ABSTRACT

Dissertation Title:	INTERORGANIZATIONAL INNOVATION: THE ROLE OF SUPPLIERS IN ENHANCING BUYER INNOVATION
	Isaac John Elking, Doctor of Philosophy, 2016
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This dissertation explores the effect of innovative knowledge transfer across supply chain partners. My research seeks to understand the manner by which a firm is able to benefit from the innovative capabilities of its supply chain partners and utilize the external knowledge they hold to increase its own levels of innovation. Specifically, I make use of patent data as a proxy for firm-level innovation and develop both independent and dependent variables from the data contained within the patent filings. I further examine the means by which key dyadic and portfolio supply chain relationship characteristics moderate the relationship between supplier innovation and buyer innovation. I investigate factors such as the degree of transactional reciprocity between the buyer and supplier, the similarity of the firms' knowledge bases, and specific chain characteristics (e.g., geographic propinquity) to provide greater

understanding of the means by which the transfer of innovative knowledge across firms in a supply chain can be enhanced or inhibited.

This dissertation spans three essays to provide insights into the role that supply chain relationships play in affecting a focal firm's level of innovation. While innovation has been at the core of a wide body of research, very little empirical work exists that considers the role of vertical buyer-supplier relationships on a firm's ability to develop new and novel innovations. I begin by considering the fundamental unit of analysis within a supply chain, the buyer-supplier dyad. After developing initial insights based on the interactions between singular buyers and suppliers, essay two extends the analysis to consider the full spectrum of a buyer's supply base by aggregating the individual buyer-supplier dyad level data into firm-supply network level data. Through this broader level of analysis, I am able to examine how the relational characteristics between a buyer firm and its supply base affect its ability to leverage the full portfolio of its suppliers' innovative knowledge. Finally, in essay three I further extend the analysis to explore the means by which a buyer firm can use its suppliers to enhance its ability to access distant knowledge held by other organizations that the buyer is only connected to indirectly through its suppliers.

INTERORGANIZATIONAL INNOVATION: THE ROLE OF SUPPLIERS IN ENHANCING BUYER INNOVATION

by

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2016

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Acknowledgements

I want to first of all thank my beautiful, patient, amazing, kind, patient, wife, Emily (did I mention she is incredibly patient?). Not only did she uproot her entire life to join me in Maryland, she also planned our entire wedding, funded all of our non-conference travels, spent many nights reading over drafts, and only rarely lamented our inability to live the "dual-income-no-kids" lifestyle like many of our friends. I cannot repay her enough for her unwavering support over these many, many, many years. I'd like to thank my family for always lending a sympathetic ear and for wielding a red pen with reckless abandon. Their steadfast encouragement helped motivate me whenever I needed an extra push in the right direction.

Words cannot express how fortunate I feel to have been a part of the Logistics, Business and Public Policy Ph.D. program at the University of Maryland. There is simply no better group of supportive, encouraging, and yet occasionally brutally honest faculty members anywhere in this world. Without the wealth of advice and guidance I received from Dr. Curt Grimm, I would still be sitting in my office trying to figure out how to justify why profits improve firm profitability or something equally inane. I cannot thank him enough for acting as my faculty advisor and Dissertation Chair. I am particularly grateful to Dr. David Cantor and Dr. Christian Hofer for the many hours, days, weeks, months, and years they have worked with me and helped guide this dissertation. Joining their team and being privy to their wealth of knowledge and expertise has been of immeasurable value to my research process. I

would also like to thank Dr. Bob Windle, Dr. Tom Corsi, Dr. Martin Dresner, Dr. Phil Evers, Dr. Yan Dong, and Dr. Stephanie Eckerd for their consistent support and encouragement.

I could not have survived without the friends I had to commiserate with in the Ph.D. program, Anupam, Adams, Kevin, Omar, Heidi, John-Patrick, Camil, Alan, Xiaodan, Kate, and Rohan. Our Ph.D. program coordinator, Justina Blanco, deserves a special mention for single-handedly keeping me compliant with all University rules and regulations (by force when necessary) and for always offering sage advice.

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Introduction

In a recent interview, Unilever's Vice President of Procurement stated that, "In the [previous] three years, about 70% of our innovations have been contributions from our suppliers" (Degun 2014). This is consistent with L'Oreal's position that, "The ability of [L'Oreal's] suppliers to propose new solutions and technology and to develop innovative products and services in partnership with the L'Oreal teams makes a direct contribution to the success of new products," (L'Oreal 2015). Similarly, BMW has stated that, "The BMW Group considers innovation the foundation of a company's economic success and future competitiveness… The BMW Group therefore recognises its most innovative suppliers as key partners who play a crucial role in the successful implementation of new developments" (BMWGroup 2013). It is clear from these statements that those in industry have recognized both the importance of their own innovation as a driver of market success as well as the criticality of leveraging the innovative capabilities of their suppliers to further drive their own innovativeness.

This raises several questions of interest from an academic standpoint. First, is there a relationship between a focal firm's innovative capability and its suppliers' innovative capabilities? How do the characteristics of the relationship between a buyer and its suppliers affect the ability of a firm to benefit from its suppliers' innovative capabilities? And finally, can a firm's suppliers provide a useful link to other innovative firms the buyer is not directly involved with, and if so what factors determine the buyer's ability to benefit from those indirect ties?

This dissertation spans three essays in an attempt to delve into these research questions and offers insights into the role that supply chain relationships play in enhancing a focal firm's innovation activities. While innovation has been at the core of a wide body of research, and recent work in the strategy field has acknowledged the role of external parties as a key source of knowledge and capabilities, very little empirical work exists that considers the role of vertical buyer-supplier relationships on a firm's ability to develop new and novel innovations. This dissertation begins by considering the fundamental unit of analysis within a supply chain, the buyer-supplier dyad. After developing initial insights based on the interactions between singular buyers and suppliers, essay two extends the analysis to consider the full spectrum of a buyer's supply base by aggregating the individual buyer-supplier dyad level data into firm-supply network level data. Through this broader level of analysis, I am able to examine how the relational characteristics between a buyer and its supply base affect its ability to benefit from the full portfolio of its suppliers' innovative knowledge. Finally, in essay three I further extend the analysis to explore the means by which a buyer firm can use its suppliers to enhance its ability to access distant knowledge held by other organizations that the buyer is only connected to indirectly through its suppliers.

Previous academic work has long espoused the value of innovation to an organization. Schumpeter (1934) first proposed the idea that a firm's competitive advantage is fleeting and is continually eroded by what he terms 'the perennial gale of

creative destruction' brought about by a firm as well as its competitors as they seek to outperform each other. Given this environment, Schumpeter suggests that the mechanism by which a firm is able to extend its competitive advantage into a sustainable advantage is through continuous innovation. This notion has been supported by the work of other notable scholars, including Teece and Pisano (1994) whose seminal work on dynamic capabilities suggests that firms should seek to align their internal operations so as to more effectively promote innovative action as a strategic priority. They argue this innovative action then leads to a firm developing and maintaining a sustainable competitive advantage. Numerous research studies have also empirically demonstrated the positive impacts of innovation on firm financial performance (e.g.,Lahiri and Narayanan 2013, Rothaermel, Hitt, and Jobe 2006).

Given the benefits inherent in the successful development of innovations, the use of external sources of knowledge that complement a firm's own internal knowledge and capabilities is crucial in order to effectively develop and introduce new technological developments (Teece 1986). Chesbrough (2006) goes on to note that internal innovation can be accelerated though a combination of internal and external knowledge while Powell, Koput, and Smith-Doerr (1996) recognize the dispersion of critical knowledge across organizations and identify the locus of innovation as residing in a network rather than internal to the firm itself.

Recognizing the importance of external parties in successful innovation development, the strategy literature has explored the role of alliance partners and joint ventures in driving innovation and offered insights into the mechanisms by which these partnerships facilitate or inhibit the flow of knowledge across interorganizational boundaries. (Sampson 2007, Srivastava and Gnyawali 2011, Mowery, Oxley, and Silverman 1996).

Despite the wealth of knowledge created by this stream of alliance partner research, there has been a dearth of research considering the role of vertical relationships characterized by traditional supply chain partnerships between buyers and suppliers. This gap is particularly cogent when considering the inherent differences between alliances and more traditional supply chain relationships that alter the role of each member and the underlying purpose of such partnerships. Alliances can be characterized as voluntary, collaborative arrangements across a broad set of participants that may include universities, research laboratories, industry groups, and competitors who band together with the intention of leveraging economies of scale while distributing risks and costs in the pursuit of joint R&D, marketing, production, and/or supply activities (Mariti and Smiley 1983, Sampson 2007). In contrast, a buyer-supplier relationship may be collaborative or adversarial in nature and fundamentally exists as a mechanism to transfer goods and/or services across organizational boundaries for pecuniary and non-pecuniary compensation (Lambert and Cooper 2000). As such, there are likely to be many dynamics specific to the supply chain exchange relationship that impact the flow of knowledge between

firms that wouldn’t be captured from considering the relationship from an alliance perspective.

Essay 1: Supplier Innovative Capabilities and Buyer Innovative Performance

1. Introduction

Innovation has long been identified as a crucial source of sustainable competitive advantage for firms (Schumpeter 1934, Lahiri and Narayanan 2013, Teece and Pisano 1994). However, firms' internal resources are often insufficient to cultivate new knowledge when acting in isolation (Teece 2007). To overcome this limitation, many firms seek to leverage the knowledge and capabilities of external parties to develop original innovations (Srivastava and Gnyawali 2011, Sampson 2007, Ahuja 2000). While researchers have examined the value of research and development (R&D) partnerships, joint ventures, and other strategic alliances as contributors to a firm's knowledge base (Mowery, Oxley, and Silverman 1996, Sampson 2007, Stuart 2000, Srivastava and Gnyawali 2011), there has been a deficiency of literature exploring the impact a supplier's innovation activity may have on buyer innovation. In this study, we theorize and empirically examine how a firm's suppliers serve as a source of knowledge and facilitate the focal firm's ability to innovate. Moreover, we examine how the dynamics of the dyadic social relationships between buyer-supplier partners facilitate or impede this flow of knowledge across interorganizational boundaries.

There is ample anecdotal evidence illustrating the importance of suppliers in firms' innovation activities. In a recent interview, Unilever's Vice President of

Procurement stated that, “In the [previous] three years, about 70% of our innovations have been contributions from our suppliers” (Degun 2014). This is consistent with L’Oreal’s position that, “The ability of [L’Oreal’s] suppliers to propose new solutions and technology and to develop innovative products and services in partnership with the L’Oreal teams makes a direct contribution to the success of new products,” (L'Oreal 2015). Similarly, BMW has stated that, “The BMW Group considers innovation the foundation of a company’s economic success and future competitiveness… The BMW Group therefore recognises its most innovative suppliers as key partners who play a crucial role in the successful implementation of new developments” (BMWGroup 2013). These examples suggest industry managers look not only at joint ventures and alliance partnerships to facilitate innovations, but also at their existing supplier network as a source of knowledge. Given the importance of the transfer of knowledge across organizational boundaries to a firm’s innovative success, this paper focuses on developing and empirically testing theoretical arguments on the ability of suppliers to act as a source of knowledge and information that enhances buyer innovation. Specifically, this paper considers the following questions: Does supplier innovation activity benefit buyer firm innovation activity? And, how do dyadic social relationship dynamics between buying and supplying firms affect how a focal firm’s innovation activity benefits from supplier innovation activity?

Previous research has established that firms which are able to leverage external knowledge sources are more innovative than firms which develop

innovations using internal information and processes only (Dyer and Nobeoka 2000, Miller, Fern, and Cardinal 2007). Strategy scholars in particular have looked at the role of joint ventures, R&D partnerships, and other strategic alliances as repositories of knowledge that a linked firm can access to enhance their own innovative performance (Mowery, Oxley, and Silverman 1996, Sampson 2007).

Researchers have also acknowledged the importance that vertical partners may have in acting as a source of external knowledge and influencing firm innovations. Srivastava and Gnyawali (2011), for example, explore the role of a firm's portfolio of suppliers in influencing the firm's development of breakthrough innovations and consider the impact of factors such as the diversity and richness of knowledge contained within this portfolio of suppliers. Ceccagnoli and Jiang (2013) examine technology suppliers and the effect of their knowledge transfer capabilities on their decision to license products downstream to buyers or to compete in the product market themselves. Other studies have focused on the role of suppliers as collaborators in new product development (Chesbrough 2006, Swink and Mabert 2000), as well as their ability to influence the speed of new product introductions (Azadegan and Dooley 2010). Alcacer and Oxley (2014) examine mobile telecommunications patents in the US to investigate the ability of a supplying firm to build technological and market capabilities through the action of selling to downstream firms. Their analysis centers on the underlying goal of suppliers to vertically integrate downstream and move into direct competition with their current customers as producers of branded products. As such, these suppliers must acquire

both technological and marketing resources. While their primary investigation centers around the accumulation of a supplier's capabilities based on its own characteristics as well as the characteristics of its customers, Alcacer and Oxley (2014) also find a positive and significant impact of higher levels of customer patenting on a supplier's patenting activity.

We make a number of contributions to the extant literature on innovation and interorganizational knowledge transfer with this study. First, despite the attention external knowledge sources have garnered in literature, there has been no theoretical or empirical investigation of the impact a supplier's innovation activity may have on the innovation activity of a buyer firm. We fill this gap through a dyad-level analysis of supplier innovation on subsequent buyer innovation in the following year. Furthermore, we build theory by extending the concept of vicarious learning from unilateral mimetic observation-oriented learning to encompass dyadic relationship dynamics that may results in bilateral actions by both members of a supply chain dyad to facilitate interorganizational learning. Finally, we also develop novel insights through archival analysis using a unique dataset constructed using a combination of financial data from Compustat, supply chain data from Bloomberg, and patent data from LexisNexis.

Organizational learning theorists have demonstrated the value of vicarious learning in explaining the means by which firms are able to learn from the experiences and knowledge accumulated by other firms while minimizing the costs

and time needed to accumulate experiences of their own (Posen and Chen 2013, Kim and Miner 2007). Despite this potential, scholars also recognize the difficulty of transferring knowledge across organizational boundaries, (Tsai 2001, Grant 1996). They consider factors such as the visibility of the external knowledge (Ingram 2002, Ocasio 1997) and the amount and quality of the information held by the external firm (Argote and Ophir 2002) as drivers of vicarious learning, but stop short of considering how the relationship between the knowledge sender and recipient may affect any knowledge transfer and assume passivity on the part of the sender (Myers 2015).

We turn to network theory to inform our expectations of how relational attributes of dyadic pairs can engender active participation in vicarious learning activities. Researchers examining network theory have demonstrated the value of social relationships to stimulate interorganizational collaboration and to positively impact firm innovation by enabling knowledge sharing routines (Inkpen and Tsang 2005, Powell, Koput, and Smith-Doerr 1996, Parkhe, Wasserman, and Ralston 2006). Uzzi (1996) outlines the concept of embeddedness between network partners and outlines how the strength of a relationship can enable joint efforts and the sharing of tacit information across organizational boundaries. Perhaps most enlightening, Rivera, Soderstrom, and Uzzi (2010) delve into the dynamics of social relationships between members of a dyad and describe specific mechanisms that determine the degree of embeddedness between network ties.

Integrating micro-level insights from vicarious learning theory with dyadic-level mechanisms highlighted by social network theorists, we theorize that supplier firm innovation activity represents an important knowledge resource buyer firms looking to magnify their own innovation activity can capitalize upon. We also extend theory on vicarious learning by suggesting that the transfer of knowledge from a supplier to a buyer firm is affected by the social relationship dynamics that exist between the two firms. We propose this relationship can shift vicarious learning from a one-way observation and imitation process to an interactive knowledge sharing process.

Empirically, we test these theoretical arguments through the use of archival data analysis to directly test the influence of suppliers' innovation on buyer innovation activity under various conditions and across a broad range of manufacturing industries. We further extend existing interorganizational theory on knowledge transfer to consider the dyadic relationship characteristics that facilitate or impede the transfer of such knowledge across firm boundaries between vertical supply chain partners. Specifically, we consider the dyadic social network relationships in terms of assortative, relational, and proximity mechanisms and determine how these enhance or impede knowledge flows that lead to improved buyer innovation performance.

