acronym in Japanese that translates into the organization of programs on fuel cells on hybrid vehicles.

in the same cluster. This observation aligns with the dense, non-competitive, hierarchically ordered characteristics of corporatist networks (Schmitter, 1974, 1981).

Moreover, given the individualistic character embodied in the “self-made-man” of associational polities, firms are more self-reliant in technology development. Thus, firms in such polities are more likely to develop internal mechanisms and structures to build on the existing knowledge base. This observation aligns with the greater prevalence of large multinational firms in fuel cell technology development, with diverse capabilities and complex internal structures for knowledge acquisition and integration in associational polities such as the U.S. and U.K.

Further, as Somaya (2000) noted, whereas in associational polities like the U.S., there exists a greater tendency to view patents as intellectual property with exclusive rights, the patent systems in corporatist polities such as Japan and Germany for example, view patents as rewards for innovation rather than property rights. Thus corporatist polities are observed to encourage rapid dissemination of innovations through licensing and collaborative arrangements. Reliance on the alliance mechanism compared to arm's-length or internalized transactions for knowledge spillovers, therefore, is likely to be far less for firms from associational polities than corporatist polities.

H1: Alliance counts will be higher for firms from corporatist polities than associational polities.

The Relationship Between Corporatism and Knowledge Spillovers

Even though firms in corporatist polities are likely to have greater number of alliances driven by communitarian⁵ principles, knowledge spillovers from such alliances is expected to be lower than for firms in associational polities. It is noteworthy that despite the lower predicted technological productivity of corporatist networks, they continue to persist. One explanation for this expected anomaly is the phenomenon of institutional isomorphism, according to which coercive, mimetic or normative pressures act on firms (DiMaggio and Powell, 1991; Garcia-Pont and Nohria, 2002) to alter the notion of viability (Kogut, 2000). Relatedly, Coleman (1990) argued that firms prefer to pay the rents for remaining in non-productive alliances as opposed to market-based or hierarchical arrangements because the norms of corporatism impose greater penalties for switching to alternative strategies.

An alternative explanation for why firms in corporatist polities continue to engage in dense networks despite marginal returns is derived from game theory. In corporatist polities, alliances constitute a repeated games setting thereby implying greater prospects of future collaboration can cast a shadow upon the present strategy (Axelrod, 1984; Axelrod and Keohane, 1986). The transparency of relationships induced by highly structured systems of information, coordination and verification, may improve cooperation (Parkhe, 1993), but it may also expose firms' competencies and weaknesses and limit their behavioral opportunism or indeterminacy⁶ for future strategic maneuvers (Walker, Kogut and Shan, 1997).

Further, the repetitiveness of alliances with the same actors in corporatist polities can curtail flexibility and limit the search for new knowledge (Glasmeier, 1991). Arguably, the repetitiveness of alliances could lead to relation-specific *absorptive capacity* by virtue of relation-specific assets and knowledge-sharing routines with existing or familiar partners (Dyer and Singh, 1998). While this improves the likelihood of spillovers from some partners, it constrains knowledge spillovers from others in its network. This is because relation-specific *absorptive capacity* by definition is non-transferable and unique to each alliance partner. According to Harrigan (1988), the specificity of physical, financial and human resources committed to an alliance raises exit barriers that are difficult to overcome should the alliance become less viable.

⁵ Such communitarian bonds could lead to firms citing one another in their patent applications, despite any real knowledge spillovers. This aspect of the measure for knowledge spillovers would only add noise to the analysis and inflate the extent of knowledge spillovers in corporatist polities.

⁶ Arthur (2004) invited a deeper approach to studying economic behavior and agents' reactions to change in an economy that is out-of-equilibrium rather than deterministic, predictable and mechanistic, thereby drawing attention to the dialectic between path-dependence and continual adjustment to changes that agents in the economy themselves create.

The presence of trust that lends greater transparency and veracity is observed to play a crucial role in forging relationships in corporatist polities. The value of trust in improving productivity of firms' relationships however, is observed to be the greatest when trust is a relatively rare phenomenon among the firms' competitors (Barney and Hansen, 1994). Further, as Das and Teng (1998) pointed out, for an alliance to be successful there must be a balance of trust and opportunism. Trust in partners in corporatist polities is not deterrence-based or motivated by uncertainty of cooperation, but instead, is derived from a common cognitive basis according to which actors tend to trust those who are more like themselves (Gulati, 1995b), creating an inertia for redirecting resources from a failing project. In addition, the salience of trust and transparency in knowledge spillovers is greatly reduced in the context of the current intellectual property regime worldwide that offers better protection for knowledge, but also makes knowledge better documented and hence more publicly visible (OECD, 2004). Thus firms in corporatist polities are not likely to wield sizeable benefits in terms of knowledge spillovers based on greater trust and transparency in relationships with their partners.

H2: Knowledge spillovers from alliance partners will be higher for firms from associational polities than corporatist polities.

Data and Methodology

Hypotheses concerning alliance counts were tested on a panel of 825 firm-year observations in 5 time periods--1980-84, 1985-89, 1990-1994 and 1995-99, 2000-2004. Owing to the lagged structure of these models, firms' alliance counts in period $t+1$ were modeled as a function of polity type and firm-level covariates⁷ in period t .

The descriptive statistics of the variables in the models and their correlation coefficients are provided in Tables 11 and 12, respectively. The mean value of the corporatism dummy variable in this sample was 0.37, indicating that there were fewer firms from corporatist polities in the sample compared to firms from associational polities. A greater proportion of firms from associational polities were largely due to a greater proportion of U.S. firms in the sample.

By recording both zero and non-zero alliance counts for firms over the 5 year time period, the panel data regression captured variations across both time and firms. However, the probability of non-zero alliance counts in any given time period is small because firms are not likely to form alliances in each time period. In models that are expected to have a large number of zero counts as the outcome variable--Greene (1997) suggested a zero inflated Poisson (ZIP) model--a non-linear mixed model that includes a logistic inflation probability function to model the outcome of zeros, in addition to a Poisson parameter⁸. The choice of the ZIP model to estimate alliance counts for the panel data regression, therefore, allowed for both fixed and random effects to be correlated with model parameters. In this manner, any systematic variations across the sub-samples with zero and non-zero alliance counts were captured in the model. The appropriateness of the ZIP model was tested using the likelihood ratio test that has an asymptotic distribution of $\chi^2_{(1-2a), 1 \text{ d.f.}}$ (Cameron and Trivedi, 1998). The likelihood ratio statistic calculated as $-2(\log \text{likelihood (fixed effects negative binomial)} - \log \text{likelihood (zero inflated Poisson)})$ was found to be significant $\chi^2_{(1-2a), 1 \text{ d.f.}}$ ($p < 0.05$). Therefore, following Cameron and Trivedi (1998) the zero inflated Poisson model was used instead of the fixed effects negative binomial model to estimate alliance counts in the panel data regression.

Unlike the panel data regression for estimating alliance counts, knowledge spillovers were estimated from cross-sectional regression models. Therefore, each observation described a firm-alliance-year. Only alliances formed until 1999 were included in the analysis to allow for a 5-year lag in knowledge spillovers. The choice of a 5-year optimum lag-length was based on previous research. Hausman, Hall and Griliches (1997) as well as a plot of the fuel cell patent citation data that showed that citations peaked at close to a 5 year lag length and declined steadily thereafter.

