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Exploring Hopes And Fears From Supply Chain Innovations: An Analysis Of Antecedents And Consequences Of Supply Chain Knowledge Exchanges

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Exploring Hopes And Fears From Supply Chain Innovations: An Analysis Of Antecedents And Consequences Of Supply Chain Knowledge Exchanges

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Dedication

To my dear father, Sayed: this is for you. Nadia, Mohamed, and Maysa: you have walked me here. You have earned me this, so you deserve it. Hoda and Nazli: you have proved not to be in the way, but indeed to be the way for mummy's success; so enjoy it!

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Dissertation Summary

Innovation is one act whose biggest risk comes from not doing the act. Dr. Reithofer, the CEO of BMW AG, precisely devises an answer to the famous question as to why his company innovates saying that: "because doing nothing was even a bigger risk". Companies deliberately choose to incur the risk of innovation to avoid a much bigger risk of not doing so. The innovation process, however, continues to evolve for businesses, calling for aggressive changes such as self-cannibalization (Sood & Tellis, 2013; Thurow, 2000), "glocalization" of operations (Svensson, 2001), and, more importantly, pushing beyond organizational boundaries in open innovation models. Recent models of shared value creation (Porter & Kramer, 2011), open source technologies (Dooley & O'Sullivan, 2007), and distributed innovation (Cash, Earl, & Morison, 2008) highlight the fact that company's ultimate innovation outcomes depend not only on its capability to innovate, but indeed on others' capabilities as well. Acknowledging the supply chain as the evolving unit of competition (Capaldo, 2007; Ketchen & Hult, 2007), it also represents a necessary "innovation ecosystem" (Adner, 2006) that must be properly managed for reaching the desired innovation outcome.

This dissertation sheds light on several *hopes and fears* from supply chain innovation in three distinct papers. Paper one introduces the concept of Process Innovation Propagation as an appropriation technique helping to extract the most returns out of a process innovation by exporting to supply chain partners. Paper two devises and empirically tests knowledge properties that best lead to radical and incremental supply chain innovative capabilities. Lastly, paper three conducts an exploratory study that introduces factors affecting a firm's optimum supply chain innovation strategy. The dissertation makes a strong argument that supply chain innovation is most prominently governed by power asymmetry that may either help or hurt innovative performance. A more elaborate summary on each of the three papers follows.

The first paper introduces the concept of Process Innovation Propagation (PIP) as a novel way to appropriate returns on process innovations through passing them to supply chain partners. The transfer process depends on power advantage to persuade partners to adopt an innovation because the propagator enjoys either: (1) market power advantage

through dependence asymmetry, or, (2) expert power through proficiency in one or more areas of expertise irreplaceable by the receiver. In either case the propagator collects innovation returns by operational improvement along the supply chain, such as process synchronization and integration, and/or improved image and reputation as in the case of propagating green practices and socially responsible initiatives.

The paper proceeds to develop the three overarching elements of PIP: partner selection, innovation properties, and governance structure. PIP partners are to be selected according to their strategic fit, which is characterized by strategic similarity, interdependence, and incentive alignment. Two innovation properties are discussed as relevant to PIP, including vertical transferability and the degree of technicality. Finally, formality of the relationship and managerial attitude comprise the supply chain governance structure, which arguably affects PIP success. The PIP novelty is threefold. It suggests external appropriation through using other firms as opposed to solely depending on internal capabilities. PIP also directly challenges the preclusive component of generative appropriability (Ahuja, Morris Lampert, & Novelli, 2013). It also introduces a new channel for collecting innovation rents through supply chain operational benefits and market image.

Rather than appropriating returns on existing ideas, the second paper addresses the challenge of creating new ideas in joint endeavors with supply chain partners. It takes a capability building perspective to characterize supply chain knowledge properties that help build collective radical and incremental innovative capabilities. Two hierarchical component models (second order reflective-formative models) are devised for human and organizational knowledge properties that are argued to drive supply chain radical and incremental innovative capabilities, respectively. Being an element of any relationship, power exercise is acknowledged for its moderating effects on each of the two links.

This paper uses a two stage PLS technique to empirically test for the hypothesized relationships. Results show that human related diversity is an effective abstraction that can explain supply chains' abilities to produce radical innovations. Counter to expectations, however, diversity in people and skills seems to create more problems of coordination and intra-team conflicts than provide a wide spectrum of ideas helpful for idea generation. The second order organizational construct, organizational capital

domination, did not succeed as a higher-level abstraction. One of its components, however, organizational knowledge gap, significantly inhibits incremental innovative capabilities of supply chains. Companies with discrepancies in size find coordination problems due to conflicting procedure, governance structures, and organizational cultures. Finally, results show that power exercise against supply chain partners will not help incremental innovations, and significantly hurt radical ones.

After addressing hopes of appropriation and building innovative capabilities with supply chain partners, paper 3 proceeds to deal with the main *fear* from supply chain innovation, that is, loss of competitive knowledge. The risk of horizontal leakage of knowledge (to competition) is inherent in vertical sharing (with supply chain partners). In this context, the unintended knowledge spillover problem becomes each firm's *deliberate* choice whether to leak its partner's knowledge to that partner's competition. The paper adopts a game-theoretic perspective in an exploratory study of supply chain knowledge exchanges to address whether a firm should 'cooperate' by readily sharing its knowledge and protecting that of its partner, or 'defect' by doing the opposite. Because each player must choose one of two alternatives the relationship between the two players can be modeled as a 2×2 game, in which each player chooses (simultaneously) whether to cooperate or defect.

The paper starts by highlighting a broad class of symmetric and asymmetric 2×2 games that can model the knowledge-sharing dilemma among supply chain partners in the context of joint innovation projects. Different firm preferences are modeled along two dimensions: collaboration motive and power advantage. The paper continues to address long-term relationships by investigating the effect of game repetition on firms' choices and outcomes using MATLAB simulation. The simulation explores the effects of firm type, opponent type, strategy type (nice versus mean), and payoff structure on repeated innovation interactions (or equivalently, long-term relations).

The three aforementioned papers are given in the next three sections, followed by concluding remarks in section 5.

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CHAPTER I. Process Innovation Propagation: Appropriating Supply Chain Innovation Returns

ABSTRACT

This paper introduces the concept of Process Innovation Propagation (PIP) as a power-based appropriation mechanism that departs from conventional strategies of protective appropriation. PIP is defined as collecting returns from process innovations through passing them over to supply chain partners. The transfer process is based on the two mediated sources of power which pre-exist in a buyer-supplier linkage prior to joint innovation endeavors: market and expert, and is novel in: (1) suggesting external appropriation through using other firms as opposed to solely depending on internal capabilities, (2) directly challenging the preclusive component of generative appropriability, and, (3) collecting innovation rents through supply chain operational benefits and market image. Acknowledging its significant potential as a profit-enhancing mechanism, PIP is distinguished as a new construct and propositions regarding its elements and antecedents are developed based on a thorough analysis and synthesis of the literature.

1. INTRODUCTION

Synchronizing the innovation process within supply chains serves as a key source of competitive advantage (Cecere, O'Marah, & Preslan, 2004). Firms are accordingly incentivized to share process innovations with supply chain partners, hoping to improve the overall operational performance, in terms of efficiency, responsiveness and quality. Doing so, however, may entail repercussions of intellectual property loss, through common suppliers and divided loyalties. A corresponding dilemma, therefore, arises regarding how to capitalize on supply chain partners to appropriate maximum value from process innovations, with minimum loss of competitive edge. Firms realize the importance of innovation "openness"; yet attempt to appropriate commercial returns from their innovative efforts (Dahlander & Gann, 2010). Accordingly, in this paper we take a step to resolving this dilemma through the concept of "process innovation propagation" (PIP), attempting to build a comprehensive theory around it regarding its elements, and viability conditions.

PIP is defined as a power-based appropriation mechanism for an existing process innovation through transferring it to one or more supply chain partner(s). Firms that propagate to suppliers process innovations, such as statistical process control, just in time, or green initiatives, are able to reap more benefits from these innovations through an enhanced supplier performance, be it in lead time reduction, higher quality or more efficient production, and/ or an enhanced company image, for example by achieving a 'green supply chain' reputation. The concept of PIP is new in departing from the conventional view of appropriation based on secrecy and intellectual property protection, and promoting sharing of ideas to maximize value by considering adopting units outside the boundaries of an organization.

The concept of PIP is relevant and timely in addressing three evolving facts: (1) an increasing importance of innovation as a source of competitive advantage (Cefis & Marsili, 2012; R. M. Grant, 1996); (2) a move away from the "myopia of protection" to capitalizing on external innovation sources (Laursen & Salt, 2006); and, (3) acknowledgement of supply chains as the new units of innovation and competition (Adner, 2006; Ketchen & Hult, 2007; Porter & Kramer, 2011). Appropriating value from existing innovations is of paramount importance to firms (Ahuja, Morris Lampert, &

Novelli, 2013). Firstly, innovations have become a pre-requisite for existence and success. Moreover, companies strive to maximize return on their vast, high-risk innovation investments of technological, human, and financial resources. Firms can appropriate "generative" value from innovations by seeking improved versions, and by deriving related (or unrelated) inventions from existing ideas (Ahuja et al., 2013).

PIP extends the concept of generative appropriability (GA) by moving beyond the boundaries of one firm, to acknowledge the potential of supply chain partners to capitalize on innovations. Although PIP supports the cumulative component of GA through expanding the scope of a process innovation, or adapting it to be implemented in a supply chain partner firm, PIP works directly against GA's preclusive component, which emphasizes excluding external parties from benefiting from an innovation, through intentionally allowing supply chain firms to profit from the propagated innovation. This is particularly significant given the increasingly dis-integrated structures of supply chains, rising move towards outsourcing, and more reliance on supply chain partners for strategic activities and knowledge exchanges.

PIP depends on power advantages to secure innovation returns. Supply chain power is the ability of a partner to induce another to do what it would otherwise not do (Dapiran & Hogarath-Scott, 2003; Emerson, 1962; Pfeffer, 1981). Power acts as an initiator for creating new adopters who may otherwise be resistant to changes and as a guard against opportunistic behavior that may harm the innovation owner. Although trust may replace power in eliminating opportunism (Ireland & Webb, 2007), it fails to overcome organizational inertia against innovations, which may be caused by risk aversion or simple resistance to change (Bantel & Jackson, 1989). Chain integrators, such as Ford, Toyota, Wal-Mart and Dell, enjoy market power and/or expert power advantage(s) that succeeds to influence suppliers to comply to directives regarding new process adoption. By striving to maintain business with a giant integrator, or perceiving technological lead, less-powerful suppliers conform to new processes, resulting in higher innovation performance for integrators, suppliers, and in turn the supply chain as a whole.

Being a power-driven mechanism, PIP challenges conventional formal appropriation means, while extending strategic, informal means. In PIP process innovations are openly shared as opposed to licensed. Propagators acknowledge the fact

that formal appropriation, such as the usage of patents, generally fails with process innovations (Teece, 1986). Protected by their power advantage, propagators readily share their knowledge and may even invest more resources, e.g., training teams, to encourage partners' adoption. PIP extends strategic appropriation mechanisms by combining secrecy and time to market, on a dyadic buyer-supplier level, as well as innovation complexity (see section 3.4). When a power advantageous firm propagates an innovation to a supplier, it can compel that supplier to maintain confidentiality, and negotiate exclusive rights to the innovation for an initial period of time, securing time to market advantage. Although PIP is expected to enhance innovation performance and profitability of all parties involved, we here focus on PIP as an appropriation mechanism, emphasizing appropriation to the propagator.

This chapter is organized as follows. Section 2 relates relevant literature on innovation appropriation. Section 3 builds the theoretical background of PIP on selecting the right partner, and innovation, and on factors that may affect the success of PIP in generating rents. Finally, concluding remarks are discussed in section 4.

2. LITERATURE REVIEW

2.1 Innovation and Appropriation

Innovation is a key form of organizational knowledge creation defined as the "embodiment, combination or synthesis of knowledge in original, relevant, valued new products, processes or services" (Luecke & Katz, 2003; Nonaka, 1994). The term "innovation" tends to be quite encompassing for any organizational change that is "new", where the degree of newness may highly vary from new to the world to merely new (or even perceived as new) to an adopting unit (Dewar & Dutton, 1986; Garcia & Calantone, 2002; Johannessen, Olsen, & Lumpkin, 2001). No attempt to our knowledge has been made to indicate changes, new to an adopting unit, that would yet not qualify as innovations (see Bantel and Jackson (1989) for a review). Several researchers have attempted to define, describe and classify innovation; notably product versus process (Utterback & Abernathy, 1975), radical versus incremental (Dewar & Dutton, 1986), open versus closed (Chesbrough, 2003a, 2003b), and autonomous versus systemic (Teece, 1996).

Innovation has almost become the base for organizational survival (Cavusgil, Calantone, & Zhao, 2003). Companies invest millions of dollars to come up with new ideas to enhance their processes or products and distinguish themselves from competition. Realizing the vast and increasing importance of innovation, companies are willing to invest resources and incur risks, attempting to develop new products and adopt new processes. Bearing these costs, however, managers strive to appropriate maximum value from inventions or ideas (Teece, 1986).

Appropriation has traditionally been associated with innovation protection and confinement. The corresponding economics of the rent view argues that by protecting knowledge against expropriation and against imitation, firms are better able to collect rent streams from innovations and are even more incentivized to invest further in innovations (Liebeskind, 1996). Accordingly firms have been adopting appropriation strategies that focus on excluding other companies from benefiting from an innovation and confine rents from an innovation to its owner. These appropriation strategies may be legal (formal) such as patents, trademarks, trade secrets and copyrights; or strategic (informal) such as secrecy, sales and service efforts, lead-time (time to market), learning and design complexity.

2.2 Formal and Informal Appropriation

The choice of formal versus informal strategies depends on several factors such as industry, firm size, innovation type (product versus process) and the involvement of partner(s) in the development process. In an early study it was found that both the usage of patents as a protection mechanism and their effect on the rate of innovation depend on the industry (Mansfield, 1986). The significant effect of industry has been confirmed in later studies (Arundel & Kabla, 1998; Brouwer & Kleinknecht, 1999; Cohen, Nelson, & Walsh, 2000). More specifically, it has been found that appropriation strategies remarkably differ between service and manufacturing industries, as the two sectors innovate differently (Leiponen & Byma, 2009). Formal proprietary rights also tend to be favored by firms involved in product innovations, as process innovations, which are likely large-scale, would enjoy the natural protection of scale economies; and are more difficult to patent (Gooroochurn & Hanley, 2007; Teece, 1986).

Firm size also acts as a significant differentiator for the choice of appropriation mechanism (Holgersson, 2013). Small firms tend to prefer informal appropriation strategies as they may lack the resources for legal innovation defense (Cohen et al., 2000), or because they simply do not perceive formal strategies, mainly patenting, as efficient protection for the competitiveness of innovations (Arundel, 2001). Moreover, inter-firm cooperation drives a choice for informal appropriation, namely speed to market, particularly when the cooperation is horizontal which is usually the case for product innovations (Leiponen & Byma, 2009). Despite being preferred in several situations, informal appropriation mechanisms have generally received little attention in the literature (Leiponen & Byma, 2009).

2.3 Generative Appropriation in the Supply Chain

Appropriation, as discussed above, has been mainly concerned with its primary dimension, defined as the individual share of the value that a firm can capture from a given (new) invention by commercialization/ licensing (Ahuja et al., 2013; Ritala & Hurmelinna-Laukkanen, 2009). This has been extended to include a second dimension that acknowledges value, as opposed to share, maximization from an idea or innovation. This is referred to as "generative appropriation" (Ahuja et al., 2013). Realizing the fact that excessive secrecy/ protection may impede value creation, firms may prefer a smaller portion of a growing pie to a bigger part of a potentially shrinking pie (Jacobides, Knudsen, & Augier, 2006). Knowing that bounded rationality limits the ability to predict possible risks, firms are shying away from full protection attempts and acknowledging the innovation potential from collaboration (Ireland & Webb, 2007; Lavie, 2006).

Accordingly, the focus is shifting to value creation, which is arguably best achieved through supply chain partners. Supply chain firms own complementary assets required for the commercialization of an innovation (Teece, 1986). On the one hand, investing in appreciating complementary assets may secure future appropriation, by stimulating a need from innovators and imitators (Jacobides et al., 2006). On the other hand, the complete value chain represents an innovation ecosystem that may define primary appropriation for an innovator (Adner, 2006) and create shared value (Porter & Kramer, 2011). By combining innovative capabilities and complementary assets from the value chain, synergies are created, allowing for future appropriation opportunities.