2. Theory and Hypotheses

Prior scholars examining the ability of one firm to learn vicariously through the accumulated knowledge and experiences of another firm focus on the efficacy of the focal firm's attempts to imitate or avoid actions taken by the other firm (Levitt and March 1988, Huber 1991). They note that this mimetic process can include the positive replication of another firm's routines, strategies, and designs and can impart knowledge to the focal firm via the offering of solutions to problems, demonstrating behaviors that lead to positive outcomes, and the spillover of technical knowledge (Kim and Miner 2007, Haunschild and Miner 1997, Posen and Chen 2013). Organizational learning theorists have suggested the amount of vicarious learning available to a firm is driven by two main factors: (1) the visibility of external information, and (2) the amount and quality of the information held at an external source (Kim and Miner 2007, Ingram 2002, Argote and Ophir 2002). Vicarious learning can be demonstrated by the focal firm altering its behaviors in response to its observation of behaviors of an external organization (Srinivasan, Haunschild, and Grewal 2007). Furthermore, innovation has often been considered one key output of organizational learning, suggesting that if greater innovation activity by one organization results in an increase in innovation activity at a focal firm, the focal firm has engaged in vicarious learning (Srinivasan, Haunschild, and Grewal 2007).

As noted by Myers (2015), one major limitation to traditional perspectives on vicarious learning is the assumption it is a one-way process of observation and mimetic action despite the substantial ambiguity present in work sites (Hofmann, Lei, and Grant 2009). By considering vicarious learning actions within the overarching

social relationships between a pair of firms, we are able to build theory on how social network mechanisms may engender a knowledgeable firm to actively assist in the transfer of knowledge to a recipient firm. Specifically, social network theorists contend that economic action is embedded in social structures (Granovetter 1985), and social relations enable interfirm coordination, resource sharing, and adaptation (Uzzi 1996). Network linkages have also been shown to serve as conduits for exchange of technological and social knowledge (Haunschild 1994). Furthermore, as the tie between two firms strengthens, the firms are increasingly capable undertaking fine-grained information transfer, including the transfer of tacit knowledge (Uzzi 1996, Mowery, Oxley, and Silverman 1996, Lane and Lubatkin 1998). In this study we leverage the typology developed by Rivera, Soderstrom, and Uzzi (2010) to examine how assortative, relational, and proximity mechanisms drive social network dynamics within dyadic relationships that may engender the development of close ties that facilitate fine-grained knowledge transfer and encourage vicarious learning actions.

Synthesizing arguments from vicarious learning theory and social network theory offers powerful insights into the means by which knowledge transfer and learning occurs between interorganizational supply chain partners. Specifically, the combination of these two theories suggests how attributes of the social relationship between a buyer and a supplier influences the efficacy of a buyer's attempts to pursue vicarious learning efforts and thus benefit from a supplier's innovation activity in a way that leads to increased buyer firm innovation.

2.1 Suppliers as a source of innovation

Firm competition is increasingly dependent on the creation and commercialization of knowledge (Sampson 2007), to the point where many scholars have asserted that innovation is the key driver behind sustainable competitive advantage (e.g., Miller, Fern, and Cardinal 2007, Brown and Eisenhardt 1995). However, a firm must continually acquire novel information or devise new ways of combining existing information as the basis for future innovation development (Miller, Fern, and Cardinal 2007). Firms have devised a number of mechanisms to explicitly facilitate the acquisition of such external knowledge, including the formation of R&D alliances (Sampson 2007), hiring well-informed employees away from other firms (Rosenkopf and Almeida 2003), and developing joint ventures with knowledgeable firms (Inkpen 2000). While this stream of research has been well developed, it is not all together surprising that firms engaged in such activities with a focus on research and development or technological collaboration are able to enhance their innovation activity (Sampson 2007).

Supply chain relationships are fundamentally different from these types of partnerships as they exist for the primary reason of providing a requisite good or service to a buying firm and any transfer of knowledge is often at most a secondary goal (Malhotra, Gosain, and Sawy 2005). Recent scholars have suggested supply chain relationships are increasingly seen as strategic arrangements that can provide value beyond the provision of goods and services as firms increasingly gain

awareness of their ability to compete at a network level, characterized as 'supply chain vs. supply chain' as opposed to the traditional 'firm vs. firm' competition (e.g., Lambert and Cooper 2000, Hult, Ketchen, and Slater 2004, Cao and Zhang 2011). Furthermore, there is evidence that firms are moving beyond traditional, competitive buyer-supplier relationships with the advent of interorganizational strategic policies such as collaborative forecasting, planning, and replenishment and vendor managed inventory, driving the pursuit of closer, more collaborative relationships (Cao and Zhang 2011, Fawcett and Magnan 2004, Xu, Dong, and Evers 2001). Despite this changing landscape, it is not clear ex ante if the benefits from these supply chain relationships include knowledge transfer that enhances buyer innovation activity.

Vicarious learning theorists posit that firms can imitate successful routines, strategies, and designs employed by other firms when they are privy to such information (Srinivasan, Haunschild, and Grewal 2007). The ability to recognize the relevant external information and employ it in a meaningful way is determined by the visibility, quantity, and quality of the external information (Kim and Miner 2007). Ongoing supply chain relationships require the firms to interact on a regular basis to place and fulfill orders, negotiate terms and conditions, reconcile any disputes, etc. (Lambert and Cooper 2000), creating ample opportunities for a buyer firm to be exposed to a supplier's internal information and processes. Furthermore, this systematic pattern of interactions can lead to the development of routines that facilitate the ability of one firm to learn from the other (Powell, Koput, and Smith-Doerr 1996).

Supply chain relationships are not limited to economic exchange only, but also incorporate social exchanges between buyers and suppliers (Griffith, Harvey, and Lusch 2006, Choi and Hartley 1996). Social network theorists contend that these social elements can have a profound impact on an economic exchange between two parties (Granovetter 1985). One particular realm of interest for this study is the impact of these social relationships on information transfer. Along this vein, researchers have demonstrated the role of social networks to facilitate knowledge sharing and interactive learning processes among participating firms (Inkpen and Tsang 2005, Powell, Koput, and Smith-Doerr 1996). Similarly, Uzzi (1996) identifies the ability of social relationships to enable interfirm resource sharing, cooperation, coordination, and adaptation. Haunschild (1994) also notes that networks of contact can act as conduits for the exchange of technological and social knowledge. This suggests supply chain relationships may also enable the buyer and supplier firms to engage in effective knowledge sharing across firm boundaries through their social ties.

Previous literature also supports the notion that suppliers are able to act as a source of knowledge for the firms with which they enter into exchange relationships. Li, Poppo, and Zhou (2010) examined multi-national firms and empirically demonstrated that local suppliers act as a source of both tacit and explicit knowledge for foreign subsidiaries. Mahmood, Zhu, and Zajac (2011) linked greater numbers of buyer-supplier ties in business groups to improved focal firm R&D capabilities.

Survey respondents have also identified suppliers as one of the most important external sources of knowledge (Leiponen and Helfat 2011, Laursen and Salter 2006).

Based on these insights from the extant literature, we contend that there are several potential means by which a highly innovative supplier firm can positively influence the innovation activity of a buyer firm. As noted by the vicarious learning literature, innovative firms contribute to the creation of a large pool of knowledge and information that another firm can combine with their own complementary knowledge to facilitate innovation (Yang, Phelps, and Steensma 2010). Furthermore, innovative firms can engender mimetic responses in terms of routines, strategies, and designs from firms looking to find similar levels of innovative success, especially when the innovative firm is not in direct competition with the learning firm – as is often the case with supply chain relationships (Srinivasan, Haunschild, and Grewal 2007). A supplier with high levels of innovation thus becomes an important target for vicarious learning actions undertaken by a buyer firm seeking to develop future innovation. The social exchange between buyers and suppliers created through their repeated contact creates pathways for the information held by an innovative supplier to cross organizational boundaries and promotes the sharing of knowledge (Inkpen and Tsang 2005), enabling a buyer firm to combine this external knowledge with its own internal knowledge repository and promote innovation activity.

Taking these arguments together, we contend that innovative suppliers represent a valuable source of external knowledge for a buyer firm, and the social

relationship between the two firms enable the buyer firm to effectively undertake vicariously learning activity in a manner that improves the buyer firm's innovation activity. Formally stated,

Hypothesis 1. Higher levels of supplier innovation lead to higher levels of focal firm innovation.

2.2 Moderators

External knowledge can be a valuable asset for firms looking to innovate, but it is difficult to identify and acquire through traditional market mechanisms as most knowledge remains in tacit form (Von Hippel 1994, Miller, Fern, and Cardinal 2007). We turn to the logic of social network theory and the role of embeddedness to understand what factors enable or impede the ability of a buyer firm to successfully undertake vicarious learning activity and acquire knowledge from an innovative supplier. Higher levels of embeddedness between two firms have been shown to create avenues for the transfer of fine-grained information, to encourage knowledge sharing activities, and to facilitate the transmission of tacit knowledge (Uzzi 1996, Reagans and McEvily 2003, Hansen 1999). We follow a call by Rivera, Soderstrom, and Uzzi (2010) to consider three distinct sociological perspectives in determining different aspects of dyadic embeddedness between firms. Specifically, we consider proximity, relational, and assortative mechanisms and investigate the role each of these plays in determining the efficacy of interorganizational knowledge transfer from innovative supplier firms to buyers.

Supply chain relationships are often described along a continuum from traditional, arms-length relationships to a highly coordinated and collaborative strategic partnerships (Mentzer, Min, and Zacharia 2000). We suggest the embeddedness between two firms can be further distilled into three distinct mechanisms as proposed by Rivera, Soderstrom, and Uzzi (2010) to provide greater understanding of how the social relationship between a buyer and supplier determines the resulting impact of any vicarious learning efforts on a buyer firm's subsequent innovation activity.

2.2.1 Proximity mechanisms

Rivera, Soderstrom, and Uzzi (2010) suggest proximity mechanisms are one fundamental determination of social relationship dynamics between firms, specifically factors such as the geographic propinquity of the firms in question. The physical distance between two firms can influence the social relationship in a supply chain dyad in a number of ways. Organizations that are located in close proximity are able to facilitate the use of frequent and rich communications such as face-to-face meetings that enable the development of interpersonal trust and collaboration (Abrams et al. 2003). Furthermore, firms located near one another are more likely to engage in direct interactions via participation in regional social networks such as industry groups, trade associations, or casual gathering places (Saxenian 1994). This social interaction creates opportunities for a mutually shared culture to emerge and further engenders the development of trust between the organizations (Corredoira and

Rosenkopf 2010). Beyond direct interactions, physical proximity increases the likelihood that both firms share similar values and norms when considering culture at a regional level, which in turn affects behaviors and knowledge sharing (De Long and Fahey 2000, Bhagat et al. 2002).

As suggested by these studies, we contend the geographic proximity aspect of embeddedness promotes greater frequency of social interactions and the formation of trust between a buyer-supplier dyad. This increases the ability of the buyer firm to successfully undertake vicarious learning actions by increasing the visibility of knowledge and innovation-oriented routines of a supplier (Ingram 2002) and the quality of the knowledge in terms of commercial value (Andrews and Delahaye 2000). Furthermore, the cooperative behavior engendered by trust and interaction frequency has also been linked to motivating a knowledgeable firm's efforts to assist a recipient firm's understating of shared knowledge (Reagans and McEvily 2003) while allaying the knowledgeable firm's fears of recipient firm opportunism (Helper 1990, Parkhe 1993) and appropriability concerns (Dhanaraj and Parkhe 2006).

We suggest that when a buyer and supplier firm are located in close proximity, they are more able and more likely to develop a collaborative relationship. Any negotiations are less likely to be subject to differing cultural norms and associated misunderstandings, and any problems or issues can be addressed through high-touch communications such as face-to-face meetings and without time zone lags. Thus, we expect greater geographic propinquity between buyer and supplier

firms in a supply chain dyad to increase the efficacy of vicarious learning actions undertaken by a buyer firm. Formally stated,

Hypothesis 2: Greater geographic proximity between the supplier and focal buyer firm strengthens the positive relationship between supplier innovation and focal firm innovation.

2.2.2 Relational mechanisms

The second perspective identified by Rivera, Soderstrom, and Uzzi (2010) that is expected to influence social dynamics are the relational mechanisms between the firms. One specific mechanism that is expected to have impacts at the dyadic-level is the tendency towards reciprocity within a relationship (Rivera, Soderstrom, and Uzzi 2010). This perspective highlights the importance of balance and symmetry between actors in bilateral relationships. Sociologists have found that one-way relationships are inherently less stable, with one study reporting such relationships are twice as likely to fail and dissolve entirely than to be reciprocated (Hallinan 1978). Thye, Lawler, and Yoon (2011) extend this notion of reciprocity to the dependencies of each party in an exchange relationship and suggest that a balanced relationship where each member has equal power results in greater cohesion, embeddedness, and relational commitment.

Management scholars have echoed these sentiments as well, noting the importance of reciprocity and commitment in interorganizational relationships. Dyer

and Singh (1998) propose greater levels of dependence in a relationship as an incentive for the member firms to share knowledge and to invest in relationship-specific assets. In their seminal paper on strategic alliance formation, Mohr and Spekman (1994) suggest greater commitment and dependence symmetry increase the probability of a successful partnership. Greater reciprocal dependence between firms is also expected to promote the use of relational contracting and drive tacit knowledge sharing (Ring and Van de Ven 1992). Furthermore, higher levels of reciprocity have been linked to greater cooperation and increased mutual support in interorganizational relationships (Oliver 1990). Goes and Park (1997) identify the role of transactional reciprocity in network exchanges to act as an intermediate form of governance between markets and hierarchies that reduces opportunism, enables monitoring, and incentivizes information and technology sharing actions. While greater reciprocity can enhance relationships, scholars have also demonstrated the potential negative impacts of asymmetry between actors. In a study of joint ventures, Park and Ungson (1997) make special note of how asymmetric dependency between partners is likely to encourage opportunistic behavior, causing instability and an increased risk of dissolution.

The importance of reciprocity within supply chain relationships can be easily understood when one considers the potential detriments of asymmetric dependencies. Many high-power firms are well known for leveraging the dependence of their suppliers to take actions that benefit their own objectives at the cost of their suppliers. Firms such as Apple and Wal-Mart use their power to force lower prices from

suppliers (Bustillo and Martin 2010, Team 2011) while other firms like Proctor & Gamble and DuPont dictate longer payment terms to their suppliers to free up cash (Ng 2013). Greater reciprocity between supply chain members, on the other hand, are linked with greater cooperation, trust, and information sharing (Handfield and Bechtel 2002).

Building upon these arguments, we suggest greater levels of transactional reciprocity between members of a buyer-supplier dyad strengthen the relational mechanisms embedded in the dyad through greater cohesion, ameliorating concerns of opportunism, and encouraging joint activities. We theorize this dynamic of transactional reciprocity will further increase the efficacy of a buyer firm's ability to develop innovations through vicarious learning actions undertaken with an innovative supplier. Formally stated,

Hypothesis 3: Greater transactional reciprocity between the supplier and focal buyer firm strengthens the positive relationship between supplier innovation and focal firm innovation.

2.2.3 Assortative mechanisms

In addition to the proximity and relational perspectives, Rivera, Soderstrom, and Uzzi (2010) propose a third perspective governing dyadic social exchanges they identify as assortative mechanisms. They contend social relationships are affected by the degree of compatibility and complementarity of each actor's attributes, including

the dynamics of homophily. Sociologists have found the existence of a strong preference for homophily across an expansive range of relationships, with greater similarities between actors increasing the probability of a connection being established (see McPherson, Smith-Lovin, and Cook 2001 for a comprehensive review of the relevant literature). Homophily is associated with a reduction in misunderstandings, potential conflicts, and monitoring costs while setting a priori expectations of acceptance and trust (Rivera, Soderstrom, and Uzzi 2010).