Since firms may have multiple alliances, repeated firm-level observations required the model to include fixed or random effects to account for the unobserved heterogeneity. Based on the Hausman specification test ($p < 0.01$),

⁷For alliance counts recorded in period $t+1$, only firms that had at least one fuel cell patent in the periods prior to $t+1$ were included in the sample so that lagged values of patent-based model covariates such as technological base, technological achievement and technological concentration could be calculated.

⁸The Dual Quasi-Newton optimization technique was used to estimate the ZIP model (Stokes, Davis and Koch, 2002).

a fixed effects⁹ specification was used. The outcome variable of knowledge spillovers (measured as counts of citations to partners' patents in the 5-year period following alliance formation) was modeled as a negative binomial regression. The choice of the negative binomial regression allowed for heterogeneity in the model arising from the inequality of mean and variance as was evident from the high deviance and scaled Pearson χ^2 statistic when the Poisson regression was used. The Pearson χ^2 statistic that had a value of close to 1 in all models provided evidence that there was no significant over- or under-dispersion in the model. All models predicting knowledge spillovers achieved convergence, thereby indicating that the possibility of small counts or zero inflation in the model did not curtail a unique solution for parameter estimates (Stoke, Davis and Koch, 2001).

As described in the preceding chapter, knowledge spillovers were predicted in two steps. As a first step, I ascertained if knowledge spillovers were significantly greater from alliances than from non-alliance mechanisms. To do this, following Almeida (1996) and Almeida, Song and Grant (2002), I included a patent dummy that assumed a value of 1 each time the firm cited its partner and 0 when it cited firms that represented proxies matched to the partner firm. The significance of the patent dummy revealed whether or not knowledge spillovers from alliances were greater than spillovers from non-alliance mechanisms, holding other factors constant through the proxy matching procedure.

Once the significance of knowledge spillovers from alliance partners was established, in a separate regression equation I modeled the outcome variable of knowledge spillovers from partners as a proportion of total spillovers from partners and matched proxies. The significance of the coefficients of the polity type dummy and model covariates revealed their relationship with knowledge spillovers from partners versus non-partners. Thus, the outcome variable was modeled as a ratio instead of as a count by including an offset variable equal to the sum of spillovers from partners and proxies.

The outcome variable ranged from a value of 0 when there were no cites to partners, to a value of less than 1 when there were cites to both partners and proxies. When knowledge spillovers were equal from both partners and proxies the outcome variable assumed a value of 0.5. Therefore, higher values of the ratio indicated a larger proportion of knowledge spillovers stemming from partners.

Table 1(a) shows the distribution of proxies according to the selection criteria used for matching them to the partners in the three samples: direct alliances, alliances with foreign partners and indirect ties. The percentages indicate the number of proxies that matched a given criterion. As can be seen from Table 1(a) in all three samples, most proxies matched the partner on the country and industry characteristics. Proxies were selected as long as they matched on at least country or industry of the partner. A high percentage of matches based on country helped ensure that both the partner and proxy's innovative activity were co-located, so that any variations in knowledge transfer arising from the institutional environment and geographical distance were controlled for. Given that the same fuel cell technology may be applicable across industry applications such as stationary power generation, transportation and portable devices, matching the proxy according to the partner's industry ensured that the choice of partner due to industry-specific applications of the technology were accounted for. Matches along the technological achievement score included proxies that were comparable in terms of the value of their knowledge. Comparability in the technological base between the partner and proxy controlled for the number of prior fuel cell patents held and hence the size of the knowledge base that could potentially be built upon. Since size may play a decisive role in determining the choice of partner and its knowledge base, this criterion was also included for selecting proxies.

Table 1(a). Distribution of Proxies According to Criteria for Matching with Partners

Model/ Matching Criteria	Country	Industry	Size	Technologic al Base	Technologic al Achievemen t
All Alliances	(269) 53%	(436) 86%	(122) 24%	(198) 39%	(457) 9%
Foreign Alliances	(97) 46%	(202) 96%	(54) 26%	(63) 30%	(17) 8%

⁹ As a robustness check, I also estimated the model relationships using a random effects specification assuming a normal probability distribution for the unobserved heterogeneity in the sample. The model relationships estimated from the fixed effects negative binomial regression remained unchanged in the random effects specification.

Number (%)

Table 1(b). Distribution of Proxies: Number of Criteria Matched

Model/ Number of Criteria Matched	Five	Four	Three	Two	One
All Alliances	39	82	204	172	11
Foreign Alliances	12	38	96	58	7

Results

The Relationship Between Corporatism and Alliance Formation

H1: Alliance counts will be higher for firms from corporatist polities than associational polities.

Table 4 illustrates the results from the model estimating the relationship between corporatism, firm-level covariates and alliance counts. Each of the four time period dummies was observed to have a positive and significant relationship with alliance counts. This result suggests that an increase in alliance activity occurred in all 5 time periods, though the magnitude of this relationship was higher for later periods. Therefore, more alliances were formed in later time periods due to possible bandwagon effects and/or relaxation of anti-trust regulations and strengthening of intellectual property regimes worldwide (Gilbert, 2004). Firms that belong to the transportation and fuel cell components manufacturing industries (versus stationary power generation sector) were observed to have a significantly larger number of alliances. Anecdotal evidence suggests that firms in the automotive industry such as General Motors have invested in fuel cell technology innovations that draw on diverse yet complementary capabilities of firms such as Dow Chemicals. Also, most automotive firms engaged in fuel cell technology development are large well-reputed multinationals that are observed to attract significant resources through partnerships with firm and non-firm actors, possibly leading to more alliances. Firms in the fuel cell components segment provide the knowledge base to complement the technological activities for all three segments of fuel cell technology developers and hence are also more likely to engage in more alliances.

Whereas the variable capturing the stock of country-level patents was not observed to have a significant relationship with alliance counts, high GDP country firms were observed to have fewer alliances than firms from countries with a lower GDP. The negative association of alliance counts with country-level GDP may stem from two possibilities. First, prior literature suggests that small sized economies are typically associated with corporatism and large economies tend to be associational (Katzenstein, 1985). Therefore, fewer alliances in larger economies may result from the influence of associationalism, which is consistent with the hypothesized relationship in this study. Second, the National Science Foundation (NSF, 2004) reported that high levels of economic prosperity reduced the need for alliances. On the other hand, more resource-sharing and joint technology development activities were necessitated for firms in countries with smaller economies.

Firm-level covariates such as number of years in fuel cell technology and technological concentration¹⁰ were found to have a significant negative relationship with alliance counts. These findings suggest that firms that have been engaged in fuel cell technology development for longer periods have fewer alliances than more recent entrants. Perhaps, the technological experience gained by these firms helped them develop sufficient in-house knowledge - and resource-base, thereby reducing the need for alliances for the purpose of knowledge acquisition. Specifically, as the number of years in the fuel cell technology sector increased by 2.7 years (log of 1 unit), alliance counts decreased by a factor of exp (0.991) or 2.69. However, firms with higher levels of technological achievement had a greater number of alliances than firms that did not. As the technological achievement score of the firm increased from 0 (no cited patents) to a maximum score of 0.32 observed in the sample (32% of patents cited by others), alliance counts increased by a factor of exp (2.815) or 4.48.

Table 3 shows that technological achievement was correlated with technological experience ($\rho=0.47$; $p<0.10$). Yet, both variables --technological experience and technological achievement--were observed to act in opposite directions with regards to the relationship with alliance counts. This observation suggests that firms that had

¹⁰ The extent to which a firm's patents were assigned to a single patent sub-class versus dispersed across several patent sub-classes.

been innovating for a long time may have cumulatively developed knowledge that was valuable but unique to their own products and capabilities and therefore contributed to fewer alliances.