3. THEORETICAL DEVELOPMENT: PROCESS INNOVATION PROPAGATION: PIP

3.1 Foundations of PIP

Process Innovation Propagation (PIP) is defined as appropriating returns from process innovations by exploiting power advantages to export innovations to supply chain partners. Table I-1 distinguishes between PIP and other related constructs. Process innovations may be well transferrable to supply chain firms, and owners of these innovations perceive direct benefit from sharing the ideas with partners, and persuading adoption (Aitken, Childerhouse, & Towill, 2003; Srai & Gregory, 2008; Walker, Di Sisto, & McBain, 2008). From logistics innovations to green initiatives, propagation creates direct economic value for the innovation owner.

Accordingly, innovation owners use their power advantage to push through transferrable process innovations, and ripple the benefit. An innovation is defined as a change that is new to the adopting unit. As such, a propagator necessarily lies within the supply chain and propagates to a supply chain partner. The owner may have obtained an existing innovation externally (from a third party) or developed it in-house. Propagating its "Retail Link" system, Wal-Mart enjoyed a significant productivity enhancement through the resulting order-of-magnitude supplier investments in the system (Schrage, 2002). Similarly, McDonald's exported its green initiatives to its suppliers, creating a "sustainability" image that has greatly benefited the company (Gunther, 2011, 2013).

Although PIP is distinct from joint R&D (see Table I-1), it entails adaptation efforts to apply an idea to a new adopter. In other words, in PIP supply chain partners do not collaborate to develop an innovation as in co-creation processes (including supplier involvement/ integration in NPD), but a propagator seeking appropriation may collaborate with the receiver to re-apply an existing innovation and adapt it to the new unit of adoption. New adopters continue to experience implementation problems with existing innovations, performing changes and reviews to the organizational procedures as part of almost any innovation implementation process (R. B. Cooper & Zmud, 1990). Implementation is in fact a managerial challenge comparable to that of initial invention (Leonard-Barton, 1988). Accordingly, inter-firm teams work together to modify the new

technology to adapt it to existing organizational structures (Majchrzak, Rice, Malhotra, King, & Ba, 2000). Appropriate interaction between the source and receiver helps overcome implementation issues for a smoother technological adaptation (R. B. Cooper & Zmud, 1990). This adaptation, however, is merely regarded as a stage in the implementation course, as opposed to being a stand-alone co-creation process, regardless of how discontinuous it may be (R. B. Cooper & Zmud, 1990; Tyre & Orlikowski, 1994).

PIP appropriates returns on an innovation owner by providing operational benefits and/ or enhancing the innovator's image. Sharing process innovations, which improve operations (flexibility, responsiveness or cost), spreads the benefits to supply chain partners, enhancing the performance of the whole supply chain (Subramani, 2004). Supply chains have become the actual units of competition as organizational boundaries between supplier and buyer have blurred due to multiple functional interfaces and relation-specific investments (Dyer, Cho, & Chu, 1998). PIP allows for harmonization of buyer and supplier processes, which highly avoids wasting resources (Lasch & Janker, 2005). This chain-wide integration synchronizes processes throughout the chain, improving the focal company's overall performance (Van-der-Vaart & Van-Donk, 2008).

Moreover, a firm's supply chain has become part of its innovation ecosystem, where full benefits are only possible through enhancing the whole system's performance (Adner, 2006). This necessarily drives efforts of each firm to develop its partners' innovation capabilites, which in turn translates into operational value for the whole chain, including the innovator. Obtaining a satisfactory share that justifies sharing the knowledge depends mostly on the innovator's power advantage.

PIP can be also regarded as a very effective marketing strategy. Exporting green practices to suppliers creates a positive "green" image for the propagator (Walker et al., 2008). Green initiatives are extended upstream and downstream to create a "green supply chain" reputation that ultimately leads to economic performance (Rao & Holt, 2005; Vachon & Klassen, 2006). Moreover, firms may propagate innovations that minimize social risks. Chain integrators are inevitably held accountable for social risks incurred by members of their supply chains. Despite their attempts to shift blame, both Apple and Samsung were publicly held accountable for their suppliers' severe working conditions, which were harsh enough to drive employee suicides (Chang, 2010; Evans, 2013; Shin,

2012). Accordingly, chain integrators propagate social innovations to publicize a socially responsible image. From there we reach the central proposition of this paper, which is:

P1: PIP enhances a firm's profitability through appropriating value from existing innovations.

Propagation is a power-driven process. A firm's power is defined as its potential influence, or capacity to affect actions of another unit (Emerson, 1962; Fidler & Johnson, 1984). Supply Chain power is, therefore, the ability of a partner to induce another to do what it would otherwise not do (Dapiran & Hogarath-Scott, 2003; Emerson, 1962; Pfeffer, 1981). It entails influence that can evoke desired actions from partners (Ireland & Webb, 2007). Innovation owners with advantageous power positions can initiate the propagation process, taking advantage of partners' relative dependence to push through their innovations. Enjoying some power advantage allows an innovation owner to both persuade a partner to overcome internal resistance to change (Walker et al., 2008), and prevent the partner from acting opportunistically by misusing/ leaking the knowledge gained. Power can take different types and bases (French & Raven, 1968), from which we acknowledge that the two sources of mediated inter-firm power that pre-exist in a buyer-supplier linkage drive propagation and affect its success. These are: expert power, and/ or market power.

Expert power refers to a firm's perception that the innovation owner is knowledgeable and skillful in the innovation area (Busch & Wilson, 1976). The receiver's perception that the innovation owner firm has greater knowledge in the salient area of the innovation pushes through the idea, incentivizing the receiver to accept it (Fidler & Johnson, 1984). Trusting the owner's capability may suffice for adopting the innovation and following its owner's directives. *Market* power constitutes the propagator's relative advantage in replacing its partner. Replaceability refers to how easily and costly each firm can substitute the other for market transactions (Brown, Lusch, & Nicholson, 1995; S. K. Kim & Ping-Hung, 2003; Kumar, Scheer, & Steenkamp, 1995). The perception that the owner may exercise its market power (e.g., withhold business from partner) persuades the partner to implement the required change. Partner's dependence on the innovation owner for knowledge and/ or market transactions also discourages any opportunistic behavior, and allows the owner to reach favorable

agreements on sharing benefits of the exported innovation (e.g., obtaining price reductions from supplier cost reduction innovations).

P2: PIP is a power-driven process; the higher the power advantage of the innovation owner (expert or market power), the higher the success of PIP.

The concept of "success" involves a fair degree of complexity making it difficult to define (Thomas & Fernández, 2008; Wilson, Desmond, & Roberts, 1994). Successful PIP can be regarded as the extent to which (managerial) objectives from the process are achieved (Balachandra & Friar, 1997). This encompasses transfer success of the process innovation, coupled with success of the innovation itself. The former is defined in terms of "the degree of institutionalization of the practice at the recipient unit" which involves implementing the innovation at the receiving unit, as well as internalizing it (Kostova, 1999). Success of a newly institutionalized process innovation entails achieving performance improvement in comparison to other supplier (partner) relationships to which no process innovation has been propagated (Corsten & Felde, 2005). Note that the latter can be a subjective measure constituting managers' perception of the level of success of the new process (Janeiro, Proença, & Gonçalves, 2013). Factors affecting PIP success can be conceptualized as moderators to the link between PIP and firm profitability.

3.2 Classical Examples of PIP

Toyota has started with JIT as an internal process that greatly improved the efficiency and reduced the inventory level in its operations, yet extended the system to other members of its supply chain making the innovation a supply-chain-wide innovation and realizing much more gains. Other companies that used to have JIT as an internal system only, later on after the arrival of the internet and Supply Chain Planning Software, extended JIT externally by demanding from suppliers to deliver inventory to the factory only when it is needed for assembly, making JIT manufacturing, ordering and delivery process even speedier, more flexible and more efficient, benefiting the initiator. In this way Integrated Supply Networks (Demand Networks) or Electronic Supply Chains have formed ("Summary of Just-in-time. Abstract," 2014).

Similarly, the use of House of Quality and Quality Function Deployment has been propagated when it was first introduced in the US market as a new process innovation.

Companies realized that not only should they be telling their manufacturers or suppliers what quality characteristics are important to the customer to manufacture or supply them, but also they could persuade other members of their supply chains to adopt the technique themselves directly with customers. Kelsey-Hayes, one of Ford's two biggest suppliers, was one of the first to build expertise on Quality Function Deployment (QFD) which it used in 1986 to develop a coolant sensor that fulfilled critical customer needs such as ''easy-to-add coolant'', ''easy-to-identify unit'', and ''provide cap removal instructions'' (Prasad, 1998). One year later, in 1987, Ford introduced QFD training to its employees and started using it, easing the supplier's job significantly (Omachonu, Ross, & Swift, 2004).

Another classical example for propagation is Boeing, which exported its concurrent engineering initiatives to its major suppliers, Rolls Royce and General Electric, and the process was then repeated at the next level up the supply chain, providing the companies with quicker component manufacturing, and minimum redesign (Backhouse & Brookes, 1996).

3.3 Partner Selection for PIP: Looking for the Strategic Fit

Exporting innovations to direct partners, such as tier-one suppliers generally presents higher potential opportunities, for a more pronounced effect on a company's operations. However, partners that are more embedded in the supply chain, such as tier-two and tier-three suppliers may also be synergetic candidates for PIP. By looking at the supplier network for instance, tier-two and tier-three suppliers can be part of a company's supply base whose innovation is directly managed (Choi & Krause, 2006).

Nevertheless, in cases where lower tiers are not directly managed by the focal company, an innovation can proceed to lower-tier suppliers by series of repeated PIP. Network flagships in GPN (global production networks) represent such a scenario, in which they exert pressure on smaller suppliers to adopt technological changes that enhance efficiency/quality of processes (Ernst & Kim, 2002). The innovation performance of "Lower tier" suppliers is managed through "Higher tier" ones that mediate the transfer, and gradually propagate repeatedly more sophisticated technologies (Ernst & Kim, 2002). This has additional implications on the choice of suppliers, which

are selected based on their ability to manage the rest of the supply network and ensure its stability in terms of synchronized processes (Bonaccorsi & Lipparini, 1994).

Another implication is the significance of 'repeated-ness' in PIP, so that the real supply chain benefit is realized when the innovation is actually *propagated* more than once, either sequentially or in parallel. A propagator starts by offering the innovation to one member of the supply chain who gives it to another and the process is repeated. First-tier suppliers, who receive an innovation from a primary propagator, act themselves as system integrators for tier-two and tier-three suppliers passing on the idea (Charlette & Sandra, 2000). Such an emphasis on re-iteration makes an innovation a supply-chain-wide practice, extracting the most benefit out of a successful idea. Accordingly, a much more tightly tiered structure is obtained from hierarchical supply chains, resulting from PIP recurrence that is a series of process innovation diffusion throughout the whole supplier network (Kogut, 2000).

In each PIP iteration a company targets the partner with the highest perceived strategic fit. Strategic fit is an encompassing term that has been used in the literature to refer to: (1) external fit, defined as alignment between an organization and its environment; (2) internal fit: alignment between two internal activities of the firm: e.g. governance structure and organizational strategy (Yin & Zajac, 2004), knowledge elements and strategy type (Hult, Ketchen, Cavusgil, & Calantone, 2006); alignment between sourcing strategy and dynamic capabilities (Murray, Kotabe, & Westjohn, 2009); and, (3) inter-firm fit: alignment between two or more firms (e.g. alliance firms) (Douma, Bilderbeek, Idenburg, & Looise, 2000). Our definition of strategic fit mimics the latter, being the matching between strategies and interests of the innovation owner and its supply chain partner (innovation receiver) (Niederkofler, 1991). This compatibility qualifies the establishment of a close, long-term relationship, cultivates trust and commitment (Bronder & Pritzl, 1992), and facilitates the implementation of agreements (Cool & Dierickx, 1993; Ellram, 1990). Based on the literature, strategic fit in a dyad constitutes three dimensions: strategic similarity, interdependence, and incentive alignment.

3.3.1 Strategic Similarity

Strategic similarity refers to the consistency between the innovator's and the receiver's competitive priorities. This can be conceptualized as how closely the two companies rank the importance of the different competitive priorities (Krause, Handfield, & Scannell, 1998). Competitive priorities that are directly tied to supply chain performance are speed, quality, cost and flexibility[1] (Hult et al., 2006). To the extent that partners value these priorities similarly, they share strategic interests, and therefore, enjoy a high degree of fit.

Process innovations are implemented to serve one or more of a company's competitive priorities. JIT, for instance, serves both cost and speed of production. To the extent that suppliers valued cost and speed similar to the exporting firm, JIT was propagated successfully. Aligned competitive priorities harmonize the operation of propagated process innovations leading to the ex ante anticipated improvement. Therefore, the PIP partner should be selected according to its strategic similarity with the innovation owner[2]:

P3a: Strategic similarity between supply chain firms is positively related to PIP success

3.3.2 Interdependence

Fit is based on mutual dependence (Ryu, So, & Koo, 2009). This is defined as firms' mutual need to maintain a relationship with each other to achieve their goals (Mentzer et al., 2001). Interdependence is inherent in supply chain relationships. It represents "a prime force in the development of supply chain solidarity" and "motivates willingness to negotiate functional transfer, share key information, and participate in joint operational planning" (John et al., 2001). In a similar way, this interdependence is the main driver behind the concept of propagation. It is due to the fact that companies in a supply chain need each other to exist and are affected by each other in their success that propagation can help. Interdependence exists not only due to transactions that take place between two companies but also due to complementarity in processes (Togar M. Simatupang, Wright, & Sridharan, 2002), knowledge (Roper & Crone, 2000), resources

[1] Other less common competitive priorities may include product/service technology, and environmental friendliness (Krause et al., 1998).

[2] This argument assumes that partner's valuation of priorities can be assessed. Partner's valuation, however, is beyond the scope of this paper.

(Swink & Nair, 2007) and assets (Teece, 1986) as well as complementarity between a firm's internal and external sourcing for R&D (Cassiman & Veugelers, 2006).

Nevertheless, interdependence varies in extent. Just the way more interdependence drives firms' long-term relationship orientation (Ganesan, 1994), higher degrees of interdependence would also motivate companies to propagate their innovations through their supply chains. Higher degrees of interdependence will also enhance the joint benefit from a propagated innovation so that how much bigger the "pie" gets varies with how much interrelated and interdependent firms in a supply chain are. The interdependence dimension of fit implies higher complementarity, which makes the presence of each firm critical for the other to achieve its goals (Jemison & Sitkin, 1986; Ryu et al., 2009).

P3b: The higher the level of interdependence between two partners, the higher the success of PIP.

3.3.3 Incentive Alignment

Incentive alignment refers to "the degree to which chain members share costs, risks, and benefits" and match their motives (Togar M Simatupang & Sridharan, 2005). The existence of "matched" motives is the third integral dimension of strategic fit (Nielsen, 2010). Some researchers, and even executives, assume wrongly that firms naturally behave in a way that maximizes their benefit as well as that of their business partners. Taking the example of Cisco, which Narayanan and Raman (2004) argue is the "rule rather than an exception", the company had to scrap about 2.5 billion dollars worth of raw materials causing it to bear a loss of 2.69 billion dollars that quarter because its partners did not act in a way that was in its best interest or even that of the supply chain. Cisco had rewarded its contract manufacturers for delivering goods quickly, and those manufacturers could negotiate lower prices from component suppliers than Cisco could, making both, contractors and component makers, "have everything to gain and nothing to lose by building excess inventory" without worrying about Cisco's real needs (Narayanan & Raman, 2004).

Although on the surface incentives might seem to be naturally aligned and benefits shared, in real life conflicts happen, such as supplier divided loyalty. The more inventory or transportation costs incurred by one supply chain partner, the more savings it

can cause another. The greater a member's share in excess supply chain profits is, the less another would enjoy. Simatupang and Sridharan (2002) mention two ways of classifying causes of conflict among supply chain members. The first classification was proposed by Stern and Heskett (1969) as three types of causes: "differences between members' goals and objectives (goal conflict), disagreements over domain of decisions and actions (domain conflict), and differences in perceptions of reality used in joint decision making (perceptual conflict)" (Togar M. Simatupang & Sridharan, 2002). The second was proposed by Etgar (1979) as "attitudinal and structural causes of conflict" where "the former stems from differences in the ways chain members acquire and process information about their chain - such as roles, expectations, perceptions, and communications" and "the later reflects a clash of opposing interests such as goal divergence, drive for autonomy, and competition for scarce resources" (Togar M. Simatupang & Sridharan, 2002).