Scholars in the management literature have found that organizations are also influenced by preferences for homophily when selecting interorganizational partners (Powell et al. 2005). Furthermore, homophily has been linked to both the probability of interorganizational linkages forming (Tsai 2000) as well as alliance success (Lavie, Haunschild, and Khanna 2012). One well established measure of homophily in management literature is the similarity of the resource profiles of firms engaged in an exchange relationship (e.g., Mowery, Oxley, and Silverman 1996, Lane, Salk, and Lyles 2001). Mowery, Oxley, and Silverman (1998) find similarity in technological profiles promotes the formation of alliances in not only research and development oriented partnerships, but also in the formation of alliances for the pursuit of production or marketing activities or for market-access. This suggests the overlap in technology profiles indicates a useful lens for considering homophilic aspects of interorganizational relationships beyond an expected driver of R&D collaborations.

We theorize that buyers and suppliers with high degrees of technological overlap benefit from homophilic mechanisms that improve both a buyer's ability to undertake vicarious learning actions as well as a supplier's incentive to assist in facilitating such learning activity. Greater technical similarity allows a buyer firm to better understand the activities being performed by an innovative supplier, both in relation to the actual knowledge (Cusumano and Elenkov 1994) as well as the routines being employed to facilitate innovation (Whetten 1981). Furthermore, these similarities are also likely to strengthen ties between the firms, assist in avoiding competitive frictions, improve communications, and reduce uncertainty about future actions (Lavie, Haunschild, and Khanna 2012, Wang and Zajac 2007, Brass et al. 2004). As these firms are more readily able to identify with each other, the social efficiency of their interactions is enhanced (Robson, Katsikeas, and Bello 2008). Formally stated,

Hypothesis 4: Greater technical similarity between the supplier and focal buyer firm strengthens the positive relationship between supplier innovation and focal firm innovation.

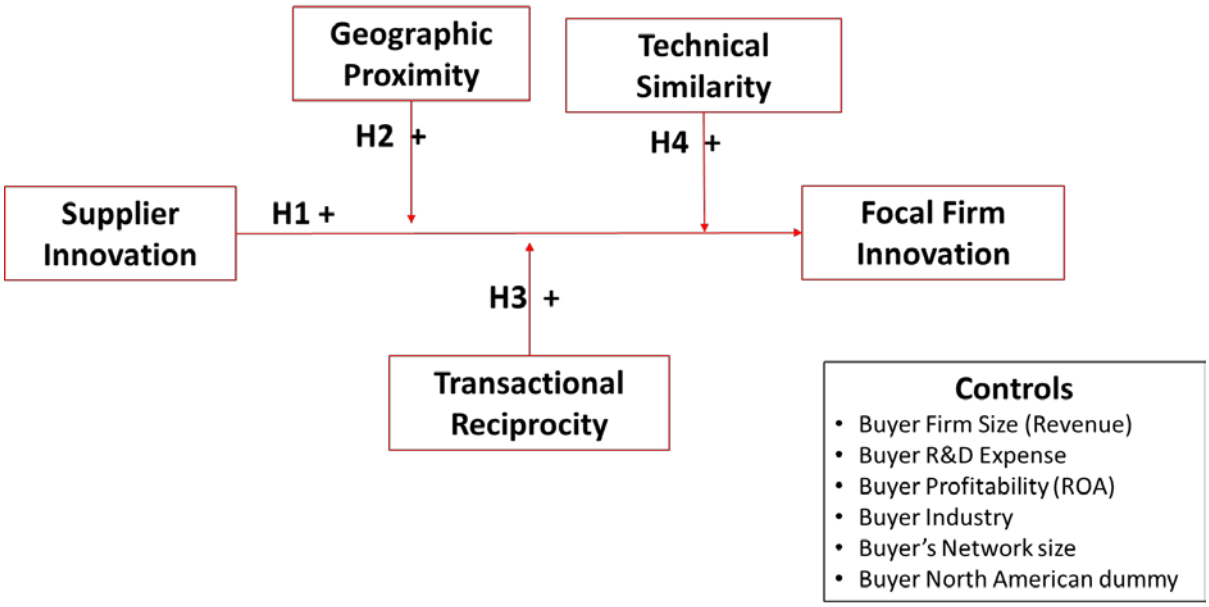
A graphical depiction of the hypothesized relationships to be tested is provided in Figure 1.

3. *Empirical Analysis*

3.1 *Data*

The data set was constructed through a multi-step process. First, we used the Compustat database to search for any firms classified with a three-digit NAICS code in a manufacturing sector (311 – 339) in 2012, the last full year of data available when data collection began. This step yielded an initial list of 2,275 US public manufacturing firms. We then accessed Bloomberg's Supply Chain Analysis (SPLC) database, which contains information that identifies the supply chain relationships between a company and its suppliers and provides insight into the financial aspects of the relationship at a dyadic buyer-supplier level. It harnesses unique, proprietary algorithms to derive quantified values to the relationships between firms despite the absence of publicly declared figures. This is done through an amalgamation of a wide range of individual sources of information, including financial statements,

Figure 1: Summary of Hypotheses and Graphical Model of Essay 1



industry data, accounting types, purchased proprietary data, channels, products, etc. This database has been utilized in other studies as a viable means to identify supply chain relationships (e.g., Steven, Dong, and Corsi 2014). Matching the data obtained from Compustat with the data available in the Bloomberg SPLC database resulted in a set of 835 manufacturing firms, as Bloomberg's database has only limited information on smaller companies. One key limitation of the Bloomberg SPLC database is that it offers a snapshot only. Historical supply chain relationship data is not available from Bloomberg. This limits our study to a cross-sectional analysis of the set of supply chain relationships reported at the beginning of the year in 2013 that were identified in our data collection effort.

We then extracted the full set of supplier data contained within the Bloomberg SPLC database linked to these 835 manufacturing firms. The resulting data included 11,648 buyer-supplier dyads, including suppliers associated with the buyer's cost of goods sold (COGS) expenses; capital expenditures; selling, goods and administrative expenses; and research and development expenses. We filtered out any suppliers not associated with COGS expenses as these are most closely aligned with traditional supply chain relationships. That is, we expect the supply of materials and services used in the manufacturing of a buyer's finished product to create opportunities for the supplier's innovations to directly influence the buyer's innovative performance. These purchases account for critical external inputs to the buyer's final products, and ensures this study differentiates itself from those where the partnerships of interest are

traditional alliances focused primarily on joint R&D activities instead of the transfer of goods and/or services. After this filtering, our data set consists of a total of 8,135 buyer-supplier dyads comprised of 736 buyer-manufacturing firms linked with 3,228 unique suppliers.

Using these 8,135 supply chain dyads, we accessed LexisNexis' TotalPatent database and extracted patent documents for each buyer and supplier identified in our dataset. We considered only patents applied to and granted through the Unites States Patent and Trademark Office (USPTO) for a multiple reasons. Considering patent documents from a single country creates consistency, reliability, and comparability across firms (Griliches 1990). Furthermore, the United States is well known for offering highly effective intellectual property protection and has a large consumer market, incentivizing foreign companies to pursue patent protections through the USPTO (Phelps 2010). Given the limited time period of data available through Bloomberg's SPLC database, our data collection was limited to successful US buyer patents applied for in 2012, which aligns with the identification of the supply chain dyads via Bloomberg in early 2013. This data was collected after the second quarter of 2015 to allow ample time for the patent to be made public. Indeed, Bellamy, Ghosh, and Hora (2014) examined patents filings from 2001 to 2011 and found the average time from application to either granting or abandonment of the patent to be 2.5 years. We then collected the associated successful supplier patent documents that were applied for in 2011 to allow us to introduce a one year lag effect into our model. After accounting for missing data from both the patent database and our control

variables, our final data set consists of 554 buyer manufacturing firms associated with 1,076 unique suppliers for a total of 5,545 buyer-supplier dyads in 2012.

3.2 Measures

3.2.1 Dependent Variable

Each focal manufacturing firm's level of innovation (*buyer innovation*) is measured as the number of successful patent applications submitted to the USPTO in 2012 using the compiled patent data (Alcacer and Oxley 2014) . Patents have been demonstrated to be good indicators of innovation performance across a wide body of previous literature (Sampson 2007, Keil et al. 2008, Ahuja and Katila 2001, Hall and Ziedonis 2001, Whittington, Owen-Smith, and Powell 2009). Furthermore, they have been found to correlate highly with alternative innovation measures such as new product announcements (Hagedoorn and Cloodt 2003). Patents are considered to be generally better measures of innovative output than non-patent based measures as they require firms to demonstrate novelty as well as utility in exchange for intellectual property protection and are clearly a measure of innovation output whereas alternative measures such as R&D expenditures are often considered to be inputs to the innovation process (Griliches 1990, Yang, Lin, and Lin 2010).

3.2.2 Independent Variables

The first independent variable of interest is the level of *supplier innovation*. This is measured by calculating the number of successful US patent applications

submitted to the USPTO by the supplier firm in 2011, measured one year prior to the buyer firm's measure of innovation. The introduction of the lag year allows time for the diffusion of information across firm boundaries and for the buyer to incorporate the knowledge developed by the supplier into their innovation activities (Alcacer and Oxley 2014).

Geographic proximity is a variable that captures the physical distance between the headquarters of the buyer and supplier firms used in this study. Information on the physical headquarters locations was first collected from Bloomberg and then converted to latitude and longitude coordinates based on Google Maps APIs and the World Geodetic System WGS84 standard via accessing the website www.latlong.net. Following Natividad (2014) we then used the Haversine formula (Robusto 1957) to calculate the great circle distance in kilometers between the headquarters locations to account for the curvature of the Earth. The localization of knowledge and the associated effects of proximity on social interactions have gained traction in recent years, including studies by Carnahan and Somaya (2013) and Corredoira and Rosenkopf (2010). The use of a physical distance variable allows us to proxy for a number of more nuanced factors in a region such as culture, norms, and overlapping professional social networks (Saxenian 1994, De Long and Fahey 2000).

The second independent variable considered is the degree of *transactional reciprocity* between the focal firm and the supplier. We develop this measure through a consideration of the financial dependence of each member of the supply chain dyad

on the other member (Emery and Marques 2011, Provan 1993, Galbraith and Stiles 1983, Dong et al. 2014). Specifically, we use the Bloomberg data and reverse code the absolute value of the difference in the percentage of the supplier's revenue that comes from the focal manufacturing firm and the percentage of the focal firm's total costs of goods sold that is spent with the supplier. Thus, as the value nears 0, there is more financial balance in the relationship as there is greater parity between a supplier's revenue dependence and the buyer's cost exposure. Greater negative values reflect a relationship where either a supplier's revenue exposure is significantly higher than the buyer's cost exposure or the buyer's COGS expense greatly outweighs the supplier's revenue exposure. This high degree of asymmetry reflects a disparity in the dependence of the dyad members and less *transactional reciprocity* and has been linked to greater opportunism and conflict (Park and Ungson 1997).

The final independent variable of interest in this study is the *technical similarity* between the focal manufacturing firm and its supplier. Importantly, this measure determines how similar or distant the areas of knowledge are in which each firm is actively innovating. We follow the work of Yang, Lin, and Lin (2010) and Rosenkopf and Almeida (2003) by estimating the technical distance between the two firms through the use of a Euclidian distance calculation. This method requires the construction of each firm's distribution of patents across technical domains (identified herein though the use of the patents' 4-digit International Patent Classification code) and then a computation of the proportion of the firm's patents that are contained within each technical domain. Once these calculations have been performed for each

firm and supplier dyad, the Euclidian distance between the supply chain partners in each dyad can be calculated by taking the square root of the sum of the squared differences between the proportions of each firm's patents in each technical domain. This is formally defined in equation 1.

$$\text{Technical Distance} = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2}, \quad (1)$$

where q_i is the proportion of firm q's patents in technical domain i, p_i is the proportion of firm p's patents in technical domain i, and n is the total number of technical domains. As a practical example, Yang, Lin, and Lin (2010, 247) offer the following explanation:

> To illustrate, if Firm A has five percent of its patents in Domain A, 55 percent in Domain B, 30 percent in Domain C, and 10 percent in Domain D, while Firm B has 10 percent of its patents in Domain A, 10 percent in Domain B, 80 percent in Domain C, and zero percent in Domain D, then the technical distance between the two firms can be calculated as the square root of the sum $[(0.05–0.1)^2 +(0.55–0.1)^2 +(0.3–0.8)^2 +(0.1–0)^2]$.

As such, this measure ranges from zero (when the firms have identical distributions of patenting activity across each technical domain) to about 1.4 (the square root of two, as indicated when each firm only has patenting activity in one technical domain and that domain is different for each of the firms). To ease interpretation and to maintain consistency with our geographic measure, we multiply these technical distance values by -1 so that more negative numbers reflect less technical similarity between a buyer-

supplier dyad and as the measure approaches 0, the firms are considered to be increasingly technically similar.

3.2.3 Control variables

A number of control variables are also included to account for other factors that might be correlated with a focal firm's innovation performance. Firm size is calculated as the revenue of the focal firm. More profitable firms may have additional resources available to invest in innovative activity and knowledge appropriation; hence, focal firm ROA is included as an additional control variable. We control for focal firm research and development expense as it is linked to the degree of effort a firm puts forth on innovation activities as well as the firm's degree of internal absorptive capacity that allows it to recognize, understand, and internalize knowledge from external sources (Ceccagnoli and Jiang 2013, Cohen and Levinthal 1990). To account for different patenting practices for firms outside of North America, we include a dummy variable valued 0 when focal firm headquarters are located outside of North America (Rosenkopf and Almeida 2003). We also control for the number of suppliers that a focal firm sources from based on the data contained within the Bloomberg SPLC database, as this represents the size of the supply network from which a firm can elicit knowledge. Finally, we include dummy variables as industry controls for the buyers based on the NIACS codes at the two-digit level to account for variations in patenting practices across different types of manufacturing industries.

3.3 Methods

There are a number of characteristics of our data that make the use of ordinary least squares (OLS) regression techniques inappropriate. First, there are repeated observations for the same focal firm linked with multiple suppliers across our data set, so the residual error terms are likely to be correlated, violating the OLS assumption of independent observations. Furthermore, the data are likely to be heterogeneous in the variance of the disturbance terms across different focal buyer firms and cause heteroscedasticity issues for which OLS is not designed to correct. Finally, our dependent variable is a non-negative count measure and as such violates the OLS assumption of a normally distributed dependent variable. To correct for the lack of independence and heteroscedasticity we employ clustered robust standard errors (Petersen 2009, Rogers 1983, Huber 1967, Cameron and Miller 2015). Additionally, because of the non-negative count nature of our dependent variable we consider both Poisson and negative-binomial regression models to conduct our analysis (Greene 2003). The significant non-zero outcome of a likelihood ratio test of the over-dispersion parameter in the negative-binomial model suggested the Poisson distribution would not be appropriate for our model (Greene 2003). As such, we make use of the negative-binomial model to account for the over-dispersion issue (Hausman, Hall, and Griliches 1984).

We conduct our analysis in an iterative fashion, adding in relevant interaction terms to evaluate each of the hypothesized relationships. The first model includes the controls along with the baseline relationship between supplier innovation and focal

buyer firm innovation. Subsequent models introduce the interactions between the dyadic focal firm-supplier characteristics of geographic proximity, transactional reciprocity, and technical similarity to investigate the associated impacts on the baseline relationship.

4. Results

The 554 buyer firms in our study are involved in 5,545 buyer-supplier dyads captured in our data collection efforts. The descriptive statistics for all variables are reported in Table 1. To verify that multicollinearity issues are not present, variance inflation factors were calculated and found to be below 2.0 for all variables contained in our regressions, well below the suggested cutoff value of 10, indicating multicollinearity is likely not affecting our results (Kennedy 2003). As expected, a Breusch-Pagan/Cook-Weisberg test for heteroscedasticity identified potential concerns related to a violation of homoscedasticity assumptions, and was corrected for in our models through the use of clustered robust standard errors in our regression models.