As in the case of technological achievement, firms with a large technological base, measured as the total number of fuel cell patents, were observed to form greater number of alliances than firms who did not. Specifically, for each additional patent, alliance counts increased by a factor of $\exp(0.064)$ or 1.06. Both the total number of patents held by a firm and a large technological base in fuel cells were positively related with alliance counts, possibly reflecting the firm's greater absorptive capacity that promotes knowledge transfer from partners. Furthermore, a firm with a large established technological base may be indicative of important knowledge resources for potential partners to access and build upon. Also, the firm's technological base, as a tangible measure of its R&D activity and capabilities in an emergent technology arena, may signal its desirability as a potential ally to other firms.

The negative and significant estimate of the coefficient associated with technological concentration or the extent to which a firm focused on a single fuel cell technology patent sub-class, versus diversified its innovative activities across many patent sub-classes showed that firms with a narrowly defined technological focus engaged in fewer alliances than firms whose technological portfolio was more diverse. Therefore, as firms moved from a highly concentrated technological portfolio (score of 1) to a diversified portfolio such that no two patents within their portfolio belonged to the same technological class (score of 0), alliance counts increased by a factor of $\exp(0.54)$ or 1.71. In part, this may have occurred because, given the likelihood of many competing technologies in the early stages of technology development, firms that concentrated their technological activities would have a smaller opportunity set of potential partners to choose from.

The corporatism dummy variable was observed to have a small, positive (but insignificant) coefficient, thereby implying that firms in corporatist polities did not have a greater propensity to engage in alliances than firms in associational polities¹¹. Hypothesis 1(a) therefore was not supported ($p < 0.05$). However, Model 2 (shown alongside Model 1 in Table 4 which estimated alliance counts for only the larger, publicly-traded firms, was observed to have a positive and significant coefficient for the corporatism¹² dummy variable ($p < 0.05$), such that alliance counts for publicly traded firms were observed to be higher by a factor of $\exp(0.44)$ or 1.55 in corporatist versus associational polities. Based on the difference in the log-likelihood ratio statistics, the model including the size variable for only public traded firms had a significantly improved fit with the data over the main effects captured in Model 1. This finding suggests that the difference between the observed and estimated values of alliance counts estimated by the model with only publicly traded firms was significantly less than the difference between the observed and estimated values from the model with both public and private firms.

As a next step, I proceeded to understand better if the estimated relationship between alliance counts and corporatism was systematically different for publicly traded firms, or if controlling for the size variable contributed to a positive and significant association between corporatism and alliance counts. To do this, in variation of the model, I excluded the size variable. The relationship between corporatism and alliance counts was still found to be positive and significant when only publicly traded firms were included in the analysis.

In another variation of the model I estimated the model with a larger sample of both public and private firms, substituting the measure for size variable as number of employees instead of revenue from sales. Results from the model with both public and private firms, including the size variable measured as number of employees yielded a positive but insignificant coefficient for corporatism.

¹¹ In a *post-hoc* analysis I excluded countries that span the boundaries of more than one polity type. Such countries, labeled as *colloidal countries* in that they reflect the characteristics of more than one polity, include Canada (liberal and state-nation polities), the Netherlands (liberal and social-corporatist), Switzerland (liberal and social-corporatist) and Australia (liberal and state-nation). The results obtained from the main model remained consistent in this analysis.

¹² In a *post hoc* model, I excluded $\ln(\text{country-level GDP})$. The rationale for this specification of the model stems from prior literature that posits a positive correlation between corporatism and country-level GDP (Schmitter, 1974; Katzenstein, 1985). Results showed a positive but small correlation coefficient of 0.29 between corporatism and $\ln(\text{country-level GDP})$. In the modified model excluding $\ln(\text{country-level GDP})$, corporatism was observed to have a positive but weakly significant effect ($p < 0.10$) on the estimated alliance counts. Similarly, in another model specification that included country dummies to account for variations within polities, the coefficient of corporatism was again found to be marginally positive and significant ($p < 0.10$).

Therefore, based on these *post hoc* tests it may be concluded that the positive relationship between corporatism and firms' alliance counts emerges significantly for publicly traded firms in particular. Given that these firms may tend to rely on public resources, and hence are liable to public litigation, the relationship between the institutional environment and their innovation strategies is likely to be stronger as observed in this analysis.

Given that the analysis was based on covariates whose measures are derived from patents filed in the USPTO, it is possible that the values of these covariates are higher for U.S. firms compared to non-U.S. firms, thereby creating a possible bias in the model results. To address the possibility of such a bias, I tested the hypothesized relationships for a simulated dataset with a 10% and 20% reduction in the patents of U.S. firms respectively. Whereas the results from the dataset with 10% reduction remained consistent with the initial results, greater sensitivity in the relationship between alliance counts and the model covariates was observed with a reduction of 20%. The simulated results for the 20% reduction in the patents and related measures of U.S. firms are reported alongside the actual model results for ease of comparison. The simulated model showed a slight decline in the fit compared with the actual data as evidenced from the difference in the log-likelihood statistic for the models ($p < 0.05$). Therefore, results from the model with a 20% reduction in the patents of U.S. firms did not provide evidence of biased relationships as estimated in the actual model, reducing concern about negative consequences stemming from 'overrepresentation' of U.S. firms in the sample.

In summary, empirical evidence from Model 1 showed that time had a positive and significant relationship with alliance counts in fuel cell technology development. Greater collaboration was also observed for firms in the automotive and fuel cell components segments that have been regarded by industry experts as the most lucrative, attracting large investments from both the public and private sectors (BTI, 2003b). The increasing trend in alliances over time strengthens the salience of examining the effectiveness of alliances as a strategy for knowledge building.

In addition, even though alliance counts of firms were not found to vary significantly according to the degree of corporatism in the firm's location of innovation, the relationship between alliance counts and corporatism changed to positive and significant when only publicly traded firms were retained in the analysis. This relationship may be regarded as being unique to publicly-traded firms rather than emerging from a size effect as evidenced from the insignificant relationship between corporatism and alliance counts when both public and private firms were analyzed, controlling for their size measured as number of employees. Therefore, it may be concluded that the relationship between the degree of corporatism and alliance counts has greater significance for firms that depend on the market for their resources. This finding is especially salient because it supports the argument for a strong influence of the social and political institutions in conjunction with market forces for determining the innovation strategies of firms.