If usual supply chain relationships require a certain level of incentive alignment, propagation in which a company would be giving away its innovation would require even greater levels of incentive alignment. Narayanan and Raman (2004) suggest three ways for aligning incentives of supply chain members: rewriting contracts, revealing hidden information and developing trust.

Contracts should be designed to make sure that members of the supply chain will act, as much as possible, according to the benefit of the chain as a whole, not according to what would maximize individual firm's shareholders' value. Simatupang and Sridharan (2002) mention three ways of aligning incentives aimed to "to personalize or internalize responsibility for the attainment of desired overall profitability". Each of these can be the basis for designing supply chain contracts. The first incentive alignment method is based on productive behavior, i.e. behavior-based, where "the steps of observable actions that lead to a specific mutual objective, rather than the attainment of the objective itself" are rewarded (Simatupang & Sridharan, 2002). The second is performance based "which means setting performance metrics to evaluate supply chain members and rewarding them based on outcomes of the most important activities" (Simatupang & Sridharan, 2002).

The third is "equitable compensation" where "the participating parties jointly agree on a single set of performance measures and on a gain sharing formula universally perceived as equitable" (Simatupang & Sridharan, 2002). A successful business model that is based on this third incentive mechanism is what is known as the "revenue chain", where members of the supply chain share profits. These contracts prevail in the videocassette rental industry. Blockbuster gives its studios a share of the rental fees instead of paying a much higher up-front price on tapes. Blockbuster can now purchase many more tapes, meaning more potential rentals, which when combined with the drastically lower cost, leads to significantly higher profits; "for the movie studio, increased tape sales and the added revenue stream also result in more profit" (Cachon & Lariviere, 2001). Given how unrealistic it is to achieve a centralized control in a supply chain, even though it can be argued to be much more efficient, supply chain contracts achieve channel coordination for supply chains with decentralized decision making, through increasing the total profits, sharing risks among supply chain partners and allowing win-win conditions for all members (Cachon & Lariviere, 2001). To the extent to which behaviors, performances, and revenues are aligned with a partner, PIP will benefit the propagator.

In propagation, companies have to bear some costs. Costs of transferring knowledge and adapting and implementing a new technology can be substantial. There is also the risk for the innovating firm, of having its knowledge leak to one or more of its competitors; and the risk for the adopting firm of not succeeding in achieving gains from the innovation after implementing the change. Therefore, just like the general case of supply chain coordination, propagation requires aligning incentives through contracts to make sure costs, benefits and risks are fairly shared (see Figure I-1).

P3c: The higher the level of incentive alignment between two partners, the higher the success of PIP. According to P3a, P3b, and P3c:

P3d: Strategic fit between supply chain partners is positively related to PIP success

3.4 Innovation Selection for PIP

3.4.1 Vertical Transferability of Process Innovations

Innovation transferability, also referred to as transparency (Hamel, 1991), is defined as the ease with which an innovation can be transferred from one domain, or unit of adoption, to another (E. B. Grant & Gregory, 1997). An innovation is transferable to the extent to which it lacks both specificity, and tacitness. An innovation may lie anywhere along a continuum that ranges from non-transferability, e.g., of physical resources, to full transferability, e.g., of financial resources (Cerrato, 2009). The literature presents contradicting arguments on the effect of an innovation's transferability on its appropriability. On the one hand, transferability is paramount to intra-organizational transfers of knowledge among functional units, subsidiaries, and management levels (Hult, 2003), which helps smooth coordination and exchanges. On the other hand, transferability implies easy imitation by competition, undermining the innovation's ability to sustain competitive advantage for its owner, and driving more need for artificial protection (e.g., through legal mechanisms such as patents) (Barney, 1991; R. M. Grant, 1996).

Although *horizontal* transferability (to competitors) is undesirable for appropriation purposes, *vertical* transferability (to supply chain partners), which is challenging to achieve (Frenz & Ietto-Gillies, 2009), helps appropriation through PIP. It is, therefore, important to explore how vertical transferability can help appropriate returns from an innovation, without loss of competitive advantage. Accordingly, we will study, in isolation, the effect of each of the transferability elements, namely, innovation specificity, and tacitness, believing that each has a distinct effect on PIP success. For PIP to be successful, a company needs to effectively transfer an innovation vertically, while precluding horizontal diffusion.

We define innovation specificity as its boundedness to a particular domain of adoption (or primary adopter), and lack of applicability across multiple domains. Highly specific innovations would have little value beyond the boundary of their primary adopter (Grover & Malhotra, 2003). Innovation specificity retards transferability, and exists distinctively from tacitness (R. M. Grant, 1996; Helfat, 1994). Lower specificity, i.e., higher applicability, is desirable for an innovation to be successfully propagated to a supply chain firm, which employs different, though related, processes and operations compared to the propagator.

Some non-specific process innovations may be expanded in scope, as opposed to independently transferred, to include implementers from the supply chain, making these innovations systemic in nature. Systemic process innovations involve more than one firm in their implementation (Teece, 1986). Chesbrough and Teece (2002) make a distinction between these innovations and "autonomous innovations" which can be pursued independently. Companies have created systemic innovations whose full benefits can only be realized through the cooperation of other members of the chain. Vendor Managed Inventory, Vendor Financed Inventory and Dells' direct sale model, mandate the participation of more than one member of the supply chain. Therefore, a company that owns such a new idea would always consider propagation and would be much more inclined to propagate, if it chooses to implement it. On the other hand, benefits from an "autonomous innovations" can be reaped without interaction with other supply chain members.

P4a: The lower the specificity of the process innovation, the higher the PIP success

The impact of tacitness on the effectiveness of PIP in appropriating innovation returns is much less clear. Companies like to embed tacit knowledge in their organizational structure, culture, and people, making an innovation costly to imitate by competition. On the other hand, PIP is an inter-firm transfer process, which occurs faster and more effectively with explicit knowledge. Tacit knowledge can only be revealed through application, making its transfer costly, slow and uncertain (R. M. Grant, 1996).

We here contend that tacitness, despite impeding the transferability of an innovation, positively impacts the effectiveness of PIP, only if accompanied with the required quality and extent of supply chain interactions. Tacitness of an innovation provides a natural protection against competitors absorbing spilled over knowledge, confining returns from a propagated innovation within the propagating chain.

To ensure successful transfer of tacit innovation from the propagating firm to its partner, a high level of effective interactions must be employed. Effective interactions through arm's length relationship and continuous communication with the supply chain partner help overcome the complexity of knowledge transfer process caused by knowledge tacitness. Tacit innovations can only be observed through their application (R.

M. Grant, 1996). Accordingly, frequent supply chain interactions in which the propagator demonstrates the application of an innovation help the receiver understand and implement the change (Wang, Tai, & Wei, 2006). The receiver can only learn a highly tacit innovation by "doing" and "using", i.e., personal assimilation, which is only possible through co-location and co-presence (E. B. Grant & Gregory, 1997; Roberts, 2000).

In addition, tacit knowledge resides within individuals or "human containers" (E. B. Grant & Gregory, 1997; R. M. Grant, 1996). The association of tacit knowledge to human actors emphasizes the importance of effective interactions for achieving a successful exchange. Individuals are distinguished from other resources by their ability to learn, apply their knowledge in new domains, and make new resource combinations (Penrose, 1959). Interactions that are characterized by strong relational ties and high social capital are particularly effective in allowing human actors to learn and successfully implement innovations (Subramaniam & Youndt, 2005). This joint collaboration of individuals allows them to develop codes of communication and coordination that evolve into "dynamic routines" which are hard to imitate (Helfat, 1994).

An example is the Japanese *keiretsu*-style supply relations, which involve large cross-firm flows of tacit knowledge. Skills, habits, and values are blended, raising the speed and quality of the exchange (Lincoln & Ahmadjian, 2000). The embeddedness of the process in vertical relationships provides significant protection against (horizontal) imitation.

> ***P4b: The higher the tacitness of the process innovation, the higher its inimitability and PIP success. The effect of tacitness on PIP success is moderated by the amount and quality of interactions between the propagator and the receiver.***

3.4.2 Technical and Administrative Innovations

The distinction between technical and administrative process innovations has a number of significant implications on PIP. Technical process innovations pertain to the direct production process technology, and basic work activities, while administrative innovations involve organizational and managerial processes such as planning, controlling and coordinating functions, mainly residing in the organization's social system (Damanpour & Evan, 1984; Knight, 1967). Adoptions of the two types are

influenced by different sets of variables, which suggests considering this classification when constructing innovation related theories (Kimberly & Evanisko, 1981). According to the organizational lag model (Evan, 1966), a discrepancy exists within organizations between the rates of adoption of technical and administrative innovations (Damanpour & Evan, 1984). This "lag" may be explained by the general, possibly faulty, perception that technical innovations are relatively more advantageous than administrative innovations, with the latter being more complex (Damanpour & Evan, 1984).

Technical innovations tend to be propagated through supply chains based on expert power, and administrative ones based on market power. On the one hand, specialization of tasks coupled with deeper expertise motivates the development of technical innovations (Damanpour, 1987). Firms that are highly specialized possess technical knowledge that can be translated into relevant innovations, which will be propagated based on receiver's perception of propagator's expertise and superiority in the relevant area.

On the other hand, chain integrators, which enjoy market power advantage, focus more on administrative innovations for coordinating the chain. These firms are "low professional districts, which have tighter coupling and a dominant administrative core" (Daft, 1978). Integrators are better off initiating administrative innovations since they come from the relevant (coordination and management) task domain (Zmud, 1982). Placing a primary focus on administrative innovations, integrators perceive more direct and pronounced benefit from propagating administrative innovations compared to technical ones (D. Kim, Cavusgil, & Calantone, 2006). These innovations are difficult if not impossible to protect by patent, making PIP a sound appropriation mechanism (Teece, 1980). Examples include JIT and TQM, which have been initiated by chain integrators and propagated for an overall chain performance (J. Cooper, 1998). Companies are further motivated to propagate these innovations, as they observe a substantial administrative inertia suffered by smaller sized companies, signaling a potential for supply chain improvement.

Furthermore, administrative innovations prosper within a formal, centralized, mechanistic environment, which tends to be the one for larger powerful firms, while technical innovations appear more in de-centralized, organic environments, which mostly

characterize smaller firms with lower market power (J. Cooper, 1998). Formal exercise, enabled by propagator's market power advantage, provides the mechanistic governance structure which helps reinforce receiver's implementation of administrative innovations (Damanpour, 1991).

The orientation of a chain's integrator towards administrative innovations may prevent a required balance of the two innovation types. Based on Evan's theory (1966) and Daft's (1978) refinement on technical innovations trickling down an organizational hierarchy and technical ones trickling up, we similarly expect administrative innovations to be propagated upstream (from more powerful buyers) and technical innovations to be propagated downstream (from knowledgeable and specialized suppliers). Given that administrative innovations often affect the technical core, innovators that are active in propagating administrative innovations may trigger technical innovations upstream a chain, rippling the effect both ways. More specifically, integrators with a network orientation focusing on the overall performance of the chain would propagate managerial systems enabling the development and propagation of technical innovations elsewhere along the chain (Figure I-2). This builds on the dual core model's assertion that adoption of administrative innovations tends to trigger the adoption of subsequent technical innovations more readily than the reverse (Daft, 1978). Propagating administrative innovations upstream may motivate smaller suppliers to innovate more in technical areas where they specialize. This can maximize the ripple effect by having each of the two types of innovations originate at both ends of the chain and propagate accordingly, especially given the synergetic interaction and total effect on performance (Han, Namwoon, & Srivastava, 1998).

P4c: Technical innovations are propagated downstream through expert power, and administrative innovations are propagated upstream through market power.

P4d: Maintaining a balance between propagating technical and administrative innovations leads to a superior supply chain performance

3.5 PIP and Governance Structure

3.5.1 Governance Formality

Supply chain governance is the mechanism through which a buyer-supplier interaction is coordinated. There are generally two types of governance: formal

(contractual) governance and informal (relational) governance. Formal contracts are used to specify parties' promises, obligations, actions, or even resolution process in cases of dispute (Poppo & Zenger, 2002). They hold each of the parties involved legally responsible for carrying out the terms specified. Alternatively, governance can emerge naturally from the values and casually agreed-upon processes found in social relationships (Poppo & Zenger, 2002).

An argument exists in the literature as to whether the two governance mechanisms are substitutes or complements (Liu, Luo, & Liu, 2009; Wuyts & Geyskens, 2005). Since this debate is beyond the scope of this paper, we will adopt a moderate view that allows both to co-exist in a dyadic relationship and assumes that each transaction is dominated by one or the other. Accordingly, governance formality is the extent to which a buyer-supplier PIP interaction is dominated by formal contracts as opposed to informal arrangements (Stock, Greis, & Kasarda, 2000).

The effectiveness of governance formality in PIP success depends on the radicalness of the innovation, as well as the type of power driving the process (Figure I-3). Formal governance is effective when propagating incremental innovations. Incremental innovations require a structured approach and clear roadmap for explicating the exact process and structure to follow (Ettlie, Bridges, & O'Keefe, 1984). In this case, formal contracts act as a more efficient coordination mechanism that provides clearly specified guidelines and detailed procedures associated with incremental innovations (Lumineau & Henderson, 2012). Incremental innovations involve a low degree of uncertainty to which formal governance mechanisms have proved more effective (Wathne & Heide, 2004). Moreover, incremental innovations primarily depend on organizational knowledge and traditional structural arrangements (Ettlie et al., 1984). Accordingly, contracts can better explicate terms regarding this type of knowledge, which is associated with documentation, procedures and well-established systems. Formal contracts are particularly effective at handling "organizational role responsibilities" (Handfield & Bechtel, 2002).

The situation is, however, reversed in the case of radical innovations. Radical innovations require flexibility, which is absent in formal governance structures, but readily allowed in relational governance (Boyle, Dwyer, Robicheaux, & Simpson, 1992;

Noordewier, John, & Nevin, 1990). They entail a substantial level of environmental, technological, and outcome uncertainty, with which formal governance fails (Germain, 1996; Leifer, O'Connor, & Rice, 2001; Sorescu, Chandy, & Prabhu, 2003). Dyadic relationships characterized by uncertain conditions require the employment of governance structures that allow for flexible adaptation to changing circumstances (Wathne & Heide, 2004). These changing circumstances necessitate responsiveness, which is readily enabled by relational governance as it is easily modified and adapted (Hoyt & Huq, 2000; Poppo & Zenger, 2002).

Radical innovations primarily depend on the human factor (human knowledge) (Subramaniam & Youndt, 2005). Projects involving heavy human interactions are better coordinated by relational governance as it provides the flexibility, participation and solidarity required in human interactions (Lumineau & Henderson, 2012). Radical innovations may require more adjustments when propagated to a different company. Adjustments require more human capital input, i.e., interaction, less specification in contracts, and therefore, more reliance on relational governance. Formal contracts will tend to limit the amount of knowledge that people contribute as they will tend to provide the minimum specified by the contract as opposed to invest more had the governance been informal, as reliance on contracts can "discourage either party to move beyond contracts" (Handfield & Bechtel, 2002). We, therefore, assert that:

P5a: Formal governance is more effective compared to informal when propagating incremental process innovations

P5b: Informal governance is more effective compared to formal when propagating radical process innovations

As discussed in section 3.1, innovations are propagated based on either market or expert power. Innovations propagated based on expertise depend more on the human factor, and involve a high degree of uncertainty, technicality, and adaptation, which is best dealt with through flexible governance structures (i.e., relational). To successfully transfer human knowledge, these changes would require more joint involvement by members, which is more effective on relational bases, where individuals get to frequently interact, discuss, and coordinate efforts, adapting changes to the adopting unit. On the other hand, innovations propagated based on market power involve higher degree of coercion (e.g., threat of punishment to withhold business from non complying partners),

which encompasses formal exercise. When the propagator chooses to take advantage of market power, it resorts to contracts to fully specify terms of compliance and consequences of non-compliance, relying more on contractual means for getting the partner to conform.