The estimation results presented in Table 2 explore the relationship between supplier firm innovation activity and buyer firm innovation in the subsequent year, as evidenced by each firm's patenting activity. The dependent variable in these negative binomial regressions is *buyer innovation*. All models include buyer industry fixed effects. Model 1 examines the baseline relationship between a supplier's innovation and a buyer firm's innovation in the following year as put forth in H1. The positive and significant coefficient of *supplier innovation* in Model 1 provides evidence in

TABLE 1

Descriptive Statistics and Correlations [a]

	Variable	Mean	Std. dev.	Min.	Max.	1	2	3	4	5	6	7	8	9
1.	Buyer Innovation	124.52	227.76	0.00	1,755.00									
2.	Supplier Innovation	51.31	132.40	0.00	877.00	0.03								
3.	Transactional Reciprocity	-3.04	7.55	-99.95	0	-0.02	-0.08							
4.	Geographic Proximity (1000 km)	5.07	4.22	0.00	19.68	0.03	0.10	-0.05						
5.	Technical Similarity [b]	-0.69	0.27	-1.41	0.00	0.22	0.20	-0.01	-0.00					
6.	RD Expense ($ Millions)	2,156.63	2,819.20	0.00	11,670.93	0.24	-0.07	-0.10	0.04	0.21				
7.	ROA	0.05	0.13	-2.48	0.78	0.17	-0.14	-0.01	-0.04	0.06	0.18			
8.	Revenue ($ Billions)	57.95	84.04	0.00	467.15	0.13	-0.11	-0.10	0.06	0.15	0.50	0.21		
9.	Buyer NA dummy	0.79	0.41	0.00	1.00	0.20	0.04	0.04	-0.14	0.01	-0.29	0.01	-0.36	
10.	Number of Suppliers	76.36	68.91	1.00	242.00	0.29	-0.13	0.02	-0.04	0.21	0.35	0.27	0.43	0.09

[a] n=5,545.

[b] n=3,101.

support of the contention that buyers can and do undertake vicarious learning actions to access the information and knowledge held by their upstream suppliers as a mechanism to learn and develop their own innovations. Furthermore, we see that R&D expense is positively linked to buyer patenting, as is ROA and North American firms have a greater propensity to submit patents through the USPTO. Model 2 introduces the direct effects of the hypothesized interaction terms.

In Model 3 we test the interaction effect of *geographic proximity* with the baseline relationship of supplier innovation activity influencing buyer innovation as outlined in H2. Contrary to our expectation, we find no significant impact of geographic proximity on the ability of a buyer firm to undertake successful vicarious learning actions. It is possible that the large size of many of our buyer firms has resulted in a less significant impact of a firm's overall headquarters location, and that between the use of regional offices and improved capabilities to engage with suppliers across international boundaries through information technology advances, geographically localized social influences are much less influential than they were in the past.

Model 4 introduces the interaction effect of the *transactional reciprocity* on the baseline relationship established in Model 1.The positive and statistically significant coefficient provides support for H3. When there is greater balance in the financial commitment to a buyer-supplier relationship, the associated social mechanisms build cohesion and encourage collaborative effort. This in turn facilitates the successful

TABLE 2

Negative Binomial Estimates for Buyer Innovation [a]

Variables	Model 1: Hypothesis 1		Model 2: Direct Effects		Model 3: Hypothesis 2		Model 4: Hypothesis 3		Model 5[b]: Hypothesis 4	
Supplier Innovation	0.0007*	(0.0004)	0.0007†	(0.00035)	0.0003	(0.00037)	0.0009*	(0.00038)	0.0026**	(0.00082)
Geographic Proximity			0.0269*	(0.00970)	0.0234**	(0.00924)	0.0277**	(0.00967)	0.0198	(0.01204)
Transactional Reciprocity			0.0051	(0.00443)	0.0053	(0.00443)	0.0014	(0.00472)	-0.0012	(0.00409)
Technical Similarity									0.8949***	(0.15794)
RD Expense	0.0002*	(0.0001)	0.0002*	(0.00008)	0.0002*	(0.00008)	0.0002*	(0.00008)	0.0002*	(0.00008)
ROA	1.7820†	(1.0299)	1.7774†	(1.01413)	1.7942†	(1.00917)	1.7997†	(0.98763)	1.1052	(1.13668)
Revenue	-0.0001	(0.0002)	-0.0006	(0.00189)	-0.0006	(0.00189)	-0.0006	(0.00189)	0.0004	(0.00209)
Buyer NA dummy	1.3212**	(0.4485)	1.3562**	(0.44404)	1.3613**	(0.44207)	1.3651**	(0.44318)	1.2312**	(0.41501)
Number of Suppliers	0.0029	(0.0027)	0.0029	(0.00270)	0.0029	(0.00270)	0.0028	(0.00269)	0.0013	(0.00259)
Supplier Innovation X Geography Proximity					0.0001	(0.00006)				
Supplier Innovation X Transactional Reciprocity							0.0001*	(0.00002)		
Supplier Innovation X Technical Similarity									0.0048**	(0.00152)
Constant	-0.3501	(0.3924)	-0.4894	(0.39668)	-0.4770	(0.39794)	-0.5090	(0.39646)	0.8731*	(0.39441)
Industry Dummies?	Yes		Yes		Yes		Yes		Yes	
Wald χ^2	204.72***		208.05***		220.66***		210.54***		369.14***	
df	8		10		11		11		12	

[a] Standard errors are in parentheses; n = 5,545

[b] n=3,101

† p < .10; * p < .05; ** p < .01; *** p<.001

Two tailed tests

employment of vicarious learning actions taken by a focal buyer firm to drive its own innovation activities.

Our final model incorporates our measure of *technical similarity* between the buyer and supplier firms. Here we analyze only a subset of our data (3,101 dyads from 360 buyer firms) as we were forced to drop observations where either the buyer or the supplier had zero patents in the observation year, thus making it impossible to assess *technical similarity* in such instances. The positive and significant coefficient of the interaction term demonstrates strong support for H4. A greater degree of technical similarity between a buyer and supplier acts as an effective assortative mechanism that improves communications and strengthens dyadic relationships, enabling a buyer firm to more efficiently extract useful knowledge from their supplier and in turn, to deploy that knowledge in innovative ways.

5. Discussion and Conclusion

Research in the management literature has increasingly focused on the need for firms to continually seek out and obtain new information and knowledge to enable the development of innovations, yet understanding how a firm's suppliers may act as a resource in the pursuit of this goal lags far behind. Furthermore, while vicarious learning has been recognized as a key enabler of interorganizational knowledge transfer (e.g., Srinivasan, Haunschild, and Grewal 2007, Ingram and Baum 1997), the extant literature has focused on vicarious learning as a one-way mimetic process and

in doing so has neglected to consider the underlying social relationship between the firm and how that may alter the efficacy of vicarious learning actions (Myers 2015).

This study makes several important contributions to the literature on innovation and interorganizational knowledge transfer. First, our results support the notion that a supplier's innovation activity can positively impact a buyer firm's innovation activity. This fills a gap in the literature that has not yet been investigated and suggests firms which rely on innovating to maintain competitive advantages should ensure their supplier selection process includes an analysis of each potential supplier's innovative activity. We also demonstrate the importance of relational dynamics in determining the efficacy of vicarious learning efforts undertaken by a buyer firm. This suggests vicarious learning is not simply a one-way observe and imitate process, but rather is a function of the relationship between the knowledge receiver as well as the source of the knowledge. Finally, we also make an empirical contribution through the development of a unique dataset constructed using a combination of financial data from Compustat, supply chain data from Bloomberg, and patent data from LexisNexis to conduct our analysis.

Our first hypothesis considers the direct effect of supplier firm innovation on a buyer firm's innovation in the subsequent year. We propose that highly innovative suppliers have a large pool of information and knowledge as well as efficient and effective innovation routines and strategies. Furthermore, we suggest that a buyer firm which is in a supply chain relationship with an innovative supplier will be able to

undertake vicarious learning actions to access that knowledge and imitate successful innovation behaviors, resulting in improved buyer innovation. As demonstrated by our results in Table 2, we find support for this concept. Despite the fact that supply chain relationships are fundamentally different from the traditional interorganizational alliance structures, especially those that are established for the explicit purpose of R&D collaborations, we find evidence that working with an innovative upstream supplier increases buyer firm innovation. Our results support the idea that supply chain relationships are not limited just to the exchange of goods and services, but operate within a broader social context that can further add value through activities such as interorganizational information transfer and vicarious learning. With suppliers becoming ever more critical to a firm's success, our findings suggest these relationships have indeed evolved from simple transactional relationships to include deeper, more strategic interactions.

Our analysis then turns to the logic of social networking theory and seeks to understand the role of the social relationship dynamics between a buyer and a supplier dyad in further enabling vicarious learning to promote buyer innovation. Specifically, we draw upon three underlying perspectives of dyads in social networks as put forth by Rivera, Soderstrom, and Uzzi (2010) and contend that proximity, relational, and assortative mechanisms strengthen relational ties between a buyer and a supplier and in turn facilitate a buyer's vicarious learning from an innovative supplier.

Our empirical results largely support these arguments. First, buyer firms benefit more from innovative suppliers when there are higher levels of transactional reciprocity. This result is positive and statistically significant at $p < .05$, providing support for the hypothesized effect. This finding suggests that when there is greater parity and balance in a supply chain relationship, especially in terms of the financial commitment and exposure from each member, the resulting cohesion and commitment encourages knowledge transfer activity such as vicarious learning. This supports the premise that relational mechanisms within dyads enhances the collaboration within a social relationship and promotes tie strength. Furthermore, our findings indicate that relational mechanisms can influence vicarious learning efforts and promote a buyer's visibility into the information held by an innovative supplier and encourage the supplier to engage in joint activities that promote interorganizational learning.

Assortative mechanisms also matter for interorganizational learning in supply chain dyads. As demonstrated in Model 4, we find a highly significant effect of technical similarity on a buyer firm's ability to benefit from an innovative supplier. This result supports the notion that firms who have greater homophily in terms of their areas of technical knowledge benefit from stronger social relationships as well. Our finding bolsters the argument put forth by Lavie, Haunschild, and Khanna (2012) that greater similarity between two firms can improve communications and understandings, reduce competitive frictions, and reduce uncertainty about the other firm's future actions. This, in turn, can promote the effectiveness of vicarious

learning thorough increasing the visibility of a supplier's information as well as reducing causal ambiguity related to innovative routines (Cusumano and Elenkov 1994, Whetten 1981).

Contrary to expectations, our analysis did not find a significant impact of proximity mechanisms in facilitating a buyer firm's vicarious learning from an innovative supplier. While geographic proximity has been suggested to act as a proxy for a number of localized relationship-enhancing factors (Saxenian 1994), it may be that the increasingly international focus of the current business environment along with information technology advances has enabled physically distant firms to develop a shared culture and norms of interaction that are equally as effective in promoting strong social relationship dynamics. We also acknowledge that our sample draws heavily upon buyer firms with large revenues. These firms are often international in nature and have operations spanning the globe, while our analysis only captures the headquarters locations of these buyers. It is possible that these buyers have facilities in the same country as their suppliers and are able to facilitate relationship building through social interactions at their non-headquarters locations. Furthermore, one of the underlying premises of geographic propinquity is that it is likely to result in more frequent interactions (Rivera, Soderstrom, and Uzzi 2010). While this may be a key factor in personal relationships, recent work in interorganizational studies has suggested working with geographically distant firms may require higher and faster rates of communication to overcome the associated difficulties (Boyd and Spekman 2008) and that e-mail communications may be more effective than face-to-face

communications in transmitting innovative knowledge (Ganesan, Malter, and Rindfleisch 2005).

These results have important practical implications for managers as well. Most notably, our findings suggest that firms seeking to increase their innovation performance should take care when evaluating and selecting their suppliers, as higher levels of supplier innovation are linked to higher levels of buyer innovation performance. This implies supplier innovation should be an important factor in the supplier selection process, which is aligned with the anecdotal evidence from industry executives who have repeatedly commented on the need to leverage the innovation expertise of their upstream suppliers. Our research also finds that these upstream suppliers appear to contribute most to firm innovation when they are engaged in a strong social relationship with the buyer. Specifically, we find buyers and suppliers with higher levels of transactional reciprocity and technical similarity encourage the development of strong social ties that facilitate vicarious learning. Contrary to expectations, we don't find that geographic proximity enhances vicarious learning in a supply chain dyad. Our findings suggest buyers looking to improve their innovation activities should focus more on the technical similarities and pursuing transactional reciprocity with innovative suppliers than physical propinquity.

Naturally, this research has important limitations. Supplier selection is a complex process that includes an extensive number of factors that must be considered. Buyers must consider and weigh the relative importance of a supplier's

characteristics to best align with their needs and the goals of their organization. While our research suggests suppliers play an important role in improving a buyer's innovation activities, it does not consider other key supplier attributes such as product quality, delivery performance, price, previous interactions, etc. Care must also be taken in generalizing these results. The supply chain dyads examined here are limited to publicly traded firms and is focused on buyers in the US manufacturing industry. Future research could consider a broader array of industries, such as retail settings, and could expand the focus to consider private firms and a more international scope to see if these results are consistent or if other factors impact vicarious learning in different situations.

A final limitation is primarily empirical. Our dependent variable and main independent variable, buyer and supplier innovation, were constructed using a patent database that we linked with Bloomberg's supply chain relationship dataset. With Bloomberg's data only providing a snapshot of the relationships, we were unable to access historical supply chain dyadic information before the beginning of 2013. With recent patent applications taking an average of 2.5 years to be granted or abandoned (Bellamy, Ghosh, and Hora 2014), our analysis was limited to patent applications submitted in 2012 to allow for sufficient time to elapse when we measured successful patents in mid-2015. Future research could benefit from extending the analysis to consider temporal effects and explore how short- or long-term supply chain relationships may impact the flow of knowledge.

Even with these limitations, the results of this study offer several broad implications. Innovation is often a result of the combination of new knowledge stemming from external sources, and we have demonstrated the ability of firms to draw upon the knowledge contained in their upstream suppliers to develop their own innovations. Furthermore, we have demonstrated important dyadic characteristics that determine the likely effectiveness of this vicarious learning across interorganizational boundaries in a supply chain setting.

Synthesizing central tenets of vicarious learning theory and social network theory, we developed and tested a model exploring the relationship between supplier and buyer innovation. Specifically, we examined the ability of buyer firms' innovation to benefit from their suppliers' innovation activities. We then investigated the moderating impact of key dyadic supply chain relationship characteristics on this effect. Combining archival data on manufacturing supply chain relationships with US patent data, we used econometric methods to empirically demonstrate the positive impact a supplier's level of innovation has on a downstream buyer firm's innovation activity. Furthermore, we found these innovative suppliers have a greater impact on buyer innovation when the firms are more technically similar and when there is a greater degree of transactional reciprocity between the buyer and supplier firms. These findings improve our understanding of interorganizational knowledge transfer in vertical supply chain relationships and shed light on the heretofore unstudied moderating effects of dyadic relationship characteristics on vicarious learning.

6. Additional Analysis

One additional analysis that can be conducted is the running of a full model with all of the interaction terms included simultaneously. While not included in the main analysis due to the limitations associated with losing a large number of observations when including the technical similarity measure, the results still merit cautious interpretation. The results of this analysis are displayed below in Table 3.

While the results are largely consistent with those in the previous analysis, we do find a positive and significant coefficient on the interaction term of Geographic Proximity and Supplier Innovation. Contrary to our hypothesis, this finding suggests buyer and supplier firms with headquarters located at *greater* geographic distances actually improve the transfer of information and knowledge across organizational boundaries. While this appears counterintuitive at first, recent work suggests that cross-border agreements between firms may actually require more communication and collaboration to overcome differences in factors such as culture and language (Boyd and Spekman 2008). This in turn creates an environment where information can flow more easily through the established communication routines and can encourage cross-organizational learning through better identification of valuable resources and capabilities (Mohr and Spekman 1994).