Table 2. Descriptive Statistics for Variables in Models Estimating Alliance Counts¹³

Variables	Min	Max	Mean	Standard Deviation
Time 5	0(0)	1(1)	0.2(0.23)**	0.4(0.42)**
Time 4	0(0)	1(1)	0.2(0.24)**	0.4(0.42)**
Time 3	0(0)	1(1)	0.2(0.17)**	0.4(0.37)**
Time 2	0(0)	1(1)	0.2(0.17)**	0.4(0.37)**
Transportation Industry	0(0)	1(1)	0.18(0.28)**	0.39(0.45)***
Stationary Power Industry	0(0)	1(1)	0.10(0.10)***	0.30(0.30)
Fuel Cell Components Industry	0(0)	1(1)	0.66(0.54)**	0.47(0.49)**
Merged Polity	0(0)	1(1)	0.02(0.03)**	0.14(0.19)***
Ln (Country-Level Patents) _t	0(0)	8.83(8.83)	6.56(6.57)	2.00(1.75)***
Ln (Country-Level GDP) _t	8.29(9.26)	10.86(10.86)	10.26(10.31)***	0.32(0.29)***
Ln(Technological Experience) _t	1.60(-1.22)	3.21(13.24)	2.55(6.39)**	0.561(2.79)
Technological Base _t	0(0)	264(264)	12.00(18.47)***	30.47(38.53)***
Technological Concentration _t	0(0)	1(1)	0.64(0.56)***	0.36(0.36)
Technological Achievement _t	0(0)	0.3226(0.322)	0.01(0.02)***	0.02(0.03)**
Ln(Total Firm Patents) _t	0	5.36	0.63	0.90
Ln (R&D) _t	(-1.22078)	(9.20)	(4.96)	(2.18)
Ln(Size) _t	(-1.22078)	(13.24)	(6.39)	(2.79)
Corporatism _t	0(0)	1(1)	0.37(0.430)**	0.48(0.49)
Alliance Counts _{t-1}	0(0)	30(30)	0.93(1.32)**	2.92(3.54)***

Full sample (Sample of Publicly Traded Firms); *** p < 0.01; **p<0.05; *p<0.10

Tests of significance based on Satterthwaite t- and F-tests for differences in mean and variance, respectively.

¹³ The model testing for interaction between size and corporatism is based on a smaller sample of publicly traded firms only for whom size data measured as revenue from sales was obtained from the *Compustat* database. Descriptive statistics are compared across the two samples—one comprising both public and private firms and the other comprising only publicly traded firms. Figures in brackets correspond to statistics for the sample with publicly traded firms. The asterisk corresponds to the significance of the difference in the mean and standard deviations of the two samples compared. No corresponding statistic for Ln (Total Patents) for the sample with public traded firms is shown because it was replaced by the Ln(R&D) in the model testing for the interaction between size and corporatism.

Table 3. Correlation Matrix for Variables in the Model Estimating Alliance Counts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
1 Alliance Counts _{t+1}	1	0.286*	0.089*	0.095*	0.132*	0.1189	0.025	0.067	-0.026	0.082	0.204	0.134	0.258	0.189	0.197	0.068			0.015	0.018					
2 Time 5		1	0.25*	0.250	0.250	0	0	0	0.004	0.211	0.185	0.307	0.571	0.088	0.086	0.019			0.322*	0.173	-0.000	-0.000			
3 Time 4			1	0.250	0.250	0	0	0	-0.001	0.108	0.082	0.172	0.366	0.082	0.010	0.060			0.359*	0.173	-0.000	-0.000			
4 Time 3				1	0.250	0	0	0	-0.001	0.107	0.081	0.076							0.043	0.257*	1148	-0.000	-0.000		
5 Time 2					1	0	0	0	-0.001	0.190	0.263	0.062							0.118	-0.029	0.257	1368	0.003	0.003	
6 Transportation						1	*	0.056	-0.684*	0.165	0.095	0.116	0.038	0.037	0.081				0.014	0.216**	*	*	0.247	0.182	0.229
7 Merged Polity							1	0.054	*	0.029	-0.026	-0.019	-0.009	0.002	-0.026	-0.041	-0.032	0.693**	*	*	0.162	0.038	0.086		
8 Components								1	0.489	0.145	0.172		0.022	-0.003	0.180	0.073	0.054			0.213**	*	*	0.306	0.195	0.260
9 Power									1	0.078					0.195	0.047	0.052						0.035		0.006
10 Ln(Country Patents) _t										1	0.026				0.462	0.309	0.132	0.115	0.066				0.995	0.480	0.411
11 Ln(Firm R&D) _t											1				0.188	0.252	0.345	0.336	0.242				0.127	0.107	0.102
																				1			0.170**	*	*

Table 4. Zero Inflated Poisson Model Estimates for Alliance Counts in t+1

Variables	Model 1 Main Effects	Model 1 (Simulated) 20% Reduction in Patents of U.S. Firms	Model 2 Main Effects (With Size For Public Firms)	Model 2 (Simulated) 20% Reduction in Patents of U.S. Firms	Model 3 Interaction Effects (Size X Corporatism)	Model 3 (Simulated) 20% Reduction in Patents of U.S. Firms
Constant	5.8894(2.87)***	5.2281(2.95)***	11.3433(2.34)**	-0.2867(-0.25)	7.2418(1.41)*	6.9942(1.36)*
Time 5	2.6542(3.71)***	2.0333(3.69)***	4.643(4.09)***	-0.141(-0.93)	7.6713(4.23)***	7.7671(4.14)***
Time 4	1.8643(3.44)***	1.7966(3.42)***	4.1315(3.81)***	2.5623(2.38)**	7.1155(4)***	7.2079(3.92)***
Time 3	0.7642(1.38)**	0.7244(1.4)**	2.556(2.35)**	2.0175(2.12)**	5.1903(2.96)***	5.2742(2.91)***
Time 2	0.5514(1.03)	0.4796(1.03)***	2.0426(2.1)**	4.6624(4.13)***	3.9323(2.37)**	3.986(2.32)**
Transportation Industry	0.9911(3.09)***	0.8199(3.13)***	1.7229(2.62)***	0.001752(0.01)	2.1419(2.95)***	2.1455(2.96)**
Stationary Power Industry	0.2531(0.83)	0.2432(0.86)	1.0107(1.49)*	1.7254(2.61)***	1.3611(1.83)***	1.3652(1.84)**
Fuel Cell Components Industry	0.5996(2.02)**	0.5408(2.06)**	1.442(2.18)**	1.0104(1.48)*	1.9478(2.67)***	1.952(2.68)***
Merged Polity	0.2378(0.93)	0.1878(0.95)	-0.00299(-0.01)	-1.1334(-2.37)**	0.3242(1.46)*	0.3335(1.5)*
Ln (Country -Level Patents) _t	0.00143(0.03)	0.009141(0.3)	0.02864(0.56)**	-1.6912(-3.81)***	0.01373(0.26)	0.01434(0.28)
Ln (Country -Level GDP) _t	-0.5413(-1.82)**	-0.3408(-1.9)**	-1.1109(-2.32)**	0.03545(0.69)	-0.8104(-1.65)**	
Ln(Technological Experience) _t	-0.9914(-3.75)***	-0.8752(-3.72)***	-1.6558(-3.82)***	4.1464(3.85)***	-2.6486(-5.54)***	-0.7827(-1.6)*
Ln(Total Firm Patents) _t	0.1553(2.31)**	0.06258(2.18)**				-2.6877(-5.52)***
Technological Base _t	0.7542(2.42)**	0.06765(2.52)**	0.141(4.27)***	0.4423(1.91)**	0.1095(3.24)***	0.1078(3.2)***
Technological Concentration _t	-0.5411(-3.61)***	-0.386(-3.58)***	-0.1387(-0.92)	-1.8414(-0.86)	-0.1659(-1.1)	-0.17(-1.13)
Technological Achievement _t	2.815(1.89)**	2.3409(1.54)*	-1.5394(-0.76)	0.1407(4.26)***	-3.0986(-1.47)*	-3.3844(-1.52)**
Ln (R&D) _t			0.02743(1.05)	0.0424(1.92)**	0.05896(2.12)**	0.05971(2.14)**
Ln(Size) _t			0.04254(1.93)**	1.4421(2.17)**	0.1228(4.46)***	0.1223(4.44)***
Corporatism _t	0.00203(0.02)	-0.01228(-0.12)	0.4444(1.92)**	11.6435(2.4)**	2.5287(5.54)***	2.5145(5.49)***
Corporatism X Ln(Size) _t					-0.2566(-5.87)***	-0.2568(-5.86)***
Number of Observations	825	825	425	425	425	425
-2 Log Likelihood	2194.1	2195.3	1224.4	1296.9	1190.1	1266.9

Dependent variable: Alliance Counts; β coefficient (t-value); *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

The Relationship Between Corporatism and Knowledge Spillovers

H2: Knowledge spillovers from alliance partners will be higher for firms from associational polities than corporatist polities.