P5c: Relational governance is more effective than formal governance for PIP driven by expert power

P5d: Formal governance is more effective than relational governance for PIP driven by market power

3.5.2 Management Attitude

Management innovation attitude refers to the extent to which managers favor change, are open to novel experiences and stimuli, and readily recognize the potential in new ideas (Damanpour, 1991; Pennings & Smidts, 2000). Management attitude has been established as a main determinant of innovation adoption and success, specifically process innovations (Zmud, 1982), and a function of management team's ages, diversity, educational backgrounds, and risk aversion (Bantel & Jackson, 1989; Gupta, Raj, & Wilemon, 1986). This human component of organizations determines independent innovation strategies and adoption decisions (Pierce & Delbecq, 1977; Rosenbloom & Abernathy, 1982). Employees with attitude favoring innovation adoption will implement innovations merely by being offered the knowledge, while those with attitudes resisting change require a directive from a powerful source before adopting (Leonard-Barton & Deschamps, 1988). These arguments have significant implications for propagations based on expert and market power.

In cases of propagation based on expert power, managers with positive attitudes toward change will value the knowledge offered from a propagator and will tend to readily accept new ideas (Zhou, Gao, Yang, & Zhou, 2005). Propagation in this case is based on the perception of the superior knowledge abilities of the innovation owner, and orientation to keep up with a higher innovative performance. A strong orientation to change coupled with managerial support is particularly important during instances of knowledge exchanges involving high degree of human interaction for effective coordination and conflict resolution among individuals (Damanpour, 1991).

In the case of propagation based on market power, however, managers are driven to acceptance based on willingness to maintain business with a highly powerful player, as

opposed to a self-motivated approach to preserve an innovative stance. In this case, regardless of the managerial attitude, managers will accept the innovation coming from a powerful partner. Supply chain market power corresponds to centralization of control, in a single organizational setting, in moderating the relation between managerial attitude and adoption. This centralization of power, equivalently control, "accelerates" the positive impact of managerial attitude on process innovation adoption (Dewar & Dutton, 1986).

P5e: Managerial attitude of the receiving firm affects the effectiveness of PIP driven by expert power more than that driven by market power

Table I-2 illustrates elements of PIP through an example of McDonald's corporation.

4. CONCLUSION

This paper introduces the concept of Process Innovation Propagation (PIP) as a power-based appropriation mechanism that departs from conventional strategies of innovation appropriation. PIP is defined as collecting returns from process innovations through passing them over to supply chain partners. The transfer process is based on two sources of power: market and expert, and is novel in: (1) suggesting external appropriation through using other firms as opposed to solely depending on internal capabilities; (2) challenging the preclusive component of generative appropriability; and, (3) indirectly collecting innovation rents through operational benefits and market image. Acknowledging its significant potential as a profit-enhancing mechanism, PIP is distinguished as a new construct, and propositions regarding its elements and antecedents are developed based on a thorough analysis and synthesis of the literature.

Appropriation through PIP is particularly important given the rising acknowledgement of supply chains as the new units of competition, failure of traditional formal appropriation mechanisms with process innovations, the increasing trend towards dis-integrated structures of supply chains, and reliance on supply chain partners in strategic endeavors including innovation. PIP is an appropriation mechanism that highly enhances profitability of firms through collecting rents on costly and valuable innovations and ideas. This is accomplished by capitalizing on the potential of supply

chain partners as units of adoption that can re-apply existing process innovations. The propagator incentivizes new units of adoption through its power advantage(s), and gains an improved operational performance of the supply chain and/ or enhanced market image.

We develop propositions based on a thorough review, analysis and synthesis of the literature regarding elements of propagation, namely, partner selection, innovation selection, and governance structure that maximize appropriation through PIP. We assert that the highest potential arises from partners that employ a strategic fit with the propagating company (innovation owner). This departs from conventional literature on supplier selection based on its innovation properties, to selection based on potential from joint work and sharing of innovations. Partners must be selected based on similarities of their strategic priorities with the focal firm, total interdependence and incentive alignment.

Properties of an innovation also have direct implications on selecting the right process change to propagate. Innovations characterized by high degree of transferability might not necessarily be effective in appropriating returns through PIP. Companies should pay more attention to specific elements of transferability, namely specificity and tacitness, realizing that although both contribute similarly to transferability, we argue that tacitness helps PIP appropriation while specificity hurts it. Moreover, the theory presented herein explains the observed bias toward propagating administrative innovations over technical ones, in attempt to promote a balance of both types for a superior supply chain performance. Integrators must therefore pay more attention to the diffusion of technical innovations from smaller, more knowledgeable suppliers, possibly by propagating the right administrative (managerial) innovations that can put a technical innovation process in place.

Finally, we also address the proper governance elements for effective PIP depending on the radicalness of innovation as well as the driving power source. More specifically, we argue that the higher the radicalness of the innovation, the higher the effectiveness of relational governance over formal one. This also implies that more radical innovations employing a high degree of knowledge, i.e., expert driven, are better

governed informally, while incremental innovations with less uncertainty can be formally governed.

This research can be extended along several dimensions. Firstly, a theory could be constructed for propagating product innovations. Product innovations require a different treatment in a supply chain context where the innovator will demand newly innovated component parts or downstream manufactured goods for its product innovation. The theory could also be explored from the perspective of the receiving company, i.e. investigating the factors that affect acceptance of a propagation request from one's supply chain member. Moreover, several external and contextual factors can be studied, given that knowledge transfer is greatly affected by such factors as the business environment, product market conditions, cultural issues and organizational distance. The (quite common) case of symmetric power in propagation can also be examined. Studies can examine how propagation can occur in balanced power relationships. Finally, both theory expansion to a network level of analysis (considering a triad or more of exchanges) and contraction to a fully integrated supply chain (intra-organizational flows) are fruitful for further research.

5. TABLES

Table I-1

Distinguishing PIP from Other constructs

Criterion	PIP	Supplier Development	Innovation Diffusion	Joint R&D[3]
Definition	Appropriating returns from process innovations through passing them over to supply chain partners.	Any activity initiated by a buying organization to improve the performance of its suppliers	Adoption of an innovation that is out there by individuals in the relevant population	Collaboration between two or more firms, horizontal or vertical, to develop an innovation that has not existed before
Directionality	Giver (owner) and taker (receiver) Giver is defined as the first firm to adopt an innovation in the chain, may or may not have developed it	Giver and taker Giver is defined as the resource owner	Only receiver to an existing innovation	Non-directional: no source or destination, but a collaborative, joint work
Main driver	Giver's power: persuades successful transfer and adoption	Taker's power (giver's dependence on taker): persuades giver's investments; otherwise supplier may be replaced	Environmental change including pace of technological change and strength of competition	Complementarity of knowledge, mutual dependence, high development costs and risks
Motivation	Desire to improve supply chain performance	Desire to improve supplier's performance	Desire to improve own performance	Desire to spread costs and risks of the innovation development
Initiation/ initial development of innovation	At the supply chain giver (innovation owner)	At the supply chain receiver; change specific to supplier, more than likely developed there	Could be anywhere outside the chain, market, or industry	Joint initiation by two firms (in a chain in the case of vertical R&D)
Management Attitude	Not necessarily needed as the process may be driven by market power	Not relevant as innovation may be in solution to problem	Required: management must place emphasis on innovation	Required: management must place emphasis on innovation
Approach	Proactive by giver	Mostly reactive, in response to supplier problems	Proactive by Receiver	Proactive by both firms
Activity	Expanding the scope of an innovation across the supply chain	Includes initiatives such as evaluation/ auditing/ problem solving	Customizing an innovation that may be out of the whole industry	Creating a new innovation, usually new to the world
Intellectual Property	Not important as the process is based on sharing	Not relevant as IP may not be involved	IP preserved to innovation's first developer	IP is shared among developers
Aim	Appropriating value from an innovation	Improving performance of a (usually mis-performing) supplier	Keep up to environmental changes	Creating an innovation

[3] Note that joint R&D includes supplier integration/ involvement in new product development (NPD) as the former encompasses any active participation in innovation development, while not necessarily implying that both partners derive immediate commercial benefits from the venture (Tether, 2002). This process is also referred to as co-development, co-creation, and innovation cooperation (Fliess & Becker, 2006)

Table I-2

An Illustration of PIP Elements: The Case of McDonald's[4]

PIP Element	PIP Element	Illustration	Biodiesel Process Innovation
Drive	**Expert-Power Driven**	Suppliers provide ideas on technical issues such as the baking process for sandwich buns based on their expertise	McDonald's receives the Biodiesel innovation persuaded by the expert power of Neutral Group in the oil conversion process. It them propagated the innovation to its supplier (upstream), e.g. Del Monte Foods, helped by its size and market power.
	Market-Power Driven	McDonald's propagates new process ideas based on its size and market power to make sure there is a consistency of taste, quality and process nationally and internationally. Different suppliers accept in attempt to keep business with McDonald's.	
Appropriation	**Operational Benefits**	McDonald's perceives a win-win situation from propagation. Suppliers enjoy operational benefits from innovations such as green building design that reduces power consumption. Savings that flow to suppliers' bottom line allow McDonald's to negotiate price reductions.	Used cooking oil has now an extra value as an input to the conversion process. The more conversion, the more value for McDonald's scrap oil.
	Enhanced Reputation	McDonald's has been very successful in promoting and establishing a green image for both operating on green standards and dealing with green suppliers.	Biodiesel translates into less oil scrapped, as well as 80% reduction in carbon dioxide emission ("McDonald's UAE Gives Cooking Oil 2nd Life as Biodiesel," 2013), giving McDonald's a responsible and sustainable image that increases with every supplier using the process.
Partner strategic fit	**Strategic Similarity**	McDonald's propagates to suppliers with years of partnerships, some exceeding 50 years. The company shares with these suppliers the same values, plans, objectives, and visions. Companies even share planning meeting and perform together their quarter reviews.	Del Monte Foods is a McDonald's "long-time partner and supplier" for years ("McDonald's UAE Gives Cooking Oil 2nd Life as Biodiesel," 2013). In addition to a vast amount of business between the two companies, they also share similar sustainable strategies, with McDonald's well-established "Global Best Practices" in Sustainable Supply and Green Initiatives ("Best Practices: About McDonalds.com," 2014), and Del Monte's formalized sustainable goals ("Del Monte Foods formalizes environmental sustainability goals," 2010).
	Interdependence	Innovation partners share a high degree of interdependence with McDonald's which spends more than $30 billion dollars on its supply chain, 80 % of which are with 16 multinational partners, making interdependence very strong.	
	Incentive Alignment	Although McDonald's suppliers deal with competition, the company works on being the preferred partner to those with whom ideas are shared, to ensure that incentives are aligned.	

[4] The information in this table was compiled based on interviews with Rob Dick, Senior Director, National Supply Chain at McDonald's Restaurants of Canada Limited; and Ala Mohammad, Senior Director Supply Chain & Quality Systems Management at McDonald's Asia Pacific Middle East & Africa.

Table I-2 (continued)

An Illustration of PIP Elements: The Case of McDonald's

Innovation Properties	**Vertical transferability**	McDonald's depends on vertical transferability to roll out ideas to different suppliers and standardize processes. These include green building design, green trucks, loading/ unloading dock design, which are all readily implementable across different businesses.	Being a transportation innovation, the Biodiesel employs a great deal of transferability, facilitating its propagation.
	Technicality of Innovation	McDonald's propagates management innovations such as teaching suppliers succession plans, how to build lead managers, innovation management process (e.g. how to conduct ideation sessions) Technical ideas originate from suppliers who have the expertise on issues such as: baking process, packaging, food storage, … etc.	Biodiesel relates to a support activity of transportation, as opposed to being part of the core production process. It was therefore, propagated successfully upstream to McDonald's suppliers.
Governance structure	**Formality**	Most changes require a substantial degree of adaptation, and therefore little documentation is used, making innovation interaction more informal. Suppliers do expect to keep secrets and confidentiality based on McDonald's market power, and willingness for repeated business.	Seeing Biodiesel as a "groundbreaking initiative" ("McDonald's UAE Gives Cooking Oil 2nd Life as Biodiesel," 2013), McDonald's has collaborated with Del Monte Foods in a very friendly, relational manner, taking the process transformation gradually and relying on encouragement and convincing in contrast to detailed contracts.
	Managerial attitude	McDonald's maintains innovation transactions with suppliers of innovative attitude	McDonald's propagated the Biodiesel innovation to Del Monte, which is a food industry leader in innovative processing, distribution, and marketing practices ("Del Monte Foods Turns to Dog Owners to Unleash Innovation," 2008).

6. FIGURES

Figure I-1

The Effect of Partner Selection on PIP Success

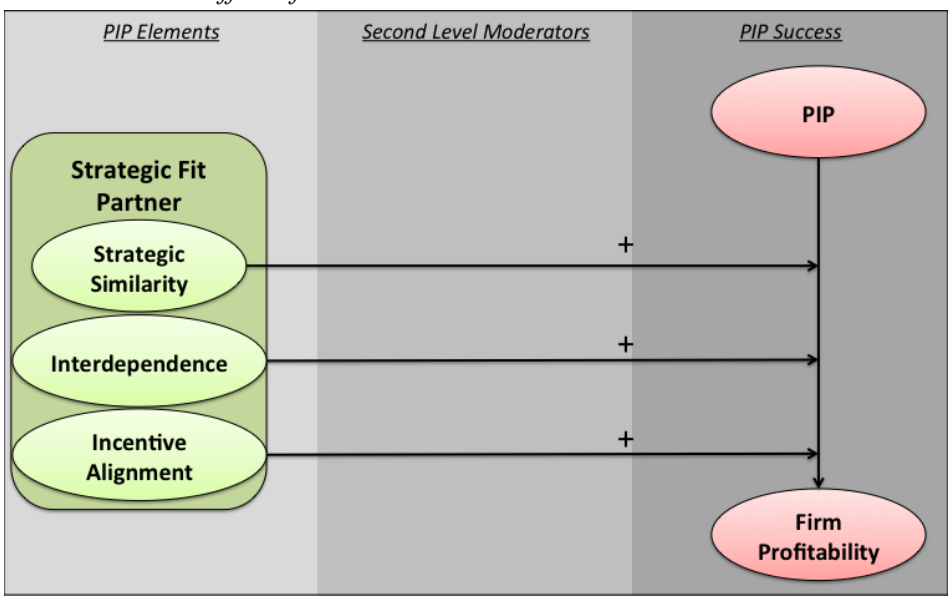


Figure I-2

The Effect of Innovation Selection on PIP Success

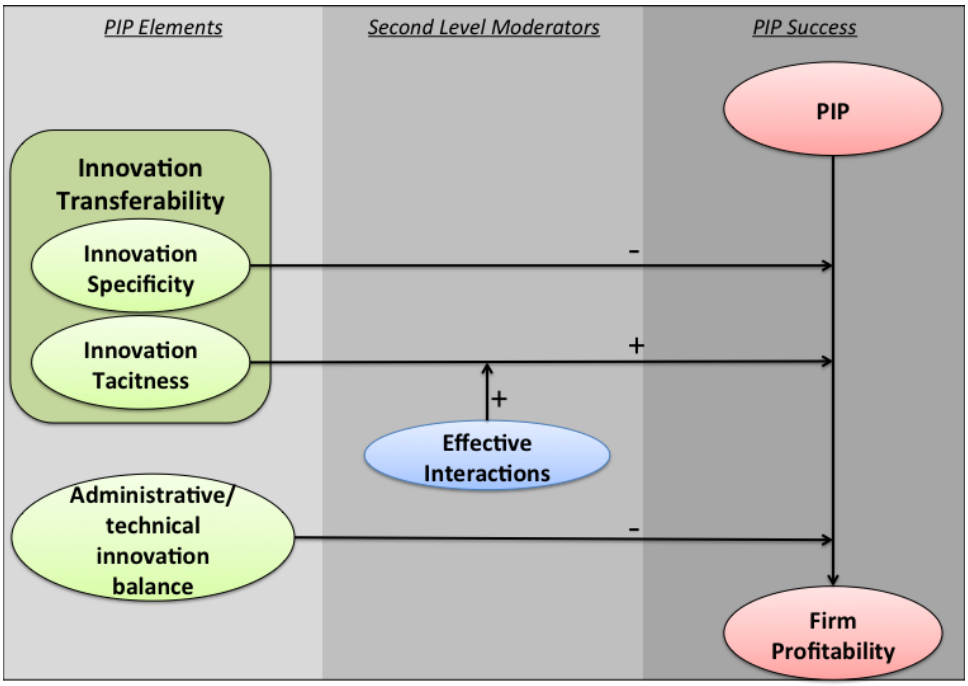
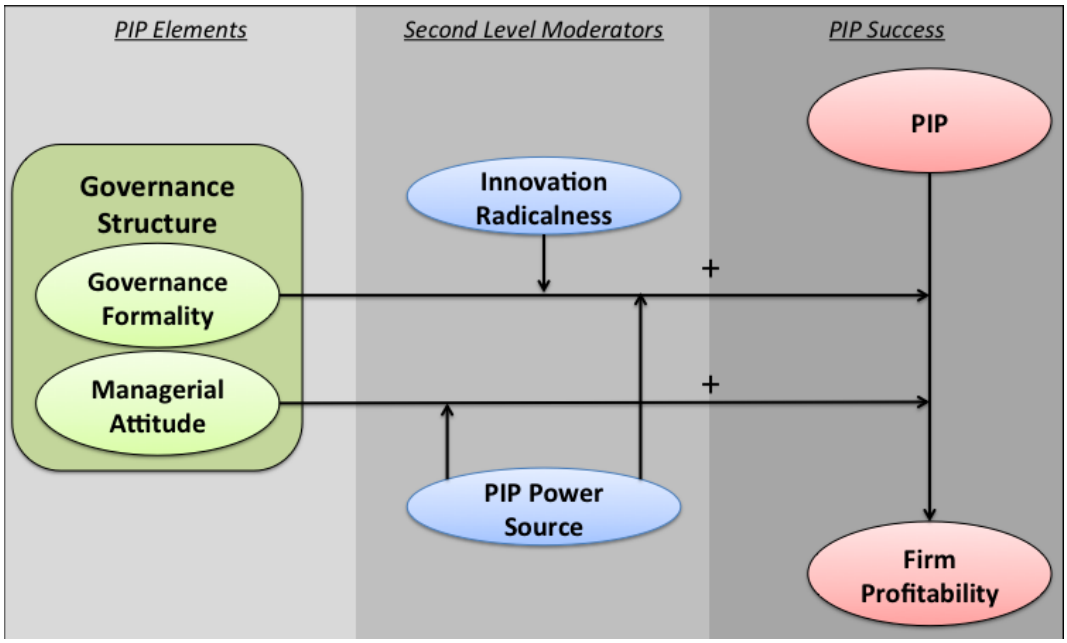