Table 3

Negative Binomial Regression Model – All Interactions

Variables	**Model 6**	
Supplier Innovation	0.0020**	(0.00069)
Geographic Proximity	0.0091	(0.01323)
Transactional Reciprocity	-0.0059	(0.00498)
Technical Similarity	0.9018***	(0.00149)
RD Expense	0.0002*	(0.00008)
ROA	1.1905	(1.09462)
Revenue	0.0004	(0.00208)
Buyer NA dummy	1.2257**	(0.40958)
Number of Suppliers	0.0013	(0.00258)
Supplier Innovation X Geography Proximity	0.0001**	(0.00005)
Supplier Innovation X Transactional Reciprocity	0.0001*	(0.00002)
Supplier Innovation X Technical Similarity	0.0047**	(0.00149)
Constant	0.9086*	(0.39998)
Industry Dummies?	Yes	
Wald χ^2	377.86***	
df	14	

Standard errors are in parentheses; n = 3,101

† p < .10; * p < .05; ** p < .01; *** p<.001

Two tailed tests

Essay 2: The Impact of Supply Base Innovation on Focal Firm Innovation

1. Introduction

Essay two of this dissertation builds upon and extends the analysis in essay one by shifting the unit of analysis from the consideration of a buyer-supplier dyad to an evaluation of a buyer firm's supply base and the associated overarching social relationship dynamics. The underlying theoretical arguments mirror those put forth in essay 1 of this dissertation but are now conceptualized from the perspective of a single buyer firm in relation to its overall supply base.

Prior literature suggests that in addition to firms being able to learn from individual suppliers (Leiponen and Helfat 2011, Li, Poppo, and Zhou 2010), the overall structure of their supply network impacts the ability of a buyer to effectively undertake interorganizational learning activities (Powell, Koput, and Smith-Doerr 1996, Mahmood, Zhu, and Zajac 2011, Bellamy, Ghosh, and Hora 2014). This study builds upon these concepts and considers the totality of innovative efforts across a firm's supply base as a key resource for the firm to access in order to drive its own innovation activity, and examines how its social relationship with its supply base as a whole affects vicarious learning.

In this essay, as I am now concerned with the impact of innovations and knowledge transfer from a focal firm's entire supply base on its subsequent innovation output, I aggregate each of the buyer-supplier dyadic relationships

identified in essay one to a buyer-supply base level of analysis. I then extend the investigation of dyadic characteristics of the relationships identified in essay one to a consideration of overall supply base social dynamics and the associated influence on vicarious learning in a supply chain setting.

2. Outline of Hypotheses

As in essay one, I first consider the total availability of knowledge a focal firm can access through their supply base. Vicarious learning theory is predicated on the ability of a firm to recognize and internalize knowledge held by another organization based on the quantity, visibility, and quality of that knowledge (Kim and Miner 2007). While a single innovative supplier may act as a valuable source of external knowledge, firms who establish a highly innovative supply base develop a large pool of external knowledge and thus increase the likelihood of encountering information or routines that can be applied to innovation pursuits (Nielsen 2005).

When a firm's supply base is highly innovative, those suppliers contain a wealth of information, innovation oriented routines, and organizational strategies (Haunschild and Miner 1997) that a buyer firm can seek to access in pursuit of its own innovation activities (Inkpen and Tsang 2005). With more knowledge available, a downstream buyer firm can identify and select the information most likely to benefit its own innovative activities and act accordingly to internalize that external knowledge (Argote and Ophir 2002). Furthermore, social networking theory identifies the role of a firm's network ties to serve as conduits for knowledge transfer

(Haunschild 1994). As such, I expect greater total level of innovation with a buyer's supply base to benefit the buyer's innovation efforts. Formally,

Hypothesis 1. Higher levels of total supply base innovation lead to higher levels of focal firm innovation.

In line with the theoretical insights developed in essay one, I propose that the social relationships between the buyer firm and its supply base can determine the efficacy of vicarious learning and interorganizational knowledge transfer. While a single dyadic relationship may be either strong or weak, a firm is embedded in a multitude of relationships across the entirety of its supply base (Powell, Koput, and Smith-Doerr 1996). As a useful extension of the study performed in essay one, I contend that the social relationship dynamics a buyer employs across the full set of suppliers with which it is engaged in exchange relationships are likely to affect the ability of a buyer to benefit from vicarious learning actions. Furthermore, the determination of any significant findings will offer additional credence to concept that social dynamics have a significant impact on vicarious learning in supply chains.

I again rely on the taxonomy developed by Rivera, Soderstrom, and Uzzi (2010) to propose three hypotheses related to the effect of proximity, relational, and assortative mechanisms on the dynamics of a buyer firm's relationship with its supply base. I expect that these same perspectives will determine the strength of the relationship a buyer has with its supply network and as such, will influence its ability to utilize the knowledge and information contained in its upstream network. In lieu of

replicating the theoretical arguments advanced in essay one, I propose three hypotheses considering the average degree of geographic proximity, transactional reciprocity, and technical similarity between a focal firm and its supply base and contend that these aggregated measures represent a buyer firm's overall degree of embeddedness with its supply base.

I begin the analysis of moderating effects with a consideration of proximity mechanisms to facilitate frequent, rich communications between a buyer firm and its supply base, and as such to engender trust and collaboration (Abrams et al. 2003). I suggest that as the supply base as a whole is located in closer proximity to a buyer firm, the associated increase in social interactions, cultural similarity, and interaction frequency (Corredoira and Rosenkopf 2010) promote relationship tie strength and increase the efficiency of interorganizational learning efforts.

Hypothesis 2: Greater average geographic proximity between the supply base and focal buyer firm strengthens the positive relationship between total supply base innovation and focal firm innovation.

I next turn to an evaluation of the relational mechanisms within the network and consider the average degree of transactional reciprocity between a buyer firm and its supply base. Building on the expected effect of greater reciprocity to promote greater cooperation and mutual support (Oliver 1990) as well as to reduce opportunism and promote knowledge sharing (Goes and Park 1997), I contend the

associated relational dynamics improve the strength of the relationship between the focal firm and its supply base as a whole, enhancing the vicarious learning activities that stimulate buyer firm innovation.

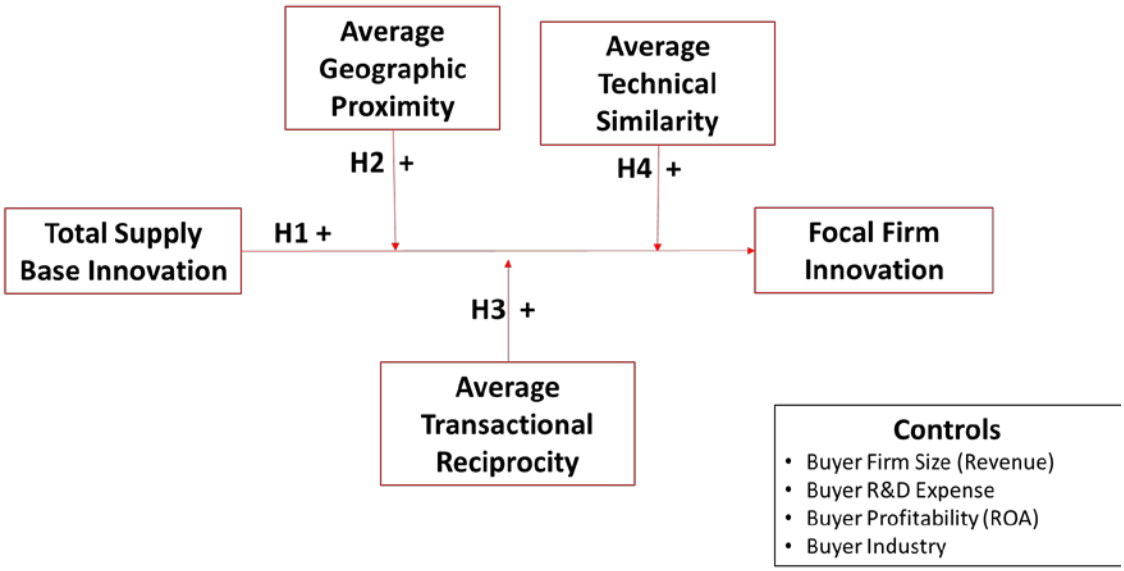
Hypothesis 3: Greater average transactional reciprocity between the supply base and focal buyer firm strengthens the positive relationship between total supply base innovation and focal firm innovation.

Finally, I extend the concept of assortative mechanisms to encompass the presence of homophily across the entirety of a buyer firm's supply base and theorize that as the average technical similarity between a firm and its supply base increases, the improved ability of the buyer to communicate with its supply base and avoid competitive frictions (Lavie, Haunschild, and Khanna 2012) increases the efficacy of interorganizational learning, including vicarious learning actions.

Hypothesis 4: Greater average technical similarity between the supply base and focal buyer firm strengthens the positive relationship between total supply base innovation and focal firm innovation.

An overview of the model and the hypotheses proposed in essay 2 is provided below in Figure 2.

Figure 2: Summary of Hypotheses and Graphical Model of Essay 2



3. Empirical Analysis

To test these hypotheses I rely on an aggregation of the dyadic relationships identified in essay one. The dataset is again based on an amalgamation of data from Compustat, Bloomberg SPLC, and LexisNexis' TotalPatent. In this case, the unit of analysis is the firm-supply base and the dependent variable the same as in essay one, the number of successful focal buyer firm patents applied for in 2012.

The key independent variable for testing the baseline relationship is the sum of the number of successful patents applied for in 2011 by each supplier to a focal firm. The first moderator independent variable of interest is simply the average geographic proximity between a buyer firm and the members of its supply base, based on the great circle distances calculated in essay one. To test the second moderating effect laid out in hypothesis three, I calculate the average transactional symmetry between the buyer firm and each supplier, as described in essay one. To test the final

hypothesis, I take the Euclidean distance between each buyer-supplier dyad calculated in essay one and average it across the entirety of each focal firm's supply base.

I also include a number of control variables to account for other factors that may influence a buyer firm's degree of innovation success. I include each buyer firm's return on assets (ROA) to capture profitability, revenue to capture size, and research and development expense. I also include control variables for each buyer firm's industry using dummy variables at the three-digit NAICS level.

Given that focal buyer firm innovation performance is again measured as a positive, integer value, ordinary least squares regression techniques are inappropriate (Greene 2003) and I instead use an empirical model that considers the count nature of the dependent variable. I evaluated both Poisson and negative-binomial regression models and found a significant non-zero outcome of a likelihood ratio test of the over-dispersion parameter in the negative-binomial model. This suggested the Poisson distribution would not be appropriate, and I instead rely on the negative-binomial model to account for the over-dispersion issue (Hausman, Hall, and Griliches 1984).

4. Results

A total of 360 buyer firms and their supply bases are used in this study based on the data captured and aggregated as described above. The descriptive statistics for

Table 4
Descriptive Statistics and Correlations

	Variable	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7
1	Buyer Patents	43.35	127.61	1.00	1,755.00							
2	Sum Supplier Patents	646.74	1,256.48	1.00	12,313.00	0.52						
3	Average Transactional Reciprocity	-2.93	4.44	-32.24	-0.01	-0.01	-0.04					
4	Average Geographic Proximity (100km)	51.92	29.21	0.05	152.96	0.05	0.11	-0.15				
5	Average Technical Similarity	-0.79	0.23	-1.41	0.00	0.22	0.23	-0.09	0.11			
6	Buyer RD Expense ($ Million)	607.48	1,497.39	0.00	11,670.93	0.31	0.41	-0.20	0.03	0.22		
7	Buyer ROA	0.00	0.23	-1.75	0.36	0.05	0.04	-0.02	-0.07	-0.03	0.12	
8	Buyer Revenue ($100 Million)	153.01	507.25	0.00	4,671.53	0.10	0.21	-0.24	-0.01	0.11	0.37	0.09

[a]n=360

all variables are reported in Table 4. To verify that multicollinearity issues are not present, variance inflation factors were calculated and found to be below 2.0 for all variables of interest, suggesting multicollinearity is not affecting the results (Kennedy 2003). A Breusch-Pagan/Cook-Weisberg test for heteroscedasticity identified potential concerns related to a violation of homoscedasticity assumptions, and was corrected for using robust standard errors in the regression analysis (White 1980).

The estimation results presented in Table 5 explore the relationship between the innovation activity across the entirety of a focal buyer firm's supply base and that buyer firm's innovation in the subsequent year, as evidenced by patenting activity. The dependent variable in these negative binomial regressions is buyer innovation. All models include buyer industry fixed effects. Model 1 examines the baseline relationship between the total innovation across the supply base and a buyer firm's innovation in the following year as put forth in H1. The positive and highly significant coefficient of sum supplier patents in model 1 provides evidence in support of the expectation that a buyer firm can access a greater pool of external knowledge and innovation oriented routines when its supply base is highly innovative and can translate that information into increased innovative output. I also find evidence that more profitable firms and those who expend greater R&D resources and are more profitable develop more innovations.

Table 5

Negative Binomial Estimates for Buyer Innovation[a]

Variables	Model 1: Baseline Effect		Model 2: Direct Effects		Model 3: Full Model	
Sum Supplier Patents	0.0002***	(0.0000)	0.0002***	(0.0000)	0.0015*	(0.0006)
Buyer RD Expense	0.0002***	(0.0000)	0.0001***	(0.0000)	0.0001†	(0.0001)
Buyer ROA	0.4011**	(0.1552)	0.4302**	(0.1462)	0..3225*	(0.1605)
Buyer Revenue	-0.0005*	(0.002)	-0.0005*	(0.0002)	-0.0003	(0.0003)
Average Transactional Reciprocity			0.0067	(0.0077)	-0.0233†	(0.0135)
Average Geographic Proximity			-0.0005	(0.0011)	0.0009	(0.0015)
Average Technical Similarity			1.1886***	(0.1655)	0.6841**	(0.2444)
Sum Supplier Patents X Average Transactional Reciprocity					0.0001*	(0.0000)
Sum Supplier Patents X Average Geographic Proximity					0.0000	(0.0000)
Sum Supplier Patents X Average Technical Similarity					0.0016*	(0.0007)
Constant	2.9660***	(0.2086)	4.2269***	(0.2644)	3.5843***	(0.2917)
Industry Dummies?	Yes		Yes		Yes	
Likelihood Ratio	94.78***		128.13***		154.58***	
df	19		21		24	
Cragg & Uhler's Pseudo R^2	0.23		0.30		0.35	

[a] Standard errors are in parentheses; n = 360

Two-tailed tests

† p < .10; * p < .05; ** p < .01; *** p < .001

Model 2 adds in the direct effects of the hypothesized interaction terms. The results provide further support for H1 as the sum supplier patents variable continues to be positive and highly significant. Model 3 includes the control variables, direct effects, and the hypothesized interaction effects. Again, the baseline effect is found to be positive and significant, consistent with the findings in models 1 and 2. Hypothesis 2 suggested a positive interaction effect of the average geographic proximity between a buyer and its supply base. Similar to the results in essay one, I fail to find empirical support for this hypothesis as the interaction term is not statistically significant. The positive and significant interaction term of the average transactional reciprocity between a buyer firm and its supply base on the baseline relationship shown in Table 5 supports Hypothesis 3. Finally, hypothesis 4 which suggests that greater technical similarity between the focal firm and its supply base facilitates vicarious learning efforts. The positive and significant interaction term of average technical similarity on the baseline relationship supports Hypothesis 4.

5. Discussion and Conclusion

This essay has built upon the analysis conducted in essay 1 and extended the investigation of vicarious learning and the role of social relationship dynamics to drive knowledge transfer within supply chains from a dyadic buyer-supplier level of analysis to that of the buyer-supply base. This acts both as a robustness check of the findings discussed in essay 1 as well as a means to derive additional insights that might not have been apparent at a less aggregated examination. The results outlined above first and foremost underscore the role of supply chain relationships as enablers

of innovation though providing access to external pools of knowledge beyond what a buyer has available within its own organizational boundaries.

More than just support for existence of interorganizational knowledge transfer from the supply base to a buyer firm, this study also found evidence that the social relationship mechanisms identified in essay one are equally as important in determining the impact of vicarious learning efforts across organizational boundaries when considering a firm's entire supply base. This again increases confidence that the findings established earlier in essay one are not limited to individual relationships, but are important considerations that can be extended to a broader analysis of a firm's supply network. As expected, knowledge and innovation oriented routines are more easily transferred from the supply base to a buyer firm when there is greater transactional reciprocity between the firm and its supply and when the supply base has a greater overlap in the areas of technical expertise as the buyer.