The model for estimating knowledge spillovers was based on a sample of 508 alliances formed in years until 1999. By including alliances only until 1999, knowledge spillovers, as evidenced from the firm's patent applications in the 5-year post alliance period until 2004, could be recorded. The descriptive statistics for the variables in the model and their Pearson correlation coefficients are shown in Tables 5 and 6, respectively. The average value for spillovers from partners was 1.72 and the average for total spillovers from partners and matched proxies was 3.25. The inequality of observed mean and variance for knowledge spillovers confirmed the choice of a negative binomial regression model.

Model 4 in Table 7 estimated the significance of knowledge spillovers from alliance partners compared to matched proxies. The estimated coefficients of the model covariates showed that time did not have a significant relationship with spillovers from neither partners nor from proxies. The relationship with industry segment, however, was observed to be significant, such that greater spillovers were observed from either source--partner or proxy--when the firms belonged to the transport, stationary power and portable device segments of fuel cell technology innovators.

Spillovers from foreign partners or their proxies were significantly lower than spillovers from domestic partners. Thereby suggesting that neither partners in foreign locations nor their proxies served as an effective mechanism for knowledge building, however, given the popularity of foreign alliances in fuel cell technology development, these alliances may have been used for developing markets rather than the technology per se. The relationship with multi-party alliances and merged polities was not found to be significant. Of the firm-level covariates included in the model, technological achievement was found to have a positive and significant relationship and the number of years in the technology had a negative and significant relationship with knowledge spillovers from either partner or proxy. Therefore, whereas firms with a valuable knowledge base may have acquired their knowledge from either the alliance partner or a proxy, older firms acquired less knowledge from the alliance partner or the proxy, but may have served as valuable partners for newer firms given the length of their experience in fuel cell technology development.

The coefficient of the patent group dummy showed that the knowledge spillovers from alliance partners were significant. This observation suggests that alliances may have served as an effective mechanism for knowledge building in fuel cell technology development. Therefore, further analysis of the factors affecting these spillovers as a proportion of total spillovers was deemed warranted.

As before, I ran simulated models to address concerns about overrepresentation of U.S. firms in the sample. For the simulated models, I reduced all patent-based measures including knowledge spillovers to and from U.S. firms by 20%. The simulated models showed results largely consistent with the initial model, though the fit of the model reduced substantially as evidenced from the log likelihood ratio that decreased from 115.6 in the actual model to -40.7 in the simulated model(s).

Having established the significance of knowledge spillovers from alliance partners versus non-alliance mechanisms, I next modeled knowledge spillovers as a proportion of total knowledge spillovers from partners and matched proxies. Model 5 results showed that earlier time periods had a significant positive relationship with the proportion of spillovers from partners, but the magnitude of this relationship was reduced in later time periods, thereby suggesting that the proportion of knowledge spillovers from the alliance partners was lower in later time periods compared to the earlier time periods. Over time, alliances may form in response to bandwagon effects or as a means to mimic (successful) competitors rather than with the objective of knowledge transfer per se. In addition, in later stages of technology development alliances may be formed for the purpose of licensing the technology rather than for the purpose of acquiring the partner's knowledge.

The relationship between the proportion of knowledge spillovers from alliance partners and the transportation and fuel cell components industry segments were found to be positive and significant,

thereby suggesting that firms from these segments built on the knowledge of their alliance partners more effectively than firms from other industry segments such as stationary power generation. Similarly, knowledge spillovers as a proportion of total spillovers from partners and proxies were positively related to country-level GDP. This finding suggests that whereas firms from larger economies acquired a greater proportion of their knowledge from alliance partners compared to proxies, firms from smaller economies acquired a greater proportion of their knowledge through non-alliance mechanisms or proxies. Therefore, the size of the economy was observed to play a significant role in influencing the effectiveness of the alliance strategy for knowledge building. Technological achievement was found to be significantly but negatively related to the ratio of spillovers, thereby implying that firms that had a valuable technological base did not necessarily acquire it through alliances.

According to expectations, corporatism was observed to have a negative and significant coefficient, thereby suggesting that the ratio of knowledge spillovers from partners to total spillovers from partners and proxies was lower by a factor of $\exp(1.0234)$ or 2.78 in corporatist versus associational polities. Therefore, even though alliance counts of firms did not vary according to the degree of corporatism in their location of innovation, the effectiveness of alliance for the purpose of knowledge building did. Given the institutional context of corporatist polities, hypothesis H2(a) predicted fewer knowledge spillovers from alliance partners due to the proclivity for enduring and repeated partnerships that may have limited the search for new knowledge. Further, the pressures for isomorphism and legitimacy may have altered the notion of viability such that firms may have continued to engage in non-productive alliances because the collaborative norms of corporatism may otherwise impose penalties for switching to alternative strategies. Hypothesis H2(a) was therefore supported ($p < 0.05$).

Table 5. Descriptive Statistics for Variables in Models Estimating Knowledge Spillovers from Alliances

Variables	Min	Max	Mean	Std
Time1	0	1.000	0.029	0.170
Time 2	0	1.000	0.065	0.247
Time 3	0	1.000	0.150	0.357
Transportation Industry	0	1.000	0.247	0.432
Stationary Power Industry	0	1.000	0.085	0.279
Fuel Cell Component Industry	0	1.000	0.660	0.473
Foreign Partner	0	1.000	0.410	0.492
Multi-Partner Alliance _t	0	1.000	0.311	0.463
Merged Polity	0	1.000	0.055	0.229
Ln(Country Level R&D) _t	0.693	8.830	6.845	1.720
Ln(Country Level GDP) _t	9.264	10.811	10.338	0.230
Ln(Total Firm Patents) _t	0	4.948	0.955	1.011
Ln(Technological Experience) _t	0	3.218	2.754	0.631
Technological Base _t	0	205.000	26.819	39.072
Technological Concentration _t	0	1.000	0.364	0.376
Technological Achievement _t	0	0.141	0.027	0.033
Patent Group Dummy	0	1.000	0.527	0.499
Structural Holes _t	0	1.000	0.707	0.355
Corporatism _t	0	1.000	0.390	0.488
Statism _t	0	1.000	0.393	0.488
Spillovers From Partner ¹⁴	0	26.000	1.728	3.208
Spillovers From Partner and Matched Proxies	1.000	38.000	3.255	4.036

¹⁴ Ratio of knowledge spillovers from partners versus non-partners is computed by dividing spillovers from partners by spillovers from partners and matched proxies. The variable defined as spillovers from partners or matched proxies in the table is the outcome variable in the model with the patent group dummy predicting significance of knowledge spillovers from partners compared to non-partners.