Figure I-3

The effect of Governance Structure on PIP Success



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CHAPTER II. Characterizing Intellectual Capital Properties that Drive Innovativeness of Supply Chains With Power Differences

ABSTRACT

How can supply chain firms' knowledge be combined to maximize their abilities to produce radical and incremental innovations? This paper attempts to answer this question by formulating properties of knowledge that are most relevant to radical and incremental innovative capabilities. We use an intellectual capital lens, classifying knowledge into human, organizational, and social, to create hierarchical component models that portray characteristics of each knowledge type on the level of a supply chain dyad. Hypotheses are developed and tested using a survey, which is administered to a population of supply chain managers in Canada. The paper provides several significant insights, advising managers regarding partner selection, team composition, and governance mechanisms. It also contributes by presenting novel ways for data collection, and a two-stage analysis technique using PLS.

1. INTRODUCTION

After establishing the knowledge-innovation link within firms (Cassiman & Veugelers, 2006; Peri, 2005), researchers have gone a step further to explore types of knowledge that have particular relevance to each type of innovative capabilities. Subramaniam and Youndt (2005) establish the associations between human capital and radical innovative capability; and between organizational capital and incremental innovative capability. Nevertheless, with a vastly growing recognition of buyer-supplier interaction as a necessity for innovation generation (Roy, Sivakumar, & Wilkinson, 2004), the extension of firm-level knowledge-innovation theories to the supply chain level of analysis still lags behind (Hult, Ketchen, Cavusgil, & Calantone, 2006). Accordingly, we present and empirically test a knowledge-innovation theory for the supply chain, taking into consideration the most pronounced governor of the exchange relationship, that is, buyer-supplier power differences.

Little is known about the *intangible* success factors of supply chain innovation, such as knowledge resources (Craighead, Hult, & Ketchen, 2009; Hult et al., 2006). Witnessing below-expected outcomes from joint innovation projects, companies strive for a sustainable solution to the problem by taking a capability-building perspective and cultivating joint innovative capabilities with supply chain partners. It, therefore, becomes imperative to determine firms' knowledge properties that lead to more effective supply chain innovative capabilities, both radical and incremental. By presenting and testing hypotheses regarding chains' knowledge properties and innovative capabilities, we attempt to fill the scarcity in the literature on this important subject, as well as answer calls about using the supply chain as the new unit of analysis (Capaldo, 2007; Christopher & Ryals, 1999; Harvey, 2000; Sharifi, Ismail, & Reid, 2006; Straub, Rai, & Klein, 2004), and the actual level where resources and capabilities reside (Barney & Mackey, 2005; Gulati, 1999; Ketchen & Hult, 2007).

Intellectual capital encompasses knowledge that is valuable and useful for a firm[5] (Edvinsson & Sullivan, 1996). In a supply chain context, it has been defined as "credible information and/or experience, held by individuals and/or residing in the infrastructure of

[5] Based on this definition, and as is custom in the literature, knowledge and intellectual capital terms will be used interchangeably (Bontis, 1998, 1999; Nahapiet & Ghoshal, 1998; Stewart & Ruckdeschel, 1998).

the firm, which can be converted into supply chain value" (Craighead et al., 2009). In pursuing our objectives, we follow Subramaniam and Youndt's (2005) intellectual capital lens, building on the prominent taxonomy that classifies intellectual capital into human, organizational, and social to devise our hypotheses.

This study aims to characterize properties of each intellectual capital element required by supply chain firms to achieve high radical and incremental innovative capabilities. We introduce three characterizations for intellectual capital elements, namely: dominant organizational capital, human capital related diversity and social capital valuation, as properties that affect supply chain innovative capabilities. The former two are argued to direct incremental and radical innovative capabilities in supply chains, respectively. Building on the reciprocity rule borrowed from the social exchange theory (Blau, 1964), we further argue that social capital valuation drives both capabilities in supply chains.

Being a focal element of interdependent supply chain relationships (Dapiran & Hogarath-Scott, 2003), inter-firm power complicates the effect of human and organizational capital elements on innovative capabilities. The pronounced effect of power exercise has ranged from driving suppliers to invest billions of dollars in innovations (Schrage, 2002) to drive supplier bankruptcy from failure to comply with innovation directives (Brown, Gabrielsen, & Pope, 2003; Turnbull, Oliver, & Wilkinson, 1992). This highlights a huge disparity in the innovation outcomes from exercising power with partners.

Driven by its Extended Enterprise, Chrysler has achieved considerable success through its Supplier Cost Reduction Effort (SCORE) program to drive mutually beneficial cost reduction and product improvements (Maloni & Benton, 2000). On the other hand, Wal-Mart threatens its suppliers to pull its orders from them if they do not meet its standards (Aston, 2009). It remains unclear why the two opposing strategies have worked successfully in these two cases. Nevertheless, GM exploits its power against its suppliers similar to Wal-Mart, dictating nonnegotiable cost reductions to suppliers (Maloni & Benton, 2000). Yet, many argue that the benefits were overshadowed by supplier resentment and a lack of synergistic improvement (Maloni & Benton, 2000), questioning success of the movement.

Accordingly, two seemingly contradictory hypotheses are examined: (1) power exercise helps because it drives propagation of existing technologies through the supply chain and, (2) power exercise hurts because it suppresses the creative abilities of less powerful chain members. We administer a survey to a population of purchasing managers in Canada using multiple novel data collection techniques, and test our model using PLS, which is the recommended approach for formative hierarchical component models.

This chapter is arranged as follows. The next section will review the relevant literature highlighting gaps, which this chapter attempts to fill. In section 3 hypotheses are developed and the proposed model is presented. Section 4 will explain the survey methodology used including population, sample and instruments used. Sections 5 and 6 offer the results and their discussion, respectively, followed by conclusions in section 7. Finally limitations and future research directions are given in sections 8 and 9, respectively.

2. LITERATURE REVIEW

2.1 Intellectual Capital and Innovative Capabilities

2.1.1 Intra-firm Intellectual Capital

After Sveiby's work on "Knowledge-based" assets ("The Know-how company", 1986, "The New Annual Report", 1988, and "The Invisible Balance Sheet", 1989), Tom Stewart initiated the term Intellectual Capital as the real "New Wealth of Organizations" (Stewart, 1991; Sveiby, 1997). Intellectual Capital (IC) is a highly strategic, intangible asset that companies increasingly create and nurture. It has been defined in several ways throughout the literature, notably as "knowledge that can be converted into value" (Edvinsson & Sullivan, 1996), "the sum of all knowledge firms utilize for competitive advantage" (Subramaniam & Youndt, 2005), and, "the sum total of the useful knowledge of an organization's employees and customers" (*The human resources glossary : the complete desk reference for HR executives, managers and practitioners*, 1998). Financially, it is sometimes regarded as the difference between book value and market value ("A Viking with a Compass," 1998).

IC is, in fact, a major source of competitive advantage and a distinguishing feature among firms (Nahapiet & Ghoshal, 1998). Ulrich (1998) gives six reasons for the

criticality of firms' IC; most importantly, being a firm's only appreciable asset that is receiving a mis-focused treatment from managers and is sometimes even ignored. IC is rapidly becoming a very important measure of the company's future performance (Roos & Roos, 1997). It is more strategic in firms and industries for which innovation is particularly important.

One common view classifies IC into: Human Capital (HC), Organizational Capital (OC), also referred to as structural capital, and Social Capital (SC), also referred to as relational capital. HC constitutes individuals' abilities, skills and other knowledge, which they can utilize in attaining the firm's objectives (Schultz, 1961). OC is defined as knowledge owned by organizations residing within its documents, structures and systems, independent from individuals (Albino, Garavelli, & Schiuma, 1998; Youndt, Subramaniam, & Snell, 2004). Lastly, SC is the goodwill that is engendered in the structure and content of relations among individuals, including trust, cooperative norms, and associations within groups (Adler & Kwon, 2002; Knack & Keefer, 1997).

This classification is particularly significant within the context of innovation as each of the three types differently affects radical and incremental innovative capabilities in organizations. The former capability is defined as the firm's ability to develop changes that can be considered as fundamental and revolutionary (Dewar & Dutton, 1986), while the latter represents a firm's ability to produce simple improvements and adjustments to current products or processes (Dewar & Dutton, 1986).

A link has been established in the literature on the particular (positive) association between HC and radical innovative capabilities, and between OC and incremental innovative capabilities in firms (Subramaniam & Youndt, 2005). Firms institutionalize their knowledge in the form of OC to be extended, deepened and strengthened, for example by making improvements and developing related patents (Martin & Mitchell, 1998; Stuart & Podolny, 1996; Subramaniam & Youndt, 2005). On the other hand, creativity, brightness and the ability to question prevailing norms come from employees' constituting a company's HC (Snell & Dean Jr, 1992; Subramaniam & Youndt, 2005; Tushman & Anderson, 1986). Relational capital, however, has been found to facilitate the two aforementioned links by providing relationships and networks that improve the

leverage of codified knowledge, encourage more sharing of knowledge, and enable more acceptance for radical changes (Subramaniam & Youndt, 2005).

2.1.2 Inter-firm Intellectual Capital

Contending that supply chains are the new units of competition (Capaldo, 2007; Christopher & Ryals, 1999; Harvey, 2000; Ketchen & Hult, 2007; Sharifi et al., 2006; Straub et al., 2004), it becomes imperative to consider the effective combination of IC elements of supply chain teams. Buyers and suppliers that individually possess human, organizational and social capital may not witness the expected success when collaborating on joint innovation projects (Devaraj, Krajewski, & Wei, 2007). This implies that it is not the mere existence of knowledge that can make inter-firm teams more effective, but it is the properties of the teams' knowledge that drive innovation outcomes. Outcomes falling below expectations may be attributed to knowledge properties, such as overlap and redundancy, conflicting cultures and norms or from an undesirable level of differences in knowledge stocks. Accordingly, we need to investigate properties of knowledge that allow buyers and suppliers to innovate effectively.

On the one hand, access to valuable complementary knowledge is one of the most cited incentives for companies to work jointly. The fact that synergies arise from complementarity in resources is well grounded in the Economic Theory of Complementarities (Milgrom & Roberts, 1995). Knowledge complementarity is "that which occurs when two firms have non-overlapping or different knowledge bases that might be combined and integrated to create value that did not exist in either firm before" (Fang, 2011). Similarly, complementary IC is "related but not the same" and is highly synergetic (Tanriverdi & Venkatraman, 2005). The importance of complementarity of resources (including IC) for synergy creation is highly recognized in literature streams on acquisitions and alliances (Harrison, Hitt, Hoskisson, & Ireland, 2001). An underlying notion is that of super-modularity in which the "whole is more than the sum of its parts" (Milgrom & Roberts, 1995). This literature stream argues that lack of complementarity implies knowledge overlap and redundancy (Fang, 2011).

An opposing argument, however, calls for knowledge overlap as a requirement for effective communication and exchange of knowledge (Cohen & Levinthal, 1990). Firms with similar knowledge bases find it cognitively easier to absorb and utilize each

other's knowledge (Cohen & Levinthal, 1990). Complementarity makes it even more challenging to combine and integrate knowledge sets (Harrison et al., 2001). In some cases, complementarity could even motivate partners to create barriers preventing their knowledge from being transferred and hindering innovation (Larsson, Bengtsson, Henriksson, & Sparks, 1998). Empirically, technological overlap is found to be a significant criterion in alliance partner selection decision (Mowery, Oxley, & Silverman, 1998). Knowledge relatedness among firms is argued to be positively associated with knowledge acquisition and transfer (Inkpen, 2000; Lane & Lubatkin, 1998; Von-Hippel, 1994).

In this paper, we argue that distinguishing between organizational and human knowledge helps resolve the opposing streams on similarity/ complementarity of knowledge. More specifically, similarity of OC is key to provide a homogenous, dominant pool of knowledge to build on for incremental innovations. However, in the case of HC, breadth and diversity of knowledge is required to reach out for radical innovations, in which case complementarity is needed.

2.1.3 Reciprocity and Social Capital Valuation

Within a firm, social capital facilitates the translation of each of organizational and human capital into innovative capabilities (Subramaniam & Youndt, 2005). This, however, may not be attainable across firms' boundaries, namely in buyer supplier innovation endeavors. Firms may resist being carried away by the relational ties, fearing opportunistic partners who may exploit "good partners" through skill acquisition (Hamel, 1991), excessive spillovers to competition (J. Dyer, Cho, & Chu, 1998), and even by becoming direct competitors (Arruñada & Vázquez, 2006). These actions present a major threat of losing competitive advantage as soon as knowledge crosses a firm's own boundaries. This risk is known as the "relational risk", defined as the probability that the partner does not comply with the spirit of cooperation and acts opportunistically in misusing the acquired knowledge (Das & Teng, 1998).

The social resolution to this "boundary paradox" (Quintas, Lefrere, & Jones, 1997) is addressed by the Social Exchange Theory's most common exchange rule, reciprocity. Firms may readily provide knowledge and act in kind for the immediate benefit of a partner, only in expectation to be reciprocated fairly (Molm, 1994).

Reciprocation is a direct consequence of high valuation of social capital, as companies place more emphasis on the mutual valuation of the relationship than risks of losing competitive knowledge.

Reciprocity, also known as Norms of Reciprocity, depends on two interrelated minimal rules: (1) individuals should assist those who have assisted them; and (2) individuals should not injure/deprive those who have assisted them (Gouldner, 1960). In our context, this means that a good act of being open in sharing competitive knowledge is met by (1) partner's openness in knowledge sharing; and, (2) partner refraining from knowledge abuse by intended spillover to competition. "Reciprocal exchange" is a process of "gift-giving" (Molm, 2003). Reciprocation is the only way for ready knowledge sharing and is only allowed because of social capital valuation. Accordingly, even though the interdependence reduces risk and encourages cooperation (Molm, 1994), great uncertainties that surround outcomes of knowledge exchanges are only addressed by social capital valuation based on norms of reciprocity (Cook & Rice, 2006).

To sum up, reciprocity norms suggest that companies do not act solely on the basis of traditional economic factors, but they may in fact place economic valuation on social factors including repeated exchanges, future obligations and the belief that each party will fulfill its obligations (Zhao, Huo, Flynn, & Yeung, 2008). In this paper, we develop this claim to investigate the effect of social capital valuation on a supply chain's innovative capabilities.