One interesting aspect to consider is the direct effects of the hypothesized interaction terms in the final model. The results in Model 3 suggest transactional reciprocity may inhibit a buyer firm's ability to innovate to some degree after controlling for the beneficial effect of accessing its suppliers' knowledge and information. The close, cooperative relationships established through this reciprocity may actually limit a firm's access to other pools of knowledge (Uzzi 1996) such as new innovative clusters (Pouder and John 1996) or innovators working within companies not previously encountered by the focal firm (Rodrik 2000). The average

geographic proximity direct effect was not found to be statistically significant, but I did find a positive and significant direct effect of technical similarity on buyer innovation. This suggests the dynamics of homophily may enable a focal firm to improve its own innovation pursuits not only through vicarious learning efforts focused on the knowledge already held by its supply base, but may encourage knowledge creation activities such as joint collaborations (Chesbrough 2006).

While these observations have not been theorized on directly, they offer interesting potential future research opportunities. An individual supplier and the full suite of a firm's supplier base are both important sources of new knowledge that enable a buyer to develop innovations. However, there may be other effects that must be considered, such as potentially confining the buyer within its existing network and limiting new sources of information, or the ability to engender joint knowledge creation activities. This is likely a fertile area for supply chain research on innovation and knowledge transfer to continue to build upon and offer new insights.

Essay 3: Innovation and Indirect Links in the Supply Chain

1. Introduction

> "We get plenty of valuable information about the market, its players in the value chain and its main drivers from our customers and suppliers. My business relies on it. It is a great input for our R&D portfolio," Dr. Ir. Kees Joziasse, Director of Innovation at Corbion Purac. (Seifert and Isaksson– October 2013).

Firms do not operate within vacuums, but instead can better be described as single nodes in a complex web of interdependencies (Pfeffer and Salancik 2003), strategic alliances (Simonin 1999), social networks (Uzzi and Lancaster 2003), and vertical supply chains (Bellamy, Ghosh, and Hora 2014). Furthermore, the influence of the members of these networks on a focal firm is not limited to the parties that directly interact with the firm, but has been shown to extend beyond to partners of their partners, better known as indirectly linked organizations (Ahuja 2000). As suggested by the quote from Dr. Joziasse, firms believe the direct relationships they have with suppliers and customers offer a mechanism to identify new innovative activities to pursue based on these suppliers'/customers' interactions with other organizations. Previous literature has demonstrated the value of external sources of information in facilitating innovation (Ahuja 2000, Sampson 2007, Mahmood, Zhu, and Zajac 2011, Powell, Koput, and Smith-Doerr 1996) which begs the question, can a firm gain access to knowledge held at these distant, indirect links that can assist its

innovation efforts? And if so, what are the key factors in determining the impact of such indirect links on a firm's external knowledge acquisition?

A firm's network of external organizations consists of both direct ties, those where the focal firm is in frequent and direct contact with the other organization, as well as indirect ties, where the organizations are linked only though a shared intermediary and are not directly involved in an alliance or exchange relationship (Shane and Cable 2002). While there has been strong evidence supporting the notion that direct ties between firms lead to knowledge-sharing (Berg, Duncan, and Friedman 1982) and innovation (Ahuja 2000), there is some evidence to support for the role of indirect ties as a source of knowledge as well. Studies have demonstrated the benefits of these indirect ties within networks of firms (Ahuja 2000) and within interpersonal networks of individual inventors (Singh 2005).

Scholars have demonstrated that the ability of knowledge to flow across networks can be affected by structural characteristics such as the density of ties between the firms operating within a network, the centrality and interconnectedness of a firm within its network, and the technological diversity of a network (Bellamy, Ghosh, and Hora 2014, Mahmood, Zhu, and Zajac 2011, Phelps 2010). Extant literature has also made an explicit distinction as to the role of direct and indirect ties as differing sources of knowledge and information (Bellamy, Ghosh, and Hora 2014, Shane and Cable 2002, Ahuja 2000, Boyd and Spekman 2008). However, despite these advances in our understanding of external knowledge sources, there has been a

dearth of research focused on isolating the impacts of these indirect ties and identifying what factors may enhance or inhibit a firm from accessing and utilizing knowledge from these indirect ties. This study seeks to fill this gap in the literature by examining indirect ties within a supply chain setting and first exploring the ability of a firm to vicariously learn from an indirect tie. I then theorize on how a focal firm's motivation, ability, and opportunity to access knowledge at indirectly linked firms affects its vicarious learning actions and its innovation efforts.

2. Indirect Ties and Innovation in Supply Chains

An indirect tie occurs when two firms are engaged in a partnership with the same third party, but do not have direct ties to each other (Boyd and Spekman 2008). In a supply chain setting, it can be conceived of as a situation wherein firm A and firm B both have supply relationships and actively procure goods and/or services from firm C, but do not have any direct business with each other. Scholars have suggested that both direct and indirect ties play an important role in providing information and knowledge to a focal firm, but they differ in the magnitude and type of impact on a focal firm (Ahuja 2000). While these studies and others offer insights into the role of a firm's network when considered in aggregate, they haven't explicitly examined the disaggregated impact of a particular organization within the network on the focal firm. As such, these studies have not identified the factors that make a particular link more or less impactful on a focal firm.

Other scholars have made extensive contributions to the study of how dyadic alliance partnerships can impact a firm's innovation (Sampson 2007, Mowery, Oxley, and Silverman 1996), and have begun to investigate how vertical supply chain relationships offer additional sources of knowledge and can assist with collaborative new product developments and information on customer preferences (Alcacer and Oxley 2014, Swink and Mabert 2000, Azadegan and Dooley 2010). However, these dyadic studies are all focused on external organizations that are directly linked to the focal firm, whether through strategic alliances or direct supply chain relationships. This leaves a surprising and substantial gap in the literature regarding our understanding of what mechanisms determine the ability of an organization in a firm's extended network, one which it is linked to only through indirect ties, to act as a source of knowledge and to impact a focal firm's innovation. I seek to fill this gap by developing theory and empirically conducting a dyadic level analysis into the means by which a focal firm's innovation can benefit from innovation at an indirectly linked firm.

Indirect ties can be identified in a number of situations, but one particularly interesting setting is that of supply chain networks. While firms can elect to engage in alliances or R&D partnerships or to avoid them, all firms require access to some set of external resources (Pfeffer and Salancik 1978), and must engage in some level of supply chain activity to obtain those resources (Lambert and Cooper 2000). Furthermore, knowledge creation and transfer is a core value within many strategic alliances and R&D collaborations, supply chains are primarily concerned with the

transfer of goods and/or services between organizations in a vertical relationship context (upstream supplier to downstream customer) (Lambert and Cooper 2000). Despite this, researchers have demonstrated the ability of direct supply chain partners to contribute to collaborative new product developments and provide information on customer preferences (e.g., Alcacer and Oxley 2014, Azadegan and Dooley 2010, Mahmood, Zhu, and Zajac 2011). However, the role of the extended supply network and the influence of indirect ties has received very little attention and is limited to studies using network analysis techniques to determine aggregated impacts on focal firm innovation, such as the study performed by Bellamy, Ghosh, and Hora (2014) that finds a firm's total network accessibility (measured using the harmonic mean length of paths in a social network to a firm) positively influences firm innovation.

I leverage insights from vicarious learning theory and the motivation, opportunity, ability (MOA) framework to theorize on the ability of indirectly linked firms to act as a source of external knowledge for a focal firm, and to develop novel hypotheses on the mechanisms that facilitate or inhibit the transfer of such knowledge. By proposing new theoretical insights and employing data on firms indirectly linked through their supply network, this study contributes to the literature on interorganizational learning through offering new insights into how these indirectly linked firms can affect a focal firm's innovation efforts. It also offers further insight into the growing body of literature investigating the role of supply

chains to act as a strategic resource for firms (Hult, Ketchen, and Slater 2004) as a key driver of firm innovation.

3. Theory and Hypotheses

Organizational learning scholars have noted firms are able to gain the benefits of knowledge and experiences accumulated by others while simultaneously avoiding the time and cost of undertaking actions to accumulate that information themselves through traditional experiential learning processes (Kim and Miner 2007). They describe the action of vicarious learning as a method of observation and imitation, whereby a firm seeks to replicate another firm's routines, strategies, and designs and to identify knowledge spillovers (Haunschild and Miner 1997). This indicates vicarious learning is an active process that requires a firm to seek out and monitor another organization from which it hopes to obtain knowledge (Gittelman and Kogut 2003). While scholars have identified characteristics of external knowledge that enable vicarious learning, including the visibility, quantity, and quality of that knowledge (Kim and Miner 2007, Argote and Ophir 2002), they fall short of identifying what factors drive a firm to actively seek out external knowledge in lieu of developing that knowledge within the firm's boundaries through traditional experiential learning processes. Indeed, Posen and Chen (2013) call for researchers to develop greater insights into what may engender a firm to undertake vicarious learning actions. I propose the MOA framework as a valuable structure from which a firm's decision to pursue vicarious learning action can be understood.

The MOA framework stems from psychology and was initially conceptualized as a theory of work performance to establish the link between an individual's performance with their opportunity to perform and the interaction of opportunity with their ability to perform and with his/her motivation to perform (Blumberg and Pringle 1982). It has since been utilized in a wide range of management literature streams including marketing (Rothschild 1999, MacInnis, Moorman, and Jaworski 1991), information systems (Ramaswami, Brett, and Strader 1998), human resources management (Boselie, Dietz, and Boon 2005, Minbaeva 2013), operations management (Siemsen, Roth, and Balasubramanian 2008), and supply chain management (Kim, Hur, and Schoenherr 2015). Most importantly for this study, the MOA framework has been conceptualized within the literature on knowledge management, including how it may affect the transfer of knowledge across organizations (Argote, McEvily, and Reagans 2003). Specifically, the MOA framework identifies the fundamental need for an opportunity to exist before a firm can gain access to external knowledge (Reinholt, Pedersen, and Foss 2011). I argue innovative indirect ties provide one such opportunity for a focal firm to engage in vicarious learning actions. Furthermore, I contend that a firm's motivation to pursue vicarious learning, as well as its ability to identify and understand the information held at an indirect tie, will likely impact the degree to which it makes use of such an opportunity and engages in vicarious learning.

A synthesis of these theoretical approaches provides substantial explanatory power. Vicarious learning theory identifies the fundamental opportunity for a firm to

gain access to external knowledge controlled by an indirectly linked firm and provides insights into when that opportunity is greater or weaker, while the MOA framework suggests what underlying factors encourage a focal firm to capitalize on the opportunity and pursue vicarious learning actions to acquire knowledge from indirectly linked firms. It is only though understanding both such dimensions that it is possible to determine how these indirect ties are able to influence a focal firm's level of innovation.

3.1 Opportunity

In line with the claim made by Dr. Joziasse at the beginning of this article, I argue that a firm's suppliers can serve as a key mechanism in identifying valuable opportunities for a firm to undertake vicarious learning actions. Specifically, I contend these suppliers enable a buyer firm to more readily identify highly innovative organizations with which they are indirectly linked to via the supplier, which creates an opportunity for the buyer firm to engage in vicarious learning activities. This conjecture is further supported by findings in literature that indirect ties enable a focal firm to access greater amounts of external information than more isolated firms by reducing the amount of time and investment necessary to gather information from beyond an organization's boundaries (Nahapiet and Ghoshal 1998).

Previous literature also supports the notion that indirect ties are valuable in their ability to act as a source of information despite not having direct contact with a focal firm (Ahuja 2000). Indirect ties have been shown to provide access to greater

amounts of information than a focal firm would have access to in isolation or limited to those firms with which it has direct relationships (Shane and Cable 2002). Indirect ties have also been identified as key sources of non-redundant information that may be particularly useful for innovation activities (Levin and Cross 2004). Research into knowledge sharing across groups suggests the creation of novel ideas can be increased though exposing group members to ideas developed by others while still allowing the group to continuously develop their own ideas and maintain their own identity (Paulus and Yang 2000).

The amount and quality of information contained in an event (Argote and Ophir 2002, Levinthal and March 1993), or in a more aggregated context the size of the external knowledge pool (Posen and Chen 2013), has also been closely tied to the amount of vicarious learning possible. Vicarious learning suggests one conduit for knowledge between organizations is the acquisition of knowledge through observation of other firms, including observation of their patents and publications (Gittelman and Kogut 2003). Furthermore, while knowledge transfer frequently occurs, Argote and Ingram (2000) note that it is frequently incomplete and firms are better able to acquire distant knowledge when there is a substantial reservoir of knowledge available at the source. Specifically, when external organizations are more innovative and have larger pools of knowledge, it creates the opportunity for a focal firm to accumulate knowledge vicariously via observation (Nadler, Thompson, and Boven 2003) or by identifying boundaries for knowledge search activities through recognition of knowledge and information repositories (Borgatti and Cross 2003).

Indirect ties are by definition more distant than direct ties, and as such any knowledge or information they contain is inherently less visible to a focal firm. However, when those indirectly linked organizations are highly innovative, they contain significant amounts of knowledge and become more visible though actions such as actively seeking patents, press releases, etc. (Gittelman and Kogut 2003). I contend when an indirectly linked firm innovates, it enhances the opportunity for a focal firm to identify relevant knowledge within the innovating organization and pursue vicarious learning actions. Greater levels of linked firm innovation thus create both larger pools of available knowledge and an environment of greater opportunity for a focal firm to acquire external knowledge from the indirectly linked firm though vicarious learning actions. With this increase in vicarious learning, a focal firm can bring in new knowledge and in turn achieve higher levels of subsequent innovation.

H1: Higher levels of innovation at an indirectly linked firm increases focal firm innovation.

3.2 Interaction Effects

Leveraging insights from the MOA framework and vicarious learning theory, I suggest that the extent to which a focal firm capitalizes on the opportunity to engage vicarious learning from an indirectly linked organization is dependent on the focal firm's ability to internalize the external knowledge as well as the focal firm's motivation to undertake the actions necessary to acquire the knowledge.

3.2.1 Motivation

While the opportunity to access external knowledge is a necessary prerequisite to learning from interorganizational sources, acquiring knowledge through external sources is more difficult and costly to undertake than accessing information already contained within the organization (Singh 2005). Firms who have developed efficient routines and innovative capabilities first seek to utilize their own knowledge and experiences to innovate rather than seeking external information from outside their firm's boundaries (Greve 2005). As such, firms must be properly motivated to expend the additional resources to seek knowledge externally through vicarious learning and expand beyond experiential learning and internal knowledge generation through actions such as trial-and-error repetition.

The firm is motivated to pursue a search for external knowledge when it is difficult to develop knowledge internally (Song, Almeida, and Wu 2003). When a firm is unable to achieve a goal, such as successfully developing innovations, it then extends the scope of its search activities in an attempt to access a means to achieve that goal in the future (Cyert and March 1963). Posen and Chen (2013) suggest a firm's motivation to pursue vicarious learning is often caused by the emergence of problems in the process of experimental learning, which then triggers a search for external knowledge, especially knowledge contained within its network. This suggests these search activities are a decreasing function of a firm's existing repository of knowledge, its own innovativeness (Kim, Hur, and Schoenherr 2015).

When firms have found success within their own organizations and have a history of innovativeness, they have already accumulated valuable experiences and developed routines and procedures for knowledge development and deployment (Song, Almeida, and Wu 2003). As such, undertaking distant search for knowledge from indirect links may disrupt existing routines, reducing the efficiencies of internal information processing and innovation development activities (Baum and Ingram 1998).

Turning to the literature on organizational learning, firms develop routines based upon incremental adjustments to prior experiences and have a self-reinforcing bias towards internal processes (Baum, Li, and Usher 2000). Firms who have developed successful mechanisms for generating knowledge and built capabilities focused on generating innovations have a core of knowledge and experience to build future innovations on and are not as reliant upon vicarious learning to supplement gaps in their organizational knowledge (Posen and Chen 2013). I contend that the level of prior innovation success determines the motivation for firms to pursue vicarious learning initiatives to bolster their internal stores of knowledge. As such, firms that are already highly successful in innovating are less motivated to seek out distant knowledge from sources such as indirectly linked firms in their network.

H2: Higher levels of previous innovation by a focal firm weakens (negatively moderates) the positive relationship between indirectly linked firm innovation and focal firm innovation.