Spillovers From Partner or Matched Proxy	1.000	26.000	2.503	2.959
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Table 6. Correlation Matrix of Variables in the Model Predicting Knowledge Spillovers

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1 Spillovers from Partners t_{t+1}	1	0.82	0.9	0.059	0.15	0.00	0.05	0.04	0.03	0.08	0.23	0.12	0.06	0.05	0.01	-	0.05	0.189	0.17		
2 Total Spillovers from Partners and Proxies t_{t+1}			1	0.8	0.064	0.16	0.01	0.00	0.00	0.04	0.17	0.22	0.05	0.04	0.13	0.02	0.071	0.08	-	0.03	
3 Spillovers from Partners Or Proxies t_{t+1}				1	0.088	0.09	0.00	0.07	0.01	0.08	0.05	0.26	0.10	0.06	0.00	0.01	0.084	0.02	0.184	0.17	
4 Time 3					1	0.11	0.07	0.02	0.06	0.00	0.10	0.18	0.04	0.07	0.02	0.09	-	0.150	0.01	-	0.06
5 Time 2						1	0.04	0.09	0.06	0.08	0.11	0.00	0.11	0.09	0.08	0.25	-	0.108	0.01	0.134	0.13
6 Time 1							1	0.09	0.04	0.03	0.00	0.07	0.20	0.04	0.12	0.49	-	-	0.10	0.219	0.21
7 Multi-Party Alliance								1	0.01	0.05	0.00	0.07	0.01	0.10	0.06	0.02	-	0.088	0.05	0.119	0.10
8 Merged Polity									1	0.17	0.22	0.11	0.01	0.10	0.02	0.11	-	0.118	0.00	0.155	0.15
9 Transportation										1	0.80	0.17	0.11	0.11	0.00	0.03	-	0.116	0.07	0.317	0.35
10 Components											1	0.42	0.14	0.06	0.00	0.06	-	0.081	0.08	0.232	0.33
11 Power												1	0.04	0.07	0.01	0.03	0.0724	0.037	0.03	0.101	0.00
12 Ln(Total Country Patents) t_t													1	0.34	-	0.18	0.2145	-	0.11	-	-

					2*	0.04	8*	7*	0.075	4*	0.513	0.41
					1				*		*	1*
									-	-		
13	Ln(Country GDP) _t				1	0.03	0.17	0.009	0.064	0.12	0.421	0.33
						1*	6*		*	6*	*	4*
											-	-
14	Ln(Total Firm Patents) _t				1		0.14	0.332	0.048	0.29	0.060	0.08
							7*			6*	1*	2*
											-	-
15	Ln(Technological Experience) _t							0.137	0.144	0.03	0.094	0.10
							1	**		7	*	2*
											-	-
16	Technological Base _t								-	0.39	0.183	0.18
									1	0.011	4*	1*
											3*	
17	Technological Concentration _t									0.16	0.058	0.01
									1	9*	8*	0
											-	-
18	Technological Achievement _t										0.229	0.21
										1	*	5*
19	Corporatism _t											0.83
											1	6*
20	Statism _t											1

* significant at p < 0.10

Table 7. Negative Binomial Estimates of Knowledge Spillovers in t+5

Variables	Model 4 (Main Effects With Patent Dummy)	Model 4 (Simulated) 20% Reduction in Patents of U.S. Firms	Model 5 (Main Effects of Corporatism on Knowledge Spillover Ratio)	Model 5 (Simulated) 20% Reduction in Patents of U.S. Firms
Constant	1.4825(0.36)	0.5729(0.14)	-24.1790(-1.84)**	-22.6944(-1.76)**
Time1	-0.1677(-0.28)	-0.2082(-0.69)	3.5783(4.17)***	3.3309(3.85)***
Time 2	0.2569(0.48)	0.2301(0.44)	1.5061(2.62)***	1.5004(2.71)***
Time 3	-0.2254(-0.73)	-0.2290(-0.40)	0.4272(1.25)	0.5248(1.51)*
Transportation Industry	1.1727(2.69)***	1.3149(2.99)***	1.6784(1.67)**	1.6073(1.56)*
Stationary Power Industry	1.9036(4.61)***	2.0131(4.67)***	0.6851(0.67)	0.7650(0.73)
Fuel Cell Component Industry	1.2618(2.42)**	1.4089(2.67)***	2.0837(2.24)***	1.9331(1.98)**
Multi-Partner Alliance _t	0.0195(0.26)	0.0234(0.33)	0.0646(0.28)	0.0783(0.34)
Merged Polity	-0.2686(-1.05)	-0.1969(-0.72)	0.1628(0.28)	0.2752(0.52)
Ln(Country Level R&D) _t	0.0741(1.27)*	0.0128(0.21)	0.0857(0.45)	0.1342(0.72)
Ln(Country Level GDP) _t	-0.2361(-0.59)	-0.1295(-0.32)	1.8201(1.36)*	1.6627(1.26)*
Ln(Total Firm Patents) _t	-0.0780(-0.93)	-0.0909(-1.09)	-0.0199(-0.15)	0.0277(0.23)
Ln(Technological Experience) _t	-0.2652(-1.57)*	-0.2901(-1.73)**	0.0950(0.24)	0.0780(0.19)
Technological Base _t	0.0025(1.02)	0.0049(1.55)*	-0.0053(-1.25)	-0.0053(-1.10)
Technological Concentration _t	-0.2228(-0.80)	-0.2184(-0.74)	0.0817(0.28)	0.0881(0.30)
Technological Achievement _t	4.2262(1.25)*	4.6785(1.26)	-14.6287(-3.25)***	-14.2567(-3.06)***
Patent Group Dummy Corporatism _t	0.7243(2.77)***	0.7265(2.66)***	-1.0234(-1.45)**	-1.0045(-1.48)*
Number of Observations	508	508	508	508
Scaled Pearson χ^2 (Value/d.f.)	1.098	1.03	0.8274	0.8085
Log Likelihood	115.6126	-40.0707	-34.3676	-160.3714

Dependent variable: Knowledge Spillovers; β coefficient (z value); *** p < 0.01; **p<0.05; *p<0.10

Robustness Checks for Models Estimating Knowledge Spillovers

The estimates for knowledge spillovers reported in the preceding sections are based on the matching approach labeled as *Approach A* whereby for each partner matches were determined by directly examining the citations in the focal firm's patents. In an alternative matching approach labeled *Approach B*, proxies were found based on the same five criteria--country, industry, size, technological base and technological achievement, used for determining proxies in Approach A. The five criteria were selected because of their expected influence on alliance formation and associated knowledge spillovers.

Whereas in Approach A, proxies were selected by directly examining the matches in the focal firm's patent citations in the 5 year post alliance period, in Approach B, matches were identified from a set of 2434 USPTO assignees in fuel cell and related patent classes including hydrogen, battery, electronics, electricity generation, electrochemical processes and semiconductor technologies. Approach A yielded one best proxy for 445 of the 508 alliances, and either 2 or 3 proxies that matched equally for 63 alliances. Therefore, Approach A included spillovers that occurred from one or more than one proxy (for the 63 instances when 2 or 3 proxies were found as the best matches) for the alliance partners. In this manner, the model estimated spillovers from the alliance partner as a proportion of total spillovers from the partner and the best matched proxy or proxies, so that all knowledge spillovers that occurred from the best matched proxy or proxies were taken into account. By examining the firm's patent citations directly, Approach A improved the probability that the proxy or proxies was relevant for the firm's fuel cell technology innovation.

In a variation of the models using proxies from Approach A discussed in the following sections, I used only one best proxy for the 63 cases where either 2 or 3 best proxies were found¹⁵. In this manner, a limitation of Approach A arising from unequal number of proxies was addressed.