2.2. Inter-firm Power

2.2.1 Background on Inter-firm Power

Power existence is defined as a potential influence, or the capacity to affect actions of another unit (Emerson, 1962; Fidler & Johnson, 1984). Supply Chain power is, therefore, the ability of a partner to induce another to do what it would otherwise not do (Dapiran & Hogarath-Scott, 2003; Emerson, 1962; Pfeffer, 1981). Being a potential influence, power does exist even if not observed (Emerson, 1962). Kim (2000), for instance, distinguishes between inter-firm power structure and the actual use of influence strategies. Supply chain exchanges, including joint innovation projects, are based on interdependence among partners, which may entail asymmetric power that interferes with

the effectiveness of outcomes. Power is an element of any relationship (Dapiran & Hogarath-Scott, 2003) and is, therefore, worth studying in a supply chain context.

Even though power can take different forms and can have several bases (French & Raven, 1968), the exercised/ unexercised classification (referred to as mediated/ non-mediated) is the most common in the literature that has gained consistent empirical support (Ke, Liu, Wei, Gu, & Chen, 2009). Exercised power, namely reward, coercive, and legal, involves the actual influence that a source applies on a target. The three different manifestations of power observed among firms are: (1) reward power involving provision or promise of rewards, (2) coercive power involving provision or threat of punishments, and, (3) legal power involving resorting to contractual agreements (Benton & Maloni, 2005; Fidler & Johnson, 1984; Ke et al., 2009; Maloni & Benton, 2000). This exercised/ unexercised classification is regarded as the most appropriate dichotomization specifically for a supply chain environment (Benton & Maloni, 2005).

The primary source that gives a firm power advantage over its partner is interdependence asymmetry. Channel members are inherently dependent on each other. Asymmetry occurs, however, when there is a discrepancy between each firm's dependence on its partner. Dependence is the extent to which it is necessary for a firm to maintain a particular channel relationship to achieve desired targets and is usually measured in terms of replaceability of a partner (S. K. Kim & Ping-Hung, 2003). Interdependence asymmetry takes into account two facts (1) dependence is mutual and has to be addressed from two sides of a dyad/ linkage; (2) what primarily matters in a dependence relation is the relative or net dependence or the discrepancy between each side's dependence on the other. Power is indicated as the primary consequence of interdependence asymmetry (Caniëls & Gelderman, 2007). A firm can find it necessary to keep relationships with a particular partner for a variety of reasons including process dependence, knowledge dependence, or unavailability of substitutes.

2.2.2 Consequences of Power in Supply Chains

Power plays a prominent role in motivating decisions in supply chains (Brewer & Speh, 2000). It allows firms to gain favorable terms in supply chain exchanges (Crook & Combs, 2007). Firms use their relative bargaining power against supply chain partners in two ways: appropriation and propagation. The former effect is generally perceived as

negative, being biased toward the more powerful partner, while the second is perceived as positive, taking a leadership position for promoting innovations.

Appropriation involves obtaining larger proportion of supply chain profits. A partner with a favorable "product category commitment ratio", used to measure the balance of power among supply chain partners, can extract additional financial returns at the expense of the other partners (Brewer & Speh, 2000). Revenue sharing contract parameters, for instance, depend on the relative contractual power of the supply chain actors (Giannoccaro & Pontrandolfo, 2004). Benefit extraction can also take the form of shifting activities or costs to partners. In VMI (Vendor-Managed Inventories) tasks related to monitoring and controlling inventories are shifted to suppliers; and in quick response programs suppliers are burdened with more frequent deliveries and higher inventory holding costs (Subramani, 2004).

From a different perspective, power allows firms to act as innovation leaders inducing partners to adopt/ develop technologies. The ripple effect of innovations on the whole supply chain drives partners to influence each other to innovate (see chapter 2). Research supports the effect of inter-firm influence strategies and technological adoption (Hausman & Stock, 2003). For instance, bargaining power explains the ability of high-volume buying firms to mandate the use of Electronic Commerce on suppliers (Min & Galle, 1999; Riggins & Mukhopadhyay, 1994).

The giant retailer, Wal-Mart, threatens to pull its orders from suppliers if they do not innovate to meet with its new "green" standards (Aston, 2009). The company's investments in technological systems resulted in an "order of magnitude impact" on its suppliers' innovations (Schrage, 2002). On another frontier, automotive manufacturers oblige suppliers to continuously innovate for annual price reductions (B. Kim, 2000; Liker & Choi, 2004; Maloni & Benton, 2000). Exploiting its power, GM dictates nonnegotiable cost reductions on its suppliers driving several process innovations (B. Kim, 2000). Some scholars, however, still argue that benefits from influence-based innovations are always biased in favor of the more powerful network leaders (Cachon & Lariviere, 2005; Dwyer & Walker Jr, 1981; Mitra & Singhal, 2008).

From the above, we notice that arguments are scattered in the literature about both the positive and negative effects of power on innovations. It is still unclear whether

power exercise would help provide leadership and direction for promoting innovations, or would kill creativity and flexibility required for more effective innovations. We here attempt to reconcile these disagreements by distinguishing types of innovations, namely radical versus incremental, for which power exercise would pay off. Theoretical development of hypotheses is shown next.

3. THEORETICAL DEVELOPMENT

3.1 Dominant Organizational Capital and Incremental Innovation

Organizational Capital is knowledge that is owned by organizations, independent from individuals (Albino et al., 1998). Organizations can both own knowledge and be knowledge actors, which are entities that possess, acquire, and exchange knowledge (Albino et al., 1998). Organizational capital is the institutionalized knowledge and codified experience residing within databases, patents, manuals, structures, systems, and processes, away from individuals working therein (Youndt et al., 2004). Firms preserve knowledge over time while "individuals come and go" (Daft & Weick, 1984).

Within one firm, the stock of institutionalized knowledge is generally homogenous, providing direction for structured recurrent activities that deepen existing knowledge, and enabling the firm to reinforce it in further incremental innovations (Katila & Ahuja, 2002; Subramaniam & Youndt, 2005). In a dyad, however, two such stocks exist simultaneously and may not necessarily be homogenous to one another. The two knowledge profiles (OC) may indeed conflict. For instance, firms may be patenting in different fields, using different technologies and systems, following different organizational structures, or adopting different innovation processes. In this case, each firm attempts to direct incremental innovation activities to its own structure, extend its own stock of knowledge, and perform what has proved to be successful for its own cause (Katila, 2002; Subramaniam & Youndt, 2005). In doing so a firm aims to enhance its existing competence and capabilities (as opposed to destroying it) (Henderson & Clark, 1990). When this is done simultaneously by several firms in a collaboration, it may jeopardize the existence of a clear and unified direction required for incremental innovations. Accordingly, the joint ability of the firms to produce incremental innovations may be adversely affected.

Why then would firms in a dyad not learn from each other? By decoupling organizational knowledge from human knowledge, the concept of organizational learning becomes moot[6]. Organizations do learn, but "only through individuals who learn" (Senge, 1990: 139). Organizational learning is usually thought of as a metaphor originating from individual learning, as organizations cannot learn independent of all individuals (Kim, 1993). Although organizations do possess memories that may exist independent from people, learning itself is not an independent trait of organizations (Hedberg, 1981). Accordingly, it is safe to argue that organizational knowledge, when decoupled from individuals, is idiosyncratic in nature and resists changes. For instance, when Standard Operating Procedures are institutionalized, they become more difficult to change, delaying the search for new procedures (Kim, 1993). Routines cause resistance to change, giving stability and rigidity to processes, and it is individuals (managers) that attempt to alter these routines. Institutionalized knowledge, i.e., OC, facilitates and smoothens regular changes and improvements, while resisting changes based on opposing stocks of knowledge coming from other firms (Nelson and Winter, 1982). Routines tend to be persistent and inflexible to adaptation to other firms' knowledge (Teece et al., 1997), as OC intensifies organizational inertia (Hannan & Freeman, 1984).

Similarly, in a buyer-supplier innovation interaction, each firm's OC resists the other's opposing stock of knowledge. The level of resistance will correspond to the difference in types of firms' OC stocks (e.g., difference in organizational cultures), and strengths of each organization's OC (e.g., strength of each organizational culture). Strong organizational cultures are more difficult to change. The conflict between comparably strong OC stocks, such as cultures, impedes the effective transfer and sharing of knowledge (Lyles & Salk, 1996). Such conflicts are particularly escalated among businesses with comparable sizes. Examples include Daimler-Chrysler's "merger of equals" which failed due to conflicting organizational cultures, where Germans failed to smoothly dominate because of the comparable strength of the two cultures (Weber & Camerer, 2003). These cross-cultural conflicts, known as "acculturative stress", hinder

[6] Note that there is a distinction between organizational learning and organizational adaptation, as change does not necessarily imply learning (Hedberg, 1981; Fiol and Lyles, 1985). Learning may include simple adaptation, while encompassing much more, such as understanding of causal relationships.

effective knowledge transfer (Larsson & Finkelstein, 1999). The higher the level of OC in a firm, the more difficult it is to disrupt it, while the smaller the stock, the easier the adaptation (Gatignon, Tushman, Smith, & Anderson, 2002).

Firms with comparable stock levels face conflicts of conventions, with no clear character of a dominant style that can guide incremental innovations. The existence of a dominant style of OC allows smooth inter-firm communication and effective development of incremental innovations. We call this Dominant OC, which is defined as the prevalence of a particular profile of institutionalized knowledge, i.e. type of processes, patent fields, documentation style, … etc. in a multi-firm pool of OC. In a supply chain linkage with a buyer and supplier working jointly, a single OC profile must dominate to provide a consistent direction for further incremental innovations. This can result from: (1) dominant OC *content*: similarity in the *type* of OC stocks in the two firms, and/ or, (2) dominant OC *magnitude*: gap in the *quantity* of OC stocks (i.e., one OC stock is much larger than the other).

Dominant OC content results from similarity in firms' OC stocks. OC similarity between two organizations, also known as knowledge symmetry/ relatedness/ overlap, facilitates inter-firm communication and two-way learning, and allows each of the firms to absorb new external knowledge from the other (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998). OC similarity entails cultural proximity, related patent fields, and common innovation processes between companies. Cultural proximity achieves organizational fit, reduces equivocality, and allows easier and more effective collaboration (Albino et al., 1998; Knoben & Oerlemans, 2006; Lui & Ngo, 2005). The presence of similar patent fields unifies the direction for extending and growing existing innovations. Lastly, organizations with common innovation processes find fewer conflicts in procedures, routines, and practices that may stand in the way of simple changes. Firms coming from detached knowledge realms employ diverging innovation "recipes" or "routines" impeding collaboration (Ahuja & Katila, 2001). Knowledge overlap with a buyer/ supplier firm, therefore, enables a firm to reinforce its in-house skills by absorbing this similar further external knowledge (Mowery et al., 1998).

A gap in OC magnitudes, i.e., difference in OC strengths, may also lead to a dominant organizational knowledge stock. Ahuja and Katila (2001) contend that *smaller*

relative size of knowledge bases (i.e. higher gaps) is required in joint innovations to minimize: (1) the relative amount of resources devoted for integrating the two knowledge bases; and, (2) modifications to existing routines and changes to organizational functions. A higher gap in organizational stocks allows a larger stock firm to take the lead and provide direction for further incremental innovations, while making minor modifications to the smaller stock firm. Well-established firms with deeper history have more complex organizational knowledge which is difficult to change, while smaller firms with simple knowledge structures can easily acquire new knowledge from other firms in joint ventures (Lyles & Salk, 1996). When the knowledge bases (to be combined) are relatively equal in size, however, it becomes more difficult to determine which of the two bases to build on or extend. Both stocks, in this case, have equal strength and would struggle, trying to reinforce themselves.

Overall, the key driver that enhances incremental innovation capability is the presence of dominant organizational capital (Figure II-1), which may come from two sources. In the first case, OC similarity minimizes conflict as to what knowledge will be extended or deepened through upcoming innovations. And in the second case, domination of quantity allows the higher stock of OC to lead the innovation process.

H1: The greater the Dominant Organizational Capital (DOC) in a supply chain, the higher the supply chain's incremental innovative capability[7]

3.2 Human Capital Related Diversity and Radical Innovation

HC constituting knowledge residing within and utilized by individuals, comprises the basis for radical innovativeness within firms (Schultz, 1961; Subramaniam & Youndt, 2005). This stems from the fact that radical innovations are triggered by tacit knowledge, which resides within individuals (Grant, 1996; Cowan et al., 2004, Hall and Andriani, 2003 and Mascitelli, 2000; Castiaux, 2007). What individuals accumulate below their level of consciousness allows them to go beyond details and specifics, recognizing interrelationships and discovering missing links forming the bases of breakthrough innovations (Mascitelli, 2000). OC is by definition mostly codified and explicit

[7] We will adopt Benton and Maloni's (2005) definition of a supply chain as a link between a firm and one of its first tier suppliers. This represents a building block, which is easily extendible throughout a supply chain (Benton & Maloni, 2005).

(documentation style, patents ... etc.) with sparse tacit content required for the undefined and uncertain context of creative processes (Polanyi, 1958; Castiaux, 2007).

In an inter-firm collaboration, transfer of tacit knowledge is mainly due to contact between individuals (Castiaux, 2007). Individuals are distinguished from other resources by their ability to learn, apply their knowledge in new domains, and make new resource combinations; which all lead to radical innovations [8] (Penrose, 1959). From an exploration/ exploitation perspective, Popadiuk and Choo (2006) argue that:

> *"Tacit knowledge (residing in individuals) ... is closely related to knowledge exploration (for radical innovation) while explicit knowledge (residing in organizations) is more concerned with knowledge exploitation (for incremental innovations)".*

Involving explorative activities, radical innovations require a diversity of skills to provide breadth for the exploration process. It is this breadth of knowledge that allows novel ideas and concepts to be cultivated, by departing from existing skills and making new associations and linkages (Benner & Tushman, 2003; Cohen & Levinthal, 1990; March, 1991). Radical innovations also involve an uncertain setting, which requires diverse knowledge for a more robust learning basis (Cohen & Levinthal, 1990). Employees who spawn a diversity of knowledge and carry a wide variety of experience present an invaluable resource that can stimulate innovative idea generation (Chen & Huang, 2009; McDermott, 1999).

Excessive diversity, however, comes at a disadvantage. Human knowledge that is too diverse may result in "unwieldy and impractical" outcomes (Taylor & Greve, 2006). On one hand, high levels of diversity in teams carry a great potential for team conflict (Taylor & Greve, 2006). Employees that are too diverse may face internal communication problems, impeding effective teamwork (Cohen & Levinthal, 1990). This raises questions regarding how diverse HC should be for effective radical innovation outcomes. We here assert that HC *related diversity*, acts as the key determinant of radical innovativeness for supply chains (Figure II-1).

Skill relatedness has been defined in the literature as a property of industries that describes skill linkages among different industries (Farjoun, 1998; Neffke & Henning, 2013). Two *industries* are said to be skill-related to the extent to which they share skill

[8] See more on the resistance of institutionalized knowledge to learning and radical changes in section 3.1.

profiles (Farjoun, 1998). Similarly, we here define skill relatedness as a property of a *skill set*. Two or more skills are related to the extent to which they are simultaneously used in a variety of products and services: the higher the co-existence of certain skill combinations in the production of various products and services, the higher the level of these skills' relatedness. Related skills, as defined above, may be highly different. Think for instance about accounting and marketing professions present in multiple types of businesses. Differences in skills can be characterized through indices like the Standard Occupational Classification (SOC) code, which classifies workers into occupational categories.

Relatedness in human capital helps minimize the disadvantages of excessive (unrelated) diversity, which include: team conflicts (Taylor & Greve, 2006), communication problems (Cohen & Levinthal, 1990), and reaching "unwieldy and impractical" outcomes (Taylor & Greve, 2006). Skills that are relatedly diverse have a higher probability of success in joint research (Sinha & Cusumano, 1991). This is particularly true for the case when the expected benefits and risks are high, i.e. radical innovations (Sinha & Cusumano, 1991). The value of a resource is enhanced by the co-presence of related resources. While radical innovations require transferring/applying skills in new domains and contexts, the value of the skill transferred may be lost due to absence of other skills that enhance its value (Farjoun, 1994). Related resources are mutually supportive, creating super-additive value synergies from their usage across different domains and contexts (Milgrom & Roberts, 1995; Tanriverdi & Venkatraman, 2005). The combination of unrelated resources may potentially produce radical innovations, but the speed and ease of their creation are much lower than with the case of related resources due to the lack of necessary absorptive capacity (Makri, Hitt, & Lane, 2010).

HC related diversity is obtained: (1) quantitatively, through a bigger pool of HC, and/or, (2) qualitatively, through complementarity in the HC pool. HC complementarity is defined in the literature as knowledge that is related but different (Tanriverdi & Venkatraman, 2005). Complementarity in supply chain firms' HC bases implies a non-overlapping character of knowledge that allows integration to create value that had not existed in either firm before (Fang, 2011; Milgrom & Roberts, 1995). Alternatively, lack

of complementarity can imply redundancy, which causes inefficiencies and conflicts (Fang, 2011).