3.2.2 Ability

The MOA framework suggests the ability of a focal firm to identify and internalize knowledge held at an indirectly linked firm is a critical factor in determining the impact of such knowledge on the focal firm's subsequent innovation. As identified by previous studies, the degree of vicarious learning available is a function of the visibility of the external knowledge (Greve 2005, Ingram 2002). For vicarious learning to occur, information must be noticed by potential learners (Kim and Miner 2007). When an organization within a firm's network is highly innovative but only linked to the focal firm indirectly, the focal firm has only limited visibility into the type, degree, and relevancy of any associated knowledge. While the network organizations that are directly linked to both firms may provide some level of information and description, I argue the ability of a focal firm to undertake vicarious learning actions is dependent on its own internal capabilities to identify and internalize any relevant knowledge.

Cohen and Levinthal (1990) suggest a firm's ability to recognize, understand, and internalize external knowledge is a function of its level of absorptive capacity. Furthermore, this absorptive capacity is a finite resource that can be exhausted and leave firms unable to absorb and apply external knowledge (Tsai 2001). As noted by Lane and Lubatkin (1998), absorptive capacity in interorganizational relationships is inherently relative and should be considered from a dyadic unit of analysis. They go on to contend knowledge similarities between the two firms are a key determinant of

the ability of one firm to learn from the other. The relative similarity of the knowledge bases between two organizations has also been shown to impact the amount of effort required to transfer knowledge between organizations, with similar knowledge transferring across firm boundaries easier than more diverse knowledge (Vasudeva and Anand 2011).

Scholars have provided broad support for the role of technological similarity between knowledge source and recipient in creating the ability for knowledge transfer to occur. Mowery, Oxley, and Silverman (1996) find that one key aspect determining the extent of a firm's absorption of technological capabilities from its alliance partners is the degree of overlap in technology between the partner firms. This coincides with Reagans and McEvily (2003)'s finding that common knowledge between two parties eases the transfer of knowledge between them. Argote and Ingram (2000) suggest for knowledge reservoirs to transfer successfully across organizations, there must be compatibility or fit with the new context in which it will be used by the recipient. Indeed, the, "[c]umulative experience with a technology is a critical factor in determining the learning capability of the recipient to understand new technologies" (Zander and Kogut 1995, 78). I argue as a firm's ability to recognize and to internalize knowledge held by an indirectly linked firm increases, the focal firm will both pursue more and be more successful at vicarious learning actions.

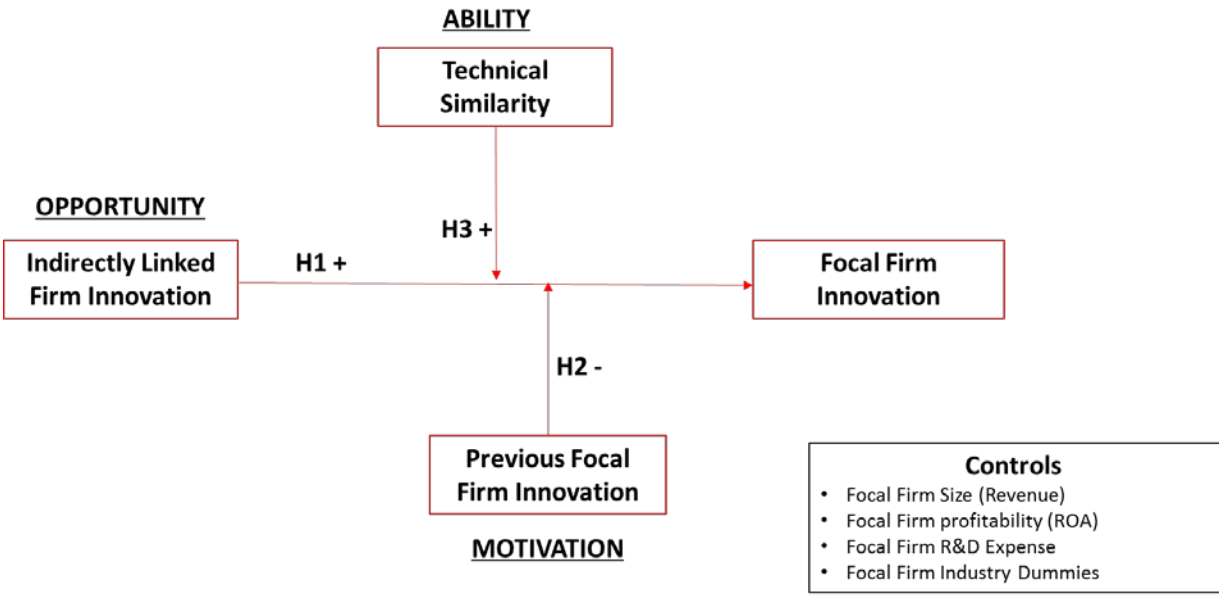
It is also possible for external knowledge to negatively impact the performance of a recipient. Specifically, if the newly acquired knowledge cannot be adapted to the new context or is inappropriate for the recipient, it may result in negative effects on performance (Argote and Ingram 2000). Baum and Ingram (1998) examine failure rates of Manhattan hotels over an 85-year period and found evidence suggesting external knowledge from sources with little overlap in existing knowledge can lead to increased failure rates. They suggest the adoption of incompatible routines resulted in an inability to effectively compete in their local market, further enforcing the notion that a firm's ability to effectively acquire, deploy, and benefit from knowledge gained through vicarious learning activities is a function of its ability to understand the external knowledge.

Taking these arguments, I contend that greater degrees of technical similarity between the indirectly linked firm and the focal firm increase the visibility of external knowledge held by the indirectly linked firm and enhances the ability of the focal firm to successfully absorb that knowledge into their organization and deploy it in an effective manner. This in turn magnifies the positive impact of vicarious learning actions undertaken that allow a focal firm to benefit from innovation at the indirectly linked firm.

H3: Higher levels of technical similarity between a linked firm and a focal firm strengthen (positively moderate) the relationship between indirectly linked firm innovation and focal firm innovation.

An overview of the model I investigate in essay 3 and a depiction of its link to the MOA framework is provided below in Figure 3.

Figure 3: MOA Framework and Summary of Hypotheses for Essay 3



4. *Empirical Analysis*

4.1 Data

The same initial data set as collected for essays 1 and 2 forms the basis for the analysis in this essay. I again make use of the manufacturing firms contained within the Compustat database with a three-digit NAICS code in a manufacturing sector (311 – 339) in 2012 and match those 2,275 US public manufacturing firms with data contained in Bloomberg's Supply Chain Analysis (SPLC) database. Using the resulting 835 manufacturing firms contained within both data sets, I then analyze the Bloomberg database to identify the suppliers used by each firm and to determine

the set of firms that have at least one supplier in common. This common supplier (or set of common suppliers) acts as the central node in determining the existence of indirect ties between the manufacturing firms. After analyzing the supply relationships of the manufacturing firms and identifying indirect links, I find a total of 33,488 dyads with indirect ties between the aforementioned manufacturing firms. Of those dyads, 1,962 were actively engaged in direct buyer/supplier relationships with each other and removed from the sample to ensure only firms linked indirectly are considered in the analysis.

I then matched each manufacturing firm to the relevant patent data collected from the LexisNexis' TotalPatent database. I use the successful US patent documents that were applied for in 2012 for the focal firm and the successful US patent documents that were applied for in 2011 for the indirectly linked manufacturing firm to introduce a one year lag effect into the model. After accounting for missing data from both the patent database and the control variables, the resulting data set consists of 24,092 indirectly linked manufacturing dyads. However, merely the existence of a supply chain relationship does not immediately engender a level of visibility or knowledge sharing actions that lead a focal firm to identify information located further afield at an indirectly linked firm. Rather, I contend that there must be a non-trivial degree of overlap in each firm's supply base for such knowledge spillover to occur. As such, I limit the analysis to indirectly linked manufacturing firm dyads where each firm has at least 5% of their total outsourcing spend with the set of suppliers they share. While this limits the number of observations to 9,675 dyads, it

also makes each manufacturing firm much more likely to expend costly effort in managing their supply relationships with that particular set of common suppliers and thus create opportunities for indirect knowledge spillovers to occur.

4.2 Measures

4.2.1 Dependent Variable

Following the previous essays, each focal firm's level of innovation is measured as the number of successful patent applications submitted to the United States Patent and Trademark Office (USPTO) in 2012 using the compiled patent data (Alcacer and Oxley 2014) .

4.2.2 Independent Variables

The first independent variable of interest is the level of *indirectly linked firm innovation*. This is measured by calculating the number of successful US patent applications submitted to the USPTO by the indirectly linked manufacturing firm in 2011, measured one year prior to the focal manufacturing firm's measure of innovation. The introduction of the lag year allows time for the diffusion of information across organizational boundaries and for the buyer to incorporate the knowledge into their innovation activities (Alcacer and Oxley 2014).

The second independent variable considered is *lagged focal firm innovation*. I follow (Kim, Hur, and Schoenherr 2015) in defining a firm's level of motivation to acquire external knowledge as indirectly proportional to its previous success in

innovating. As such, I use the number of successful US patent applications submitted to the USPTO by the focal manufacturing firm in 2011.

The final independent variable of interest in this study is the *technical similarity* between the focal firm and the indirectly linked firm, which determines how similar or distant the areas of knowledge are in which each firm is actively innovating. I use a Euclidian distance calculation to estimate the technical distance between the two firms (Yang, Lin, and Lin 2010, Rosenkopf and Almeida 2003). To develop this measure, I first identified the distribution of each firm's patents across technical domains (identified herein though the use of the patents' 4-digit International Patent Classification code) and calculated the relative frequency of the firm's patenting actions within each technical domain. At this point, the Euclidian distance between the indirectly linked manufacturing firms is calculated by taking the square root of the sum of the squared differences between the proportions of each firm's patents in each technical domain. This is formally defined in equation 2.

$$\text{Technical Distance} = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2}, \qquad (2)$$

where q_i is the proportion of firm q's patents in technical domain i, p_i is the proportion of firm p's patents in technical domain i, and n is the total number of technical domains. As a practical example, Yang, Lin, and Lin (2010, 247) offer the following explanation:

To illustrate, if Firm A has five percent of its patents in Domain A, 55 percent in Domain B, 30 percent in Domain C, and 10 percent in Domain D, while Firm B has 10 percent of its patents in Domain A, 10 percent in Domain B, 80 percent in Domain C, and zero percent in Domain D, then the technical distance between the two firms can be calculated as the square root of the sum $[(0.05–0.1)^2 +(0.55–0.1)^2 +(0.3–0.8)^2 +(0.1–0)^2]$.

I then multiply this value by -1 to reverse the sign of the variable and allow larger numbers to represent greater technical similarity rather than greater technical distance to better align with the hypotheses developed previously. As such, this measure ranges from about -1.4 (the square root of two multiplied by -1), as indicated when each firm only has patenting activity in one technical domain and that domain is different for each of the firms, to zero (when the firms have identical distributions of patenting activity across each technical domain).

4.2.3 Control Variables

I include a number of control variables to account for other factors that might be correlated with a focal firm's innovation performance. Focal firm research and development expense has been linked to the degree of effort the firm puts into innovation activities, (Ceccagnoli and Jiang 2013). Learning theory suggests greater quantities of slack resources enable firms to increase their search activities and innovation adoption rates (Cyert and March 1963). As such, I include controls for two common measures of slack resources, firm size and profitability. I control for firm size effects using the revenue of the focal firm and for firm profitability using the

focal firm's ROA. Finally, I include dummy variables as industry controls for the buyers based on the NIACS codes at the three-digit level to account for variations in patenting practices across different types of manufacturing industries.

4.3 Methods

As the dependent variable of interest, focal firm innovation, is measured as a positive integer value, ordinary least squares regression is not an appropriate model to conduct the econometric analysis. Instead, I use a negative binomial model that addresses the count nature of the dependent variable and also accounts for potential over-dispersion issues that can be caused when there are a large number of zero and small integer values within the measurement of the dependent variable (Hausman, Hall, and Griliches 1984). A Poisson model was also considered, but discarded based on the significant value of the over-dispersion parameter in the negative binomial model (Greene 2003).

The model is then run in an iterative fashion, adding in relevant interaction terms to evaluate each of the hypothesized relationships. The first model includes the controls along with the baseline relationship between indirectly linked firm innovation and focal firm innovation. Subsequent models introduce the interactions of the lagged focal firm innovation measure and the technical distance measure with the indirectly linked firm's to investigate the associated impacts on the baseline relationship.

It is important to note in this model not all observations are independent. Each focal manufacturing firm is indirectly linked to multiple other manufacturing firms and each dyad is entered into the model as a separate observation. To correct for this lack of independence I cluster the standard errors on each of the focal manufacturing firms, allowing for the correct interpretation of the statistical significance of the resulting coefficients (Petersen 2009, Rogers 1983, Cameron and Miller 2015). There is no adjustment to the parameter estimates required, as the maximum likelihood estimates remain unbiased and consistent when the independence assumption is violated (Greene 2003).

5. Results

The 476 focal manufacturing firms in this study have links with a total of 9,675 other manufacturing firms through indirect ties captured in the data collection effort. The descriptive statistics for all variables are reported in Table 6. It is important to note the measure of the technical similarity variable is based on a Euclidean distance calculation and as such, any observations where either the focal firm or the indirectly linked firm had zero patents could not be included in that part of the analysis. Thus, in models where the technical similarity measure is introduced, the number of observations drops to 5,590 dyads. In order to verify that multicollinearity issues are not present, variance inflation factors were calculated and found to be well below the standard cutoff threshold of 10 for all key variables contained in the regressions, suggesting multicollinearity is not affecting the results (Kennedy 2003). A Breusch-Pagan/Cook-Weisberg test for heteroscedasticity identified potential

Table 6

Descriptive Statistics and Correlations[a]

	Variable	Mean	Std. Dev.	Min	Max	1	2	3	4	5
1.	Focal Firm Innovation	59.20	169.18	0	1,755					
2.	Indirectly Linked Firm Innovation	69.67	168.25	0	1,427	0.04				
3.	Technical Similarity[b]	-0.73	0.27	-1.41	0	0.19	0.24			
4.	Focal Firm R&D Expense ($ Millions)	746.70	1,664.49	0	11,670.93	0.27	0.04	0.21		
5.	Focal Firm ROA	0	0.19	-1.75	0.50	0.05	-0.02	0.06	0.14	
6.	Focal Firm Revenue ($ Millions)	12,031.35	31,349.59	0	467,153	0.13	0.01	0.16	0.54	0.13

[a] n=9,765

[b] n=5,590

TABLE 7

Negative Binomial Estimates for Focal Firm Innovation [a]

Variables	Model 1: Hypothesis 1		Model 2: Hypothesis 2		Model 3[b]: Hypothesis 3		Model 4[b]: Full Model	
Indirectly Linked Firm Innovation	0.00039***	(0.000)	0.000509**	(0.000)	0.000977**	(0.000)	0.000733**	(0.000)
Lag Focal Firm Innovation			0.009957***	(0.002)			0.007917***	(0.001)
Technical Similarity					1.479617***	(0.243)	0.993002***	(0.131)
RD Expense	0.00071*	(0.000)	0.000070	(0.000)	0.000560~	(0.000)	0.000091	(0.000)
ROA	0.67078	(0.779)	0.772212~	(0.395)	0.376052	(0.851)	0.542610	(0.343)
Revenue	0.00001	(0.000)	0.000001	(0.000)	0.000001	(0.000)	-0.000003	(0.000)
Indirectlly Linked Firm Innovation X Lag Focal Firm Innovation			-0.000003***	(0.000)			-0.000001~	(0.000)
Indirectlly Linked Firm Innovation X Technical Similarity					0.002332**	(0.001)	0.001472**	(0.000)
Constant	-0.12556	(0.368)	0.123385	(0.352)	2.345195***	(0.432)	2.006926***	(0.310)
Industry Dummies?	Yes		Yes		Yes		Yes	
Likelihood Ratio	3417.53***		8995.14***		2905.21***		8228.15***	
df	20		22		20		22	
McFadden's Adjusted R2	0.04		0.105		0.051		0.145	
Cragg & Uhler's Pseudo R2	0.298		0.605		0.405		0.771	

[a] Standard errors are in parentheses; n = 9,675

[b] n=5,590

† p < .10; * p < .05; ** p < .01; *** p < .001

concerns relating to a violation of homoscedasticity assumptions, and was corrected for in the regression models through the use of robust standard errors (White 1980).