In Approach B, one best-matched proxy was randomly selected from a set of matches obtained from the 2434 USPTO assignees. Table 8(a) provides the profile of proxies using Approach B. The approach yielded better matched proxies in terms of the number of proxies that matched the partner on all five criteria compared to Approach A (Tables 1(a) and 1 (b)). However, these proxies were not always cited in the focal firm's patents. Therefore, a larger number of observations recorded zero spillovers from proxies under Approach B. Even though zero spillovers from proxies *per se* did not present a limitation for this analysis, it is plausible that the random proxy selected from a sample of 2434 USPTO assignees was not relevant to the focal firm's fuel cell technology innovation, thereby presenting the possibility of undercounting spillovers from proxies.

In the following sections, I compare the results for estimating knowledge spillovers from partners based on proxies from Approaches A and B.

Table 8(a). Profile of Proxies Using Matching Approach B

Type of Alliance/Matching Criteria	Country	Industry	Size	Technological Base	Technological Achievement
All Alliance Partners	508(100%)	452 (89%)	309(78%)	411(81%)	417(82%)
Foreign Partners	211(100%)	177(84%)	76(36%)	88(42%)	70(33%)

Number (%)

Table 8(b). Profile of Proxies: Number of Criteria Matched Using Approach B

Type of Alliance/Number of Criteria Matched	Five	Four	Three	Two
All Alliance Partners	65	116	170	157
Foreign Partners	19	55	88	49

Table 9 compares the results from variations of models estimating the relationship between corporatism and knowledge spillovers. Results from Model 5 that estimated the proportion of knowledge spillovers

¹⁵ For better comparability of results across models with proxies from Approaches A and B, in a variation of the models using proxies from Approach A, I recorded spillovers from one randomly selected best matched proxy rather than average spillovers from proxies for the 63 cases where either 2 or 3 best matched proxies were found.

based on proxies from Approach A are shown alongside results from other variations of Model 5 for the ease of comparison. In Model 5(a), I estimated knowledge spillovers as counts after controlling for spillovers from proxies using Approach A for identifying the matches. The estimates for most model covariates remained consistent across both models estimating knowledge spillovers as a ratio and as a count. However, the model predicting alliance counts had an improved fit as evidenced from a higher value of the log-likelihood ratio statistic. In Model 5(a) knowledge spillovers from proxies were found to have a positive and significant relationship with knowledge spillovers from the partner. The negative relationship of knowledge spillovers with corporatism was found to increase in both magnitude and significance in Model 5(a), such that counts of citations to partners in corporatist polities were only 63% of counts of citations to partners for firms in associational polities.

In Model 5 (b), I replaced the counts of citations to proxies using matching Approach A with counts of citations to proxies using matching Approach B. A comparison of Models 5(a) and 5(b) reveals that whereas knowledge spillovers from the matched proxies using Approach A had a positive and significant relationship with spillovers from partners, spillovers from the randomly selected matched proxy in Approach B had no significant relationship with spillovers from the partner. These results suggest that knowledge spillovers from alliance partners were significantly related to spillovers from non-partners (or proxies) also cited by the firm. Therefore, a firm's ability to build on the knowledge from its alliance partners was related to the knowledge it acquired from proxies (through non-alliance mechanisms) also cited in the patents. However, knowledge spillovers from alliance partners were not significantly related to spillovers from a randomly selected proxy that may or may not have been cited by the firm. Hence a firm's success in knowledge building through alliance and non-alliance mechanisms appeared to have been correlated after controlling for the characteristics of the source of knowledge (in this case alliance partners and their proxies). The negative and significant relationship between corporatism and knowledge spillovers from partners, however, remained unchanged across both models.

In summary, the relationship with corporatism in both models estimating knowledge spillovers as counts versus ratios remained consistent in sign and significance. The overall fit of the model however was considerably higher in the model estimating knowledge spillovers as counts. The magnitude of the relationship with corporatism was also higher when knowledge spillovers were estimated as counts instead of ratios, thereby implying that not only were knowledge spillovers from alliance partners fewer relative to spillovers from proxies in corporatist polities, but these spillovers were also fewer in absolute terms. Similarly, consistent results were obtained when the relationship between corporatism and knowledge spillovers from partners was estimated based on spillovers from proxies using matching Approach B.

Table 9 Negative Binomial Estimates of the Relationship Between Corporatism and Knowledge Spillovers in t+5

Variables	Model 5 Main Effects of Corporatism on Knowledge Spillover Ratio	Model 5 (a) Counts of Spillovers from Partner Controlling for Knowledge Spillovers from Proxy (Approach A)	Model 5 (b) Counts of Spillovers from Partner Controlling for Knowledge Spillovers from Proxy (Approach B)
Constant	-24.1790(-1.84)**	-49.4045(-2.78)***	-40.3925(-1.92)
Time1	3.5783(4.17)***	1.6104(1.64)**	1.5914(1.47)*
Time 2	1.5061(2.62)***	2.4565(3.65)***	2.2072(3.00)***
Time 3	0.4272(1.25)	0.9407(1.96)**	0.7596(1.6)**
Transportation Industry	1.6784(1.67)**	1.8925(2.85)***	1.3441(1.76)**
Stationary Power Industry	0.6851(0.67)	2.5174(3.00)***	2.0691(2.09)**
Fuel Cell Component Industry	2.0837(2.24)***	2.0864(3.14)***	1.4032(1.91)**
Multi-Partner Alliance _t	0.0646(0.28)	0.088(0.6)	0.0343(0.26)
Merged Polity	0.1628(0.28)	0.8852(1.58)**	0.6159(0.87)
Ln(Country Level R&D) _t	0.0857(0.45)	-0.1362(-1.23)	-0.0504(-0.42)
Ln(Country Level GDP) _t	1.8201(1.36)*	4.6093(2.67)***	3.8947(1.86)**
Ln(Total Firm Patents) _t	-0.0199(-0.15)	0.0972(0.68)	0.1361(0.89)
Ln(Technological Experience) _t	0.0950(0.24)	0.0621(0.14)	-0.4298(-0.77)
Technological Base _t	-0.0053(-1.25)	0.0024(0.85)	0.0032(1.09)
Technological Concentration _t	0.0817(0.28)	-0.1523(-0.25)	-0.3699(-0.52)
Technological Achievement _t	-14.6287(-3.25)***	1.7074(0.52)	0.2781(0.06)
Spillovers from Proxy _{t+1}		0.1411(2.47)**	-0.1192(-0.62)
Residual Statism _t			
Corporatism _t	-1.0234(-1.45)**	-2.7607(-3.95)***	-2.2536(-2.86)***
Number of Observations	508	508	508
Scaled Pearson χ^2 (Value/d.f.)	0.8274	0.9497	1.029
Log Likelihood	-34.3676	92.6396	87.527

Dependent variable: Knowledge Spillovers; β coefficient (z value); *** p < 0.01; **p<0.05; *p<0.10

Main Findings: Implications for Theory and Practice

In the introductory section I noted that even though transaction-cost economics provides a powerful theoretical lens, it is often inadequate to explain the rationale for engaging in alliance as opposed to non-alliance strategies. This is true especially in the context of knowledge-based transactions as in the case of fuel cell technology development, where partners' knowledge is seldom revealed *ex-ante*, thereby making it difficult to assess the costs of the transaction. In addition, transaction-cost based approaches do not fully account for the effect of institutions and social capital that are likely to affect knowledge-based transactions. Similarly, even though the resource-based view greatly strengthens our understanding of variations in firms' propensities to engage in alliances and acquire knowledge from the innovation system, it does not fully account for the *sources* of firms' resources and the interaction with the institutional environment. The resource-based view also does not make a distinction between firms' *ability*, accounted for by its resource base, and the *motivation* to deploy these resources in a productive manner as evidenced from the variations in the propensities to engage in technology development alliances, and actively build upon the partners' knowledge.