Larger teams are by definition more diverse making team size another source of HC related diversity (Carpenter, 2002). Getting together more people to work on innovation projects presents an invaluable resource (McDermott, 1999). A team's size is proportional to the amount of resources contributing to an innovative output (Hambrick & D'Aveni, 1992). A higher input of human capital implies a wider spectrum of knowledge and a greater opportunity for radical innovations (van-den-Bergh, 2008). More "creators" provides knowledge diversity required for radical innovations (West & Anderson, 1996). This would lead to a more effective exploration process and, accordingly, a higher output of radical innovations. A higher level of HC implies skilled and creative employees, who would likely question prevailing systems and attempt to change them significantly (Snell & Dean Jr, 1992; Tushman & Anderson, 1986). In the highly creative environment of radically innovative teams, unique individual stocks of knowledge, obtained from a greater HC pool, carries particular importance (Taylor & Greve, 2006).

Note that in the case of management teams, bigger size may entail conflicts (Amason & Sapienza, 1997). Nevertheless, this view does not find consensus as some scholars have empirically found that larger top management teams perform better (Haleblian & Finikelstein, 1993; Hambrick & D'Aveni, 1992). It is imperative to note, however, that decision-making teams are beyond the scope of this discussion, since we only focus on innovation teams. Empirical studies have found innovation teams to be more effective when larger, especially that innovation is arguably a process characterized by conflict in attempting to adapt changes to organizations (Curral, Forrester, Dawson, & West, 2001; Dailey, 1978; West et al., 2003).

H2: The greater the HC Related Diversity (HRD) in a supply chain, the higher the chain's radical innovative capability.

3.3 The Moderating Role of Power Exercise

Little is known about whether influence strategies positively or negatively affect innovativeness of businesses (Hausman & Stock, 2003). Supply chain firms may resort to influence strategies, coercive, reward or legal, attempting to affect partners' innovation

performance. Wal-Mart, for instance, pushes its suppliers to invest in new technologies like RFID and green initiatives by threatening to withhold business from non-conformers (Aston, 2009). This study argues that power exercise will be effective when the direction and source of lead for the innovation process is clearly defined, i.e. in the case of incremental innovation, while it would be ineffective in the case of the more uncertain radical innovation, when higher flexibility and creativity is needed.

Power exercise stimulates actions directly by decoupling emotional attachments (Ireland, Hitt, & Webb, 2005; Ireland & Webb, 2007). It provides the high level of reinforcement needed for organizational capital to translate into incremental innovative capability. When exercised, power can overcome both active and passive resistance of firms to implement innovations (Fidler & Johnson, 1984). It is therefore effective when it comes to adopting existing technologies or expanding their scope (Maute & Locander, 1994). Firms exercise power to induce partners to follow their lead in innovation projects. In the case of incremental innovations, compliance is required to unite firms along a single direction for extending a specific dominant knowledge profile. Influence strategies ensure that the less powerful firm abides by the dominant firm's directives (Ke et al., 2009). Power exercise is, therefore, expected to have both a direct and moderating positive effect on incremental innovative ability:

H3a: Power exercise positively affects a supply chain's incremental innovative capability

H3b: Power exercise positively moderates the relationship between DOC and incremental innovative capability of a supply chain

On the other hand, power may inhibit the ability of individuals to produce radical innovations. Depriving individuals from taking part in the decision making by exercising power impairs their creativity and their willingness to make fruitful suggestions (Fidler & Johnson, 1984). This can result in negative attitudinal orientations further dampening radical innovative capability. In developing radical innovations, it is difficult to evaluate or monitor innovation efforts. It is, therefore, imperative for participating individuals to have the willingness to be effectively involved. Power exercise typically results in low involvement levels as (less powerful) firms perform in a minimally acceptable manner for which punishment is avoided or reward is present (Fidler & Johnson, 1984).

The control induced by exercising power adversely affects creativity and flexibility needed for radical innovative capability. New ideas and knowledge requires not only creative and highly skilled employees but also flexibility in adapting and implementing (March, 1991). Flexibility has been cited as a necessary requirement for radical innovations. Companies pursuing high level of innovations are in fact decreasing their hierarchical control (Kanter, 1989). The substantial level of control and direction employed by use of influential strategies between linkage firms will largely diminish people's flexibility, deterring the overall human capital from being translated into radical innovations. Radical innovation is facilitated by the flexibility following from a lack of enduring relations between firms (Bart, 1999). Strategic commitments caused by a powerful firm's influence will make the weaker firm more rigid and less flexible, standing in the way of breakthrough innovativeness.

Moreover, negative feelings are generated and autonomy is lost from forced compliance, again, adversely affecting radical innovations (Ke et al., 2009). As one firm complies with directives from another under power influence, it foregoes the opportunity to demonstrate its competence (Ke et al., 2009). This means that power exercise inhibits radical innovative capability and dampens the effect of competence HRD may have on the capability (Figure II-1).

H4a: Power exercise negatively affects a supply chain's radical innovative capability

H4b: Power exercise negatively moderates the relationship between HRD and a supply chain's radical innovative capability

Although Wal-Mart, which had changed supply chain process almost radically, may seem like a counter example to our argument, a closer look will actually show the opposite. On one hand, Farrell (2003) argues that the retailer's real gains were obtained only by redefining and enhancing relationships with suppliers as opposed to exercising power. Suppliers that witnessed excessive usage of power such as Vlastic have declared bankruptcy, indicating failure of the forceful strategy in radical changes (Crook & Combs, 2007). This situation of suppliers having little choice but to comply with retailer's innovations, is completely different from joint work on the actual creation and development of innovations. No studies, to our knowledge, have investigated the actual effect on joint innovation capability, as an outcome, of a Wal-Mart-supplier dyad. Studies

do argue, however, that the outcomes of Wal-Mart's power has been unequal returns on ideas and resources, biased against suppliers; and that win-win collaborations exist between Wal-Mart and firms with comparable-power such as Procter and Gamble, where no excessive power can be exercised on either side (Corsten & Kumar, 2005). Success of the partnership has been specifically attributed to the lack of relative power between the two players (Tang, 1999). Another study found that the less the market-share of Wal-Mart's suppliers (i.e., more chance of power exercise), the higher the failure rate of these suppliers (Bloom & Perry, 2001). Finally, scholars have further argued that Wal-Mart's innovations are all about cost reduction, which may have in fact impeded product and quality related innovations manufacturers wished for (Bianco et al., 2003). Evidence has thus indicated that Wal-Mart's forceful strategies fail in *joint* radical innovation endeavors.

3.4 Social Capital Valuation

A discussion on intellectual capital is not complete without considering its third element, social capital. The effect of supply chain social capital on innovation outcomes can be attributed to the *value* firms place on their relational ties. Companies that highly value inter-firm social capital and the importance of relational ties are better able to collaborate for both the effective creation and implementation of innovations. Studies confirm significant financial value from perceived buyer-supplier trust, not only through transaction cost reduction, but also from enhanced sharing and collaboration, which directly translates into higher innovative abilities (J. H. Dyer & Chu, 2003).

Social elements are "externalities" described as goods and commodities with real, practical economic value (Arrow, 1974). This "calculus-based" view of trust ensures tangible, economic outcomes from creating and sustaining the relationship relative to the costs of severing it (Lewicki & Bunker, 1996). Accordingly, companies that adopt this view comply with implicit knowledge sharing rules, including ready provision and secrecy, ensured by the expected rewards of being trusting and trustworthy (and possibly avoiding "threats" of violating trust) (Ba, Whinston, & Zhang, 2003).

The effect of social capital valuation on innovation can be attributed to the "best known" exchange rule borrowed from the social exchange theory: reciprocity or payment in kind (Cropanzano & Mitchell, 2005). According to that rule, "voluntary actions of

individuals … are motivated by the returns they are expected to bring and typically do in fact bring from others" (Blau, 1964). In a buyer-supplier knowledge exchange, social capital valuation by one party drives more sharing of knowledge, i.e. providing benefit to the other, in attempt to invoke reciprocation from the other and provision of knowledge in return (Blau, 1964; Whitener, Brodt, Korsgaard, & Werner, 1998). Accordingly, high valuation by both parties builds up a larger shared "knowledge repository" retrievable by all members to jointly produce radical and incremental innovations (Cress & Martin, 2006). As participating firms allocate and share adequate resources, the endeavor will more likely succeed (Samaddar & Kadiyala, 2006).

Social capital economically incentivizes companies that value it to allocate more knowledge to the dyadic pool and to behave honestly by refraining from opportunism (Ba et al., 2003). The mere valuation of social capital elements such as mutual trust and respect reflects on the effective sharing of ideas and exchanges of knowledge, boosting both radical and incremental innovation capabilities (Figure II-1):

H5a: Social capital valuation positively affects a supply chain's incremental innovative capability

H5b: Social capital valuation positively affects a supply chain's radical innovative capability

4. METHODOLOGY

4.1 Method Overview

To test the hypotheses above we used a self-administered web-based survey for being a more efficient and cost effective method (Braunscheidel & Suresh, 2009). The survey targeted a population of purchasing managers in Canada. The purchasing manager role necessitates extensive dealing with suppliers and hence fair knowledge about supplier innovation relations, making the position a conventional choice for target respondents in similar studies (Braunscheidel & Suresh, 2009; Choi & Hartley, 1996; Johnston, McCutcheon, Stuart, & Kerwood, 2004). Respondents were all contacted by email, with a brief introduction and link to the formal invitation/consent letter that proceeds to the survey (invitation letter is given in Appendix II-A).

We used two sources of motivation for managers to increase participation. First, we informed them that the study is funded and supported by Social Sciences and

Humanities Research Council (SSHRC). Secondly, they were promised a copy of the results upon study completion (see invitation/ information letter in Appendix II-A). Mentioning the funding by a federal research agency, along with associating the research to a credible academic institution provided legitimacy to the research and diverted fears of potential harm from the survey website, in the way of computer viruses (Braunscheidel & Suresh, 2009).

4.2 Survey Design and Measurements

The survey was designed to start with simple and straightforward questions that introduce the topic (R&D, competition, industry … etc.). Questions perceived as more difficult followed in a logical order (independent variables, dependent variables, moderator), in line with survey design recommendations (N. K. Malhotra, 2006). Less important, more descriptive questions including ones about company age, respondent tenure, and company size were placed at the end (Leung, 2001; Taylor-Powell & Marshall, 1996). A short introduction was provided asking respondents to identify one supplier of their choice as follows:

> *"To complete this survey, please identify a supplier that you are knowledgeable about and with whom there has been some recent joint work (or attempt for joint work) on product or process improvements. This can include, but is not limited to, product enhancements, new product development, cost reduction techniques such as setup time reduction, waste minimization or other process improvements."*

All reflective (first order) measurements for this study are borrowed from the literature (see Table II-1) and have been adapted to the current study's buyer-supplier context and dyadic level of analysis. Subramaniam and Youndt (2005) offer measurement scales for innovative capabilities, organizational capital and human capital. Scales for innovative capabilities were reworded to ask about the entire dyad. The stems for items of organizational capital and human capital were adapted to ask about similarity in the former and complementarity for the latter.

Power exercise items are well anchored in the literature (Handley & Benton Jr, 2012a, 2012b). The legal power options were adjusted to reflect the directionality of legal power exercise. Relative coercive power, and relative reward power were calculated from difference scores among parallel items as in Kumar et al. (1995). Similarly, total scores (such as total social capital valuation, and total R&D) were calculated for parallel items

to reflect their total value for the buyer-supplier level (i.e., dyadic level), similar to total interdependence calculation by Kumar and colleagues in the mentioned paper.

Buyer-supplier size difference was used as a proxy for organizational capital gap. This is based on the fact that larger firms have higher organizational capital compared to smaller ones. Larger firms enjoy more patent count due to their financial resources and higher R&D expenditures; while smaller firms patent with a much lower propensity (Arundel & Kabla, 1998; Brouwer & Kleinknecht, 1999; Hall & Ziedonis, 2001; Scherer, 1983). Moreover, larger firms employ more rigid structures and codified rules (administrative complexities) compared to smaller counterparts (Greiner, 1972; Miller, 1987a, 1987b; Sharma, 1999). Their organizational cultures are also stronger and better established (Barney, 1986).

Finally, control variables were added to the survey questionnaire as appropriate (Table II-2). All measurement items for multi-item constructs are given in Appendix II-B.

4.3 Pre-Test and Pilot Study

The survey instrument was run by senior professors of Operations Management and Marketing to make any suggestions for changes that may enhance clarity, comprehensibility, and/ or comprehensiveness of answers. A draft questionnaire was pre-tested with three subject matter experts in purchasing, coming from three distinct industries (plastic packaging manufacturing, automotive, and display technology) to maximize the breadth of improvements. These managers were interviewed, asked to take the survey, and encouraged to suggest any improvements or changes they deem appropriate.

A number of changes were made to improve the quality of the questionnaire. These included clarifying the level of inquiry, i.e., whether respondents answer questions based on a particular project or general relationship; and answer based on the level of the plant, subsidiary or whole company. Wording was further simplified to avoid unintended meanings. Finally, one question was rewritten for being perceived as double-barreled.

4.4 Sampling

To maximize sample size, a combined approach was used to collect three sub-samples from a population of purchasing managers in Canada. The first one was to

contact *supply chain* consulting companies, motivating their interest about the research, asking them to share their client list, and promising a copy of study findings upon completion. A search was done on supply chain consulting companies in Canada, which were contacted by email accordingly. One company responded with interest, and shared its list of contacts.

In the second approach, we used LinkedIn's InMail service to contact subject matter experts. LinkedIn is evolving as a venue to reach appropriate professional in supply chain management research (Moori, Pescarmona, & Kimura, 2013; Weinstein, Jin, & Barrett, 2013). We performed an advanced search for (current) titles of "Purchasing Managers" located in Canada. Other relevant titles that appeared in the search results, such as "Senior Buyer" and "Supplier Quality Manager", were also contacted. To help eliminate non-response bias, we restricted search results to respondents not connected to the sender (i.e., not in the sender's network. In LinkedIn, this is described as "3rd and everyone else". What LinkedIn considers to be 1st and 2nd connections were excluded for being connected directly or indirectly to the sender).

Finally, a snowballing approach was used, contacting our three pilot study companies, asking them to recommend five contacts deemed appropriate for taking the survey, and the process was repeated with each of their contacts that showed interest and took the survey. Both techniques of resorting to personal contacts and combining multiple approaches for maximizing sample size have been used in high quality survey research and studies on supply chain management (Cousins & Menguc, 2006; Lovelace, Shapiro, & Weingart, 2001; Tatikonda & Montoya-Weiss, 2001). We obtained a total of 145 responses. Descriptive statistics are shown in Appendix II-C.

4.5 Usable Sample

List-wise deletion was used to eliminate cases with excessive and non-replaceable missing data, with the former being defined as: more than two missing items in multi-item questions; and the latter as one or more missing stand-alone question (such as team size). From the total sample, 22 responses were eliminated for excessive missing data (more than two blank questions/ items). Responses with a missing stand-alone question (i.e., one that does not belong to a multi-item construct) were also eliminated for not being eligible for estimation. This resulted in 105 usable responses, 19 of which have one

or two missing items of multi-item constructs. Given a maximum of 8 arrows directed into our endogenous variables (see Figure II-4), our usable sample size exceeds the "conservative" rule of 10:1 ratio (10 samples for each arrow directed to a dependent variable), with much more liberal statisticians satisfied with 2:1 ratio, and a mid-position of 5:1 ratio (Falk & Miller, 1992). PLS has been consistently used for comparable and much lower sample sizes, as small as 50 (Klein, 2007; Morgan, Kaleka, & Gooner, 2007; Rosenzweig, 2009; Sawhney, 2013).

To estimate missing items, we performed case mean substitution (across items and within the individual), as opposed to total mean substitution for being generally more recommended (Roth, Switzer, & Switzer, 1999). Moreover, to our knowledge, there is no evidence/ argument that has been made of the former decreasing variability (Tsikriktsis, 2005). It does, however, assume equal means and standard deviations between predictors and missing variables (Tsikriktsis, 2005). A total of 26 items were estimated using the mean substitution imputation approach. The missing item count falls well short of the rule of thumb cutoff of 10%, deeming the estimation appropriate ((26*100/46*105) = 0.54%)[9] (Ettlie, Perotti, Joseph, & Cotteleer, 2005; Power & Terziovski; Rosenzweig, 2009).