The estimation results presented in Table 7 examine the relationship between an indirectly linked firm's innovation activity and a focal buyer firm's innovation in the subsequent year, as evidenced by each firm's patenting activity. The dependent variable in these negative binomial regressions is *focal firm innovation*. All models include focal firm industry fixed effects. Model 1 examines the baseline relationship between an indirectly linked firm's innovation and a focal firm's innovation in the following year as put forth in H1. The positive and significant coefficient of *indirectly linked firm innovation* in Model 1 provides evidence in support of the contention that buyers can and do leverage the innovation and knowledge generated by firm they are only indirectly linked to through their supply chain network as a mechanism to learn and develop their own innovations. Furthermore, we see that R&D expense is positively linked to buyer patenting, while ROA and revenue have positive coefficients but are not found to be statistically significant.

Model 2 introduces the interaction effect of *lag focal firm innovation* on the baseline relationship established in Model 1. The negative and statistically significant coefficient provides support for H2. When a focal firm has previously been successful in developing innovations, it is less motivated to undertake costly search actions to access distant knowledge that is held at an indirectly linked firm. As such, any knowledge contained within the indirectly linked firm's innovation activity is less

likely to be transferred across the focal firm's network and thus less likely to impact subsequent focal firm innovation activities.

In Model 3 I test the interaction effect of *technical similarity* between the focal firm and the indirectly linked firm. Here I analyze only a subset of the data (5,590 dyads from 312 buyer firms) as I am forced to drop observations where either the focal firm or the indirectly linked firm had zero patents in the observation year, thus making it impossible to assess *technical similarity* in such instances. The positive and significant coefficient of the interaction term demonstrates strong support for H3. A greater degree of technical similarity between a focal firm and a firm it is indirectly linked to enhances the ability of the focal firm to extract useful knowledge from the link and in turn, to deploy that knowledge in innovative ways.

The fourth model incorporates both interactions terms simultaneously and can be considered the full model. All of the findings demonstrated in the first three iterations of the model are further supported in this full model, as evidenced by the results in Table 6. This provides additional support for the robustness of the findings reported above.

6. *Discussion and Conclusions*

This essay builds on the two previous essays contained in this dissertation, offering greater insight into the role of extended supply chain network members to act as sources of knowledge and to influence a focal firm's innovation output. While

essays 1 and 2 provided detail into how direct ties with suppliers can introduce new and useful information to a buyer firm, this essay extends the analysis to the indirect links made through sharing a common set of suppliers with another buyer firm. The findings in essay 3 provide clear support for the concept that indirect ties can and do act as a source of knowledge that enable a focal firm to improve its innovation activities.

Much of the previous work in the management literature on the value of these indirect ties has only considered their role in aggregate, that is how the total complement of these indirect ties combine to influence interorganizational knowledge sharing and innovation (e.g., Bellamy, Ghosh, and Hora 2014, Ahuja 2000). By investigating the role of these indirect linkages at the dyadic level, this study offers insights into which specific ties are most likely to offer valuable knowledge to a focal firm, and when a focal firm is likely to seek out knowledge from these more distant firms. In doing so, I find broad support for the expectations suggested through a synthesis of the vicarious learning theory as well as the MOA framework.

The empirical results support the arguments made earlier in the study. First, firms are able to improve their innovation output when they have even indirect links to other firms that are highly innovative. This result was highly significant and was robust across all of the models tested in the analysis, providing strong support for the first hypothesis. With access to knowledge and innovation becoming ever more critical to a firm's success, the need to understand how different sources of

knowledge can be accessed and utilized is a growing concern firms must address. The positive result in the first hypotheses supports the premise of the vicarious learning theory that firms are better able to access external knowledge when the available pool of information to draw upon is larger (Posen and Chen 2013). When these indirectly linked suppliers have a wealth of information, as demonstrated by high levels of patenting activity, it creates an environment rich in opportunity for a focal firm to undertake vicarious learning actions and acquire that knowledge despite its location at a distant node. This also supports the notion that firms who regularly patent are adept at codifying knowledge and creating opportunities for the knowledge to flow across organizational boundaries (Grant 1996).

The results also demonstrate that while it is necessary for an opportunity to exist before a firm can access external information, the degree to which that firm is able to incorporate that knowledge into its own activities is a function of the firm's motivation to undertake costly search activities. Firms that have successfully applied their existing reservoir of knowledge into successful innovations are likely to have developed efficient internal routines for developing and processing information (Greve 2005). The success of these routines often results in a focus on experiential learning, as firms seek to repeat actions that previously led to positive outcomes and avoid more risky activities associated with external search (Baum, Li, and Usher 2000). This bias thus reduces a firm's motivation to expend costly time and effort in undertaking actions to learn vicariously from distant sources, even if those indirectly linked firms have a large pool of knowledge available.

These results also shed light on the importance of a firm's ability to identify and internalize knowledge contained at an indirectly linked firm for it to be a useful source of external information. I find the technical similarity between the focal firm's innovative activities and the indirectly linked firm's innovative activities allows for increased visibility into the external knowledge held by the indirectly linked firm, and enhances the ability of the focal firm to recognize its usefulness. This finding suggests the benefits of leveraging knowledge held by an indirectly linked firm can be best realized when a focal firm has similar areas of technical focus and the external knowledge complements the existing stock of the focal firm's knowledge. As proposed by the vicarious learning theory and the MOA framework, such technical similarity creates a substantial ability for the buyer firm to recognize new knowledge within its search parameters, and minimizes the strain on the focal firm's limited absorptive capacity when internalizing the new information. This premise is consistent with previous research on alliance networks that suggests interorganizational technology sharing/transfer benefits are reduced when partners are very technologically diverse (Sampson 2007).

These results have important practical implications for managers as well. Most notably, the findings suggest that firms can leverage the knowledge contained in firms they are only indirectly linked to via their supply networks to enhance their own innovative activities. As such, firms seeking to increase their access to external knowledge should consider not just the innovativeness of their direct supply partners,

but should be cognizant of the other firms with which the suppliers are actively engaged in relationships. They also caution that firms which are already highly innovative may not have sufficient motivation to expend the resources necessary to acquire such distant sources of knowledge through vicarious learning actions. If a firm wishes to make use of those indirect links, it must actively engage in search and encourage the transfer of knowledge from those sources. Similarly, when the focal firm and the indirectly linked firm are technically similar, the ability of the focal firm to recognize and internalize the indirectly linked firm's knowledge is maximized and enhances the impact on the focal firm's innovative activities. However, when the two firms are technically distant, the difficulties in knowledge recognition and transfer may diminish the benefits realized by the focal firm, and in some cases may actually impede its ability to innovate.

This research has important limitations that must also be taken into account. The supplier selection process is multifaceted and includes a wide number of factors that must be considered above and beyond the knowledge potential of other firms with which a supplier actively does business. A focal firm must consider and weigh the relative importance of various supplier's characteristics to best align with their needs and the goals of their organization. Care must also be taken in generalizing these results. The dyads examined here are limited to publicly traded firms and is focused on manufacturing firms located in the United States. Future research could consider a broader array of industries, such as retail settings, and could expand the focus to consider private firms and a more international scope to see if these results

are consistent or if other factors impact the flow of knowledge in different situations. Furthermore this analysis does not include other factors that may affect the motivation, opportunity, or ability of a focal firm to undertake vicarious learning actions. It would be worthwhile investigating the role of attributes such as the reputation of the indirectly linked firm, or if the indirectly linked firm is recognized as an industry leader,

Similar to the previous essays, there is an empirical limitation to this study as well. The dependent variable and main independent variable, focal firm and indirectly linked firm innovation, were constructed using a patent database that I linked with Bloomberg's supply chain relationship dataset. With Bloomberg's data only providing a snapshot of the relationships, the study was limited to analyzing a cross-sectional set of data. Future research could benefit from extending the analysis to consider temporal effects and explore how long it takes for information to begin or to stop flowing when relationships are created or abandoned.

Even with these limitations, the results of this study offer several broad implications. Innovation is often a result of the combination of new knowledge stemming from external sources, and this study has demonstrated the ability of firms to draw upon the knowledge contained in firms they are only indirectly linked to though their supply network partners. Furthermore, I have demonstrated important characteristics that determine the opportunity, motivation, and ability of a firm to

undertake vicarious learning actions and the likely effectiveness of this flow of knowledge on the focal firm's innovation efforts.

Synthesizing central tenets of the vicarious learning theory and the MOA framework, I developed and tested a model exploring the relationship between the innovation output of a focal firm and previous innovation at an indirectly linked firm. Specifically, I examined the opportunity, motivation, and ability of a firm to undertake vicarious learning actions and to positively impact its innovation performance by leveraging knowledge held by indirectly linked firms. Combining archival data on manufacturing supply chain relationships with US patent data, I used econometric methods to empirically demonstrate the positive impact an indirectly linked firm's level of innovation has on a focal firm's subsequent innovation efforts. Furthermore, I found the knowledge contained within these indirectly linked firms has a greater impact on focal firm innovation when the focal firm has less success in previous innovation activities and is more motivated to search for external knowledge and when the firms are more technically similar, improving the visibility of the external information and enhancing the ability of the focal firm to recognize and internalize the external knowledge. These findings improve our understanding of interorganizational knowledge transfer across firms indirectly linked through their supply chain relationships and shed light on dyadic knowledge transfer across distant nodes in a network.

7. Additional Analysis

While the above analysis provides strong support for the notion that indirectly linked firms provide access to knowledge a focal firm can utilize to improve its own innovative outputs, it does not explicitly test the impact of innovations at non-linked firms on a focal firm's subsequent innovation output. It may be that when firms publish their innovative activities in the form of patents, the important aspects of the information are made public and allow any firm to benefit from the newly available knowledge. Thus it is important that I rule out the possibility that general increases in public information made available through patent documents are actually driving the increases observed in a focal firm's patenting activity, and any indirect links between the firms in question is merely coincidence and the results above caused by spurious correlation.

To test this premise, I randomly generate 500 manufacturing firm dyads from data set that have no indirect links at all in their supply networks. I then run the same analysis as I did for hypothesis 1 with these unlinked dyads and report the results below in Table 8. As evidenced by the insignificant coefficient of unlinked buyer 2 patents in 2011 on the focal firm's patents in 2012, there is no support for the notion that firms are able to make use of any public patenting information to the same effect as accessing knowledge held by a firm they are indirectly linked to through their supply network.

Table 8
Negative Binomial Estimates for Focal Firm Patents in 2012

	Coef.	Std. Err.
Unlinked Buyer 2 Patents 2011	-0.00021	(0.0005)
Buyer 1 R&D Expense	0.00098*	(0.0003)
Buyer 1 Revenue	0.00000	(0.0000)
Buyer 1 ROA	1.27257***	(0.3400)
Constant	-0.60752	(0.5866)
Buyer 1 Industry Dummies	1.22186~	(0.6971)
313	-17.718***	(1.1651)
315	-18.092***	(1.1567)
316	0.00655	(0.7503)
322	2.66889**	(1.0066)
324	1.02538	(1.9745)
325	2.41081***	(0.6160)
326	2.45155***	(0.6869)
327	2.29630***	(0.5701)
331	0.46450	(0.9050)
332	2.03844**	(0.7054)
333	2.79044***	(0.6597)
334	3.50804***	(0.6375)
335	2.71486**	(0.8241)
336	1.73713**	(0.6101)
337	0.66344	(0.6307)
339	2.14968**	(0.6335)
# Observations	500	

Common supplier attributes

The above analysis is centered around the characteristics of the focal firm and the indirectly linked firm and their associated impacts on the transfer of knowledge between the two firms. However, the possibility also must be taken into account that the characteristics of the common supply base that acts as the link between the two manufacturing firms plays a role in the transfer of knowledge between the indirectly linked firms. This would suggest that rather than merely acting as a contact point to

these other firms, the supplier plays a central role in identifying, absorbing, and then passing the information from one buyer firm to the other.

Previous literature has suggested knowledge flows across networks can be affected by the density of ties between the firms operating within the network (Bellamy, Ghosh, and Hora 2014, Mahmood, Zhu, and Zajac 2011). These studies find that as the number of linkages between network members increase, knowledge flows are enhanced and the focal firm is better able to develop innovations. Following this rationale, it is possible that strengthening the link between two focal firms in terms of the degree of overlap in their supply bases provides additional paths for knowledge transfer between the two organizations to occur, thereby increasing the impact of knowledge spillover between two buyer firms.

The innovative capabilities of the shared suppliers may also be a key factor in determining the impact of knowledge transfer between indirectly linked buyers. Suppliers who are actively innovating have a higher level of absorptive capacity (Cohen and Levinthal 1990) and are thus better able to recognize and internalize the knowledge from their downstream buyers. This increases the suppliers' repository of available knowledge, thus increasing the ability of the supplier to act as effective conduit of knowledge between indirectly linked buyer firms and strengthening the spillover effect between these buyer firms.

Table 9
Negative Binomial Estimates for Focal Firm Patents in 2012

Variable	Coef.	Std. Err.
Indirectly Linked Firm Innovation	0.0002324	(0.00018)
Buyer 1 RD Expense	0.000699*	(0.00032)
Buyer 1ROA	0.6804062	(0.771000)
Buyer 1 Revenue	0.0047700	(0.00730)
Number of Shared Suppliers	0.0209317	(0.01577)
Total Innovation Shared Suppliers	0.0000241	(0.00021)
Indirectly Linked Firm Innovation X Number of Shared Suppliers	-0.0000004	(0.00002)
Indirectly Linked Firm Innovation X Total Shared Supplier Innovation	0.0000001	(0.00000)
Constant	-0.1186872	(0.36528)
Buyer 1 NAICS Industry Dummies		
312	0.4442085	(0.55225)
315	-17.6527200***	(0.82256)
316	0.0678678	(0.35646)
322	3.218985***	(0.56966)
324	1.4288680	(60132)
325	2.914799***	(0.48744)
326	2.475059***	(0.60628)
327	2.699737***	(0.50300)
331	2.3423**	(0.67875)
332	1.825599***	(0.42188)
333	3.093332***	(0.48961)
334	3.44343***	(0.49534)
335	2.591783**	(0.76144)
336	2.079898***	(0.40000)
337	0.9983322*	(0.48074)
339	2.100437***	(0.46780)

n=9,635

I test these effects and report the results in Table 9. As evidenced by the lack of significance associated with the number of shared suppliers and the level of innovation of the shared suppliers, it does not appear the characteristics of the

suppliers are pivotal to the transfer of knowledge between indirectly linked firms. Rather, it appears these shared suppliers merely act as nodes that direct a focal firm's knowledge search activities towards other innovative firms with which they are engaged in supply chain relationships.

Conclusion

This dissertation takes a comprehensive look at the role of suppliers and their ability to act as a source of both direct knowledge and a link to indirect sources of knowledge a downstream buyer firm can access and internalize to improve its own innovative output. Through the application of organizational learning theory, vicarious learning, social network theory, and the MOA framework, I have developed and tested hypotheses ranging from the most basic level of supply chain analysis, the buyer-supplier dyad, to the full spectrum of a buyer and its entire supply base, and to the extended network of indirectly linked buyer firms that share a common set of suppliers.

This study builds upon literature that has been conducted in the management field investigating the role of external knowledge (Ahuja 2000, Miller, Fern, and Cardinal 2007), the impact of specific dyadic relationships with external partners (Sampson 2007, Mowery, Oxley, and Silverman 1996), as well as work on the role of a firm's network to act as a source for innovative knowledge (Bellamy, Ghosh, and Hora 2014, Burt 1992, Tsai 2001). It extends this literature through a focus on supply chain relationships and further supports the conceptualized transition of sourcing activities from a transactional function to a strategic operation that can provide value to a company beyond a simple exchange of goods and/or services.

The results demonstrate the need for firms to consider not just the typical factors when selecting suppliers: price, warranty, delivery, etc., but if they want to

drive innovative behavior they should also consider the degree of innovation within the set of potential suppliers. Furthermore, the results in this study suggest a firm is able to access not only the knowledge held by a specific supplier within its supply network, but the indirect ties to other buyer firms a supplier is in an exchange relationship with can also transmit knowledge and information that facilitates innovation at the focal buyer firm.

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