By incorporating the institutional dimension, as well as the temporal and cross-sectional dimensions of firms' innovative activity in a single technology arena—fuel cells—this research has demonstrated two important aspects related to the phenomena under study. In summary, the study has found that variations in the degree of corporatism characterizing the national institutional environment in the firm's location of innovation interact with firm-, dyad- and network-level variables to have a significant impact on: 1) firms' motivation to engage in technology development alliances and, 2) firms' propensities to benefit from alliances by absorbing and effectively building on the knowledge spillovers from partners.

The salience of the national institutional environment emerges from the observation that most firms tend to concentrate their R&D activity in new technology development in just one country—in most cases, their home country. In new technologies such as fuel cells, U.S. patenting records revealed for instance that in less than 2% of the patents, one or more inventors were located outside the home country of the innovating firm. Similar findings with regards to predominantly locating R&D in the home country were reported by Held, McGrew, Goldblatt and Perraton (1999). The effect of the institutional environment, therefore, is likely to be especially pronounced in new technology innovation.

Even though most firms may not regard locating their innovation activities abroad as a strategic choice due to the likely preferential treatment by home country governments and familiarity with the national institutional environment, the observed significance of the location of innovation (or the country where the bulk of the innovation occurs) in predicting both alliances and knowledge spillovers suggests that location decisions for innovation matter to firms. Further research that investigates the factors contributing to the strategic location of R&D and the characteristics of firms that make them especially suited for carrying out R&D outside their home country can make an important contribution to the extant literature on the subject.

Interestingly, firms from corporatist polities were not found to have a greater number of alliances as compared with firms from associational polities. This observation reveals that the propensity to engage in technological collaboration was not lower for firms in associational polities. In part, this deviation from theory may be explained by an emergent institutional transformation in associational polities, leaning towards greater cooperation as evidenced from the relaxation of antitrust regulations and competition policies (Gilbert, 2004). Alternatively, consistent with theory, it is plausible that there exist variations in the extent to which alliances are enduring; alliances may be longer lasting in corporatist polities but more transient in associational polities.

The qualitative analysis showed, for example, that even though public-private partnerships were a prominent feature of FCT innovation across most countries, the characteristics of these partnerships in terms of their structure and duration could be quite distinct. In contrast to highly encompassing and hierarchically organized network approaches led by government agencies and a few large private firms in Germany and Japan, public-private partnerships in the U.S. often involved a broader range of firms and technologies, and in most instances were initiated by private actors themselves.

As an extension, it may be hypothesized that even though firms did not demonstrate significant variations in the propensity to *form* alliances according to the degree of corporatism in their location of innovation, greater variability in the structure and duration of these alliances may be investigated in future research, in light of the observed variation in the effectiveness of these alliances as a strategy for knowledge building.

Even though firms in both corporatist and associational polities showed similar propensities to engage in alliances, the benefit from these alliances in terms of knowledge spillovers from partners as a proportion of total spillovers was found to be significantly lower for firms from corporatist polities than for firms in associational polities. As an example, Proton Motor, a German firm carrying out the bulk of its fuel cell R&D activity in Germany, has 11 publicly announced alliances with German firm and non-firm actors. On examining the patent applications of Proton Motor, however, not a single citation was made to any of the 11 partners. In fact, all citations were to patents of U.S. firms whose characteristics did not match those of Proton Motor's alliance partners.

The findings point to the possibility that even though firms' networks in corporatist and associational polities do not differ significantly in terms of size or density, the quality of these networks in terms of productivity gains from knowledge spillovers does vary. As Hansen (1999) aptly summarized, in dense corporatist networks, strong ties lead to redundancy of knowledge because everyone within a group knows what others know. This observation together with the results from this empirical study suggest that even though firms with high levels of technological achievement from corporatist polities may not successfully absorb knowledge from partners, these firms could be attractive partners for foreign firms (from associational polities) that are likely to benefit from the valuable knowledge embodied in these firms.

Relatedly, variations in strategies for building on the technological base through internal versus external knowledge acquisition strategies may be investigated (Rosenkopf and Nerkar, 2001). Thus, given the relatively lower effectiveness of external knowledge building strategies through alliances in corporatist polities compared to associational polities, despite a strong technological base, firms in corporatist polities in particular, could benefit more from internal or market-based knowledge building strategies. Further, hypotheses that test for variations in firms' propensities to *share* knowledge as opposed to *acquire* knowledge across polities, may be developed in subsequent research.

The practical implications of findings from this research are three-fold. First, innovative activity through technology alliances is a function of not only firm-, dyadic- and network-level characteristics, but also the institutional environment and related technology policies that can either impede or facilitate firms' strategic efforts geared towards knowledge building. Managers in firms, therefore, must develop necessary capabilities to recognize the strengths and weaknesses of the institutional environment within which innovation occurs and devise strategies for knowledge acquisition that help optimize the positive aspects of the institutional environment. In so doing, managers may select the location of innovation strategically, taking into account characteristics such as size, technological base, technological concentration and technological distance, to maximize benefits from technology alliances. In this regard, dispersing R&D efforts across different locations that help offset constraints and maximize gains may be particularly helpful.

Second, managers responsible for developing technological alliances with firms across polities must determine the complementarities with the institutional environment for the alliance to be successful. Thus, managers in firms that forge technology alliances with the intent of capturing global markets must seek to understand the various norms of innovation and collaboration in an array of target countries across the globe. The alliance between the U.S. firm Ceramtec and its Norwegian partners illustrate this dynamic in terms of the ability of the U.S. firm to acquire the knowledge from its Norwegian partners in a short period, and capitalize on this newly acquired intellectual property to launch a subsidiary SOFCo in the U.S. Anecdotal evidence suggests that the alliance termination affected the Norwegian partners unfavorably, making it difficult to continue the innovative activity initiated as a result of the alliance. Therefore, whereas the U.S. firm's strategy embodied characteristics of associationalism that focused on rapid internalization of the partner's knowledge, development of intellectual property with exclusive rights and reliance on internal structures for harnessing the acquired knowledge, the Norwegian partners in the tradition of corporatism may have expected a long-term, enduring partnership, with gradual incrementalism in the knowledge-building activity, and were therefore, perhaps, unable to derive commensurate benefits from the alliance.

Finally, managers of firms from polities that are undergoing an institutional transformation need to devise especially innovative strategies that do not penalize their firms for non-conformity with the institutional norms from the past. Special capabilities, therefore, may be needed to equip managers with the skills required to cope with changes in the domestic *and* international landscapes.

In conclusion, findings from this study provided evidence to support the claim that firms are social actors as much as agents of economic activity; their knowledge building strategies reflect individualistic versus communitarian ideologies inherent in their institutional environment. Further, even as the search for knowledge increasingly transcends local and national boundaries, the local and national environment remain critical in this regard. In addition, the study found that changes in the institutional environment are

perhaps inevitable, but a unified world order still remains elusive, such that variations continue to abound, contributing to innovation and growth.

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