4.6 Analysis

Three of our constructs, namely power exercise, HC related diversity and dominant OC are formative combinations of first order reflective constructs, i.e., second order constructs of type II (reflective first order-formative second order) (Hair, Hult, Ringle, & Sarstedt, 2014). Hierarchical component models provide higher levels of abstraction that help achieve more theoretical parsimony and less model complexity (Akter, D'Ambra, & Ray, 2011; Edwards, 2001; Vinzi, Chin, Henseler, & Wang, 2010; Wetzels, Odekerken-Schröder, & van Oppen, 2009). According to our cases of formative (second order) constructs, PLS-SEM is the recommended analysis method, given that it completely avoids the identification problem with formative models (Akter et al., 2011; Chin, 1998a; Gefen, Rigdon, & Straub, 2011; Wetzels et al., 2009). We, therefore, perform PLS analysis, using SmartPLS 2.0 (Ringle, Wende, & Will, 2005).

[9] Note that the maximum percentage of missing responses per item is 3.4 %.

To test the model, a PLS two-stage approach was adopted. There are three ways to deal with second order constructs. The first one is the repeated indicator approach (Ringle, Sarstedt, & Straub, 2012; Wetzels et al., 2009). This is not recommended in our model because the number of indicators should be similar across all first order constructs making up the second order one (Hair et al., 2014). In each of 'HC Related Diversity' and 'Dominant OC' their component first order constructs have different numbers of indicators (one versus four), which can lead to significant biases (Becker, Klein, & Wetzels, 2012). The second method is known as the hybrid approach (Wilson & Henseler, 2007). In this method, indicators of each first order construct are split between itself and the second order construct. Such an operation is not applicable to our model as some of our first order constructs have a single indicator (namely team size and organizational size gap), defying the possibility of splitting.

Lastly, the third method and the one that is used in this study is the two-stage approach. In stage one the structural model is analyzed and latent variable scores estimated *without* the presence of second order constructs. Latent variable scores are obtained from this analysis and subsequently used as indicators in a second higher-order structural model analysis (stage two) as shown in Figure II-2 (Becker et al., 2012; Ciavolino & Nitti, 2009). The first stage PLS path analysis provides latent variables scores for lower-order latent variables, which can be used in a second stage as manifest variables for the higher-order latent variables (Wetzels et al., 2009). In other words, a second-order factor is measured using the scores of its first-order factors (Luo, Li, Zhang, & Shim, 2010). One limitation of this method is the fact that it does not account for the whole model when estimating latent variable scores in the first stage.

5. RESULTS

5.1 Stage One

Stage one model constitutes a decomposed version of the main effects hypothesized in section 3 (i.e. without the presence of second order constructs) as shown in Figure II-3. The decomposed model is used for factor analysis of first order (reflective) constructs, and for obtaining latent variable scores that will be used as indicators for second order constructs in stage two. Items that did not load well on the intended scales

(less than 0.65 loading) were dropped prior to further analysis, leading to our final outer model as shown in Table II-3. Researchers have commonly used lower cutoffs for item loadings (Brah, Wong, & Rao, 2000; Falk & Miller, 1992; Flynn, Huo, & Zhao, 2010; Li, Liu, Li, & Wu, 2008; Oke, Burke, & Myers, 2007; Park, Hartley, & Wilson, 2001; Samson & Terziovski, 1999).

Our lowest factor loading was HCC2, with a lower loading of 0.43, which we kept to avoid having a single item latent variable (Human Capital Complementarity); a practice that has consistently been recommended against (Anderson & Gerbing, 1988; Peter, 1981; Shore & Tetrick, 1991; Zaichkowsky, 1985). This can be justified by the high composite reliability score of the underlying latent variable (0.714), and by the fact that knowledge complementarity measures are less established in the literature, leading to lower acceptable loading cutoffs (as low as 0.4), and Cronbach alpha (as low as 0.5) (Nunnally, 1967). Cronbach alpha for the rest of the constructs met the "practical lower bound" of 0.6, as indicated in several research papers (Flynn, Schroeder, & Sakakibara, 1994; M. K. Malhotra & Grover, 1998; Narasimhan & Jayaram, 1998; Prater & Ghosh, 2006), including ones using existing measures (Vaidyanathan & Devaraj, 2008).

To consider the reliability and validity of our measurements we used several approaches that test for indicator reliability, composite reliability, convergent and discriminant validity. All results well exceeded recommended cutoffs, confirming the reliability and validity of all our measures (see Table II-8 for a summary).

5.2 Stage Two: Structural Model

The structural model was assessed by a PLS analysis and a subsequent bootstrapping technique. The former provides path coefficients (Figure II-4 and Table II-10), R square values, and communalities from which a global criterion of goodness of fit (GoF) can be estimated[10] (Table II-9). In the latter technique, multiple subsamples from within the same sample are used to build a distribution for each parameter and derive a standard estimate, avoiding any distributional assumptions for the data (Sumukadas & Sawhney, 2004). To ensure the stability of our results, we ran bootstraps using several

[10] Although a global Goodness of Fit index has been suggested for PLS, (Tenenhaus et al., 2004), valued at 48.16% in our model, this has been found to be mainly a diagnostic tool, not a formal testing technique and not very suitable for model validation (Henseler and Sarstedt, 2013; Wetzels et al., 2009).

sub-sample sizes (500, 700, 1000), finding estimates to be very stable. We, therefore, only report results of the 1000 sub-samples. As shown in Figure II-4 and Table II-9, the model accounts for 36.4% and 35% of the variance in radical and incremental innovation capabilities, respectively. R square values exceed the recommended cutoff of 0.25[11] (Hair et al., 2014). Lying above 33%, both R square values are considered moderate effect sizes (Chin, 1998b). The software converged after 10 iterations only (out of the maximum of 300 allowed), signaling a good estimation (Wong, 2013).

Support for our developed hypotheses is assessed by examining path coefficients from the PLS run and their significance levels obtained from t-values resulting from the bootstrap as in Figure II-5 (Sawhney, 2013). Because of the novelty of the concepts developed in this research, we examine two-tailed results of the t-test to consider both directions of each effect, and we follow the liberal rule describing p values < 0.01 to be very strongly significant, < 0.05 as strongly significant and < 0.1 as significant (Ahmad & Schroeder, 2003; Jayaram, Ahire, & Dreyfus, 2010; Lo, Wiengarten, Humphreys, Yeung, & Cheng, 2013; Srinivasan, 1985).

Results indicate that the relationship between HRD and supply chain radical innovative capability (H2) is negative and significant at the $p<0.05$ level. The path coefficient indicates that a standard deviation increase in HC related diversity is associated with a 0.188 standard deviation *decrease* in radical innovation capability, statistically controlling for the effect of other explanatory variables. Similarly, the relationship between power exercise and radical innovative capability is confirmed at the $p<0.05$ level, showing support for hypothesis H4a. The corresponding path coefficient indicates that a standard deviation increase in power exercise is associated with a 0.184 standard deviation *decrease* in radical innovation capability, statistically controlling for the effect of other explanatory variables. The result for the interaction between power exercise and HRD demonstrates weaker support for hypothesis H4b at $p<0.1$.

Hypotheses H5a and H5b are both strongly supported at the $p<0.01$ and $p<0.05$ levels, respectively. A standard deviation increase in social capital valuation is associated with a 0.194 standard deviation *increase* in radical innovation capability, and a 0.287

[11] Much more lenient researchers recommend cutoff of 0.1 (Falk and Miller, 1992).

standard deviation *increase* in incremental innovation capability, statistically controlling for the effect of other explanatory variables.

Nevertheless results for incremental innovative capability are less conclusive. With the exception of social capital valuation, our hypothesized antecedents of incremental innovative capability (dominant organizational capital, power exercise and their interaction) are insignificant, failing to support hypotheses H1, H3a, and H3b. It is also worth noting that from the path coefficients shown, the effects of HC related diversity and dominant OC on radical and incremental innovative capability, respectively, are both negative. This comes counter to our hypotheses as developed in section 3. Results for hypothesis testing are shown in Table II-10.

6. DISCUSSION

Results regarding social capital valuation confirm our *reciprocity* theory. When companies perceive higher profitability from social capital, they not only work on building and nurturing trust, but also act in the direct and immediate benefit of the partner. Companies do so by giving away more knowledge, and protecting the partner's proprietary knowledge. These actions directly cultivate and preserve social capital in a supply chain relationship. To the extent to which such *in kind* actions are duplicated by both firms in a dyad, both radical and incremental buyer-supplier innovative capabilities are enhanced.

Similarly, the effect of power exercise on radical innovative capability comes in line with our expectations. Active influence upon supply chain partners seems to have a daunting effect on radical idea generation in buyer-supplier teams. Radical innovations rely on freedom of ideas and flexibility of governance as opposed to rigid structures and stone-set directions. This implies that supply chain teams working on the development of radically new products must refrain from resorting to threats (e.g. of withdrawing business), rewards, and legal right usage. This result can be viewed in line with "brainstorming" sessions consistently used for radical idea generation, in which ideas are not evaluated (no threats, rewards or punishments) to encourage the production of as many new ideas as possible (Leonard & Sensiper, 1998). Royal Dutch/Shell, for example, developed "innovation labs" with more flexible processes that circumvent the usual rigid

processes of the company to encourage unconventional idea generation (Hamel & Getz, 2004).

Although we expected the *relatedness* inherent in supply chain teams to overcome problems of increasing team diversity (i.e., a positive overall effect of HRD), results fail to support this claim. We conducted further analysis to test a decomposed model separating first order constructs of human capital complementarity and team size to investigate the separate effects (Figure II-6). Results of the two-tailed t-test (Table II-11) show weak significance of human capital size and lack of significance of human capital complementarity, with both having negative effect sizes. This comes in line with an existing view that argues that too diverse teams can be dysfunctional and come up with less practical output (Taylor & Greve, 2006). According to our results, the negative effect of diversity on inter-team conflict and lack of coordination, (De-Dreu & Weingart, 2003; Williams & O'Reilly, 1998), seems to outweigh the exploration potential of members' knowledge breadth. Moreover, the weak/ lack of significance of first order variables' main effects imply the significance of HC related diversity as a higher-level abstraction that has a strongly significant effect on radical innovative capability.

Results of HC related diversity may also be attributed to the quality of data (see descriptive statistics in Appendix II-C). For example, the discrepancy between means and medians of both human capital complementarity and total HC suggest the presence of outliers, which may have affected our results. Data is positively skewed for both variables with high positive kurtosis, implying that, for example, the range of team sizes may have been too small to allow for the diversity required. This presents a limitation to this analysis as PLS may not be as robust for highly skewed distributions (Wetzels et al., 2009).

The combined effect of power exercise and HC related diversity is shown to be positive. Larger supply chain teams may be effective, if extra control is put in place. Increasing size and diversity with little control may lead to chaos and ineffective results. Accordingly, power exercise may reverse the negative effect of diversity on radical innovative capability, providing discipline and control for larger sized teams with members of various backgrounds. Active power exercise can be particularly important to

help diverse teams that may find higher inertia from their big size and/or from their differences, achieve radical changes to current products/ processes.

This result comes in line with the Microsoft practice of "directing" the creativity of people in large teams (Cusumano, 1997). In larger teams, Microsoft would exert some degree of influence, similar to what can be done among supply chain companies, by directing specific features for product innovation, putting pressure on projects, and stabilizing evolving product properties incrementally (Cusumano, 1997). This can be similarly implemented in large supply chain teams, where for instance buyers have deeper market/user knowledge, and are therefore better able to dictate to the buyer-supplier team what features to focus on developing. This approach becomes more important in larger teams where ideas may completely diverge and processes go out of control.

On the other hand, results fail to support the importance of power exercise for driving incremental innovations. Our prior theorizing for power to provide direction, lead, and control has proved to be required in extreme cases, such as ones with excessively diverse or largely sized teams as discussed above. In less troubled interactions, however, as in the case of incremental innovations, projects may run smoothly, with no need to interfere with influential strategies.

This can also be attributed to the fact that incremental changes face less inertia for their less pronounced effects, and possibly for the increasing acknowledgement of the necessity of *improvements*. Managers generally resist radical changes that they perceive as disruptive, time consuming and expensive (Orlikowski, 1993), while they tend to accept improvements, which require less upsetting for current processes/ products, without any need to impose forces of power exercise. Organizations may be readily open for "convergent" changes with no need for imposing influence (Greenwood & Hinings, 1996).

Similar to the lack of effectiveness of power exercise on incremental innovation, the concept of domination fails too with organizational knowledge. Dominant knowledge seems to be detrimental to the effectiveness of joint innovation work. With a closer investigation for the decomposed dominant OC construct (see Figure II-6), the effect of size gap is negative and strongly significant. This can be attributed to the fact that small

changes and incremental improvements may not be applicable to firms of differing sizes. Counter to our expectation that domination by size may provide a more defined direction for change, size discrepancy leads to diverging structures, objectives and priorities for changes making successful incremental innovations unattainable. Therefore, the concept of domination, by exercising power or even by knowledge tends to be detrimental to incremental innovation.

7. CONCLUSION

This research takes a novel approach to characterize knowledge properties in a supply chain dyad, by adopting an intellectual capital classification system. We develop a hierarchical component model that captures properties of human and organizational knowledge, believed to drive a supply chain's radical and incremental innovative capabilities. We also build on the social exchange theory, to define social capital valuation as determinant of both innovative capabilities through actions of reciprocity. Finally, our study acknowledges power as a key element of supply chain relationships, being a relationship primarily based on market transactions (market power), joining expertise (expert power), and contract settlement (legal power). Upon empirically testing our hypotheses using a PLS two-stage approach, our results offer several significant insights that advance our knowledge about the supply chain innovation and help managers with more effective innovation management strategies.

On one frontier, we conclude that supply chain teams are more effective in producing radical innovations when less diverse. Both positive and negative effects of diversity can be spotted in literature, with the former including higher spectrum of ideas, more breadth of knowledge, and the latter including higher chance for intra-team conflict and less coordination effectiveness. Our results advocate the latter argument, indicating that, even in a *related* supply chain context, bigger and more diverse teams are not able to produce radically innovative ideas. Further analysis reveals that the effect can be more attributed to team size rather than complementarity. In other words, reducing team size in a supply chain joint innovation project minimizes clashes, conflicts and coordination problems leading to more effective radical innovation outcomes. What supports this claim even further, is the moderating effect of power exercise, which when present

enables the operation of more diverse teams by facilitating coordination and providing rigid discipline.

Counter to our expectations, incremental innovations are not driven by domination of knowledge or power. The idea of domination, either as a property of knowledge or through power exercise, seems not to work with innovation teams, including ones aimed at incremental changes. Even with incremental innovations, flexibility is still required to make the necessary adaptations, which may still be surrounded by uncertainties (Cooper & Zmud, 1990; Leonard-Barton, 1988; Tyre & Orlikowski, 1994). This is one reason why some scholars qualify changes as innovations as soon as they are new to an adopting unit. Supply chain partners' discrepancy in size acts as a significant barrier to the development of incremental changes. Firms with different sizes likely employ maximally different governance structures, documentation systems, patent strategies and administrative processes, which may stand in the way of a smooth joint process for building extensions and incremental changes.

Our study further confirms the importance of acknowledging the economic value of social capital. Companies that highly value social capital are significantly better able to produce both radical and incremental innovations. We attribute these results to the reciprocity rule, borrowed from the social exchange theory, which necessitates working for the immediate benefit of the other, reciprocating good acts, and expecting reciprocation. Companies that perceive tangible benefits from building and preserving social capital reciprocate by openly sharing knowledge, protecting the other's knowledge and refraining from opportunism, in an effort to build good reputation with the partner and preserve relational ties.

Finally, the empirical study presented in this chapter suggests a resolution to the opposing arguments on the effectiveness of power exercise on innovative capabilities of supply chain firms. Power exercise fails to help innovation in supply chain teams. Although anecdotal examples of firms, such as Wal-Mart, advocate the positive results of exercising power in driving partners to invest in innovations, we here argue that performance would be significantly improved with more flexibility and less influence.

8. LIMITATIONS AND FUTURE RESEARCH

This study suffers from several limitations worth noting. Although our proxies are highly justified, team size and firms' size gap may not be perfect representations of the underlying constructs. Total human capital, for instance, includes people's skills, qualifications and experience along with their number. Size gap is not an exact representation of discrepancies in organizational capital, which can be captured more effectively by differences in patent counts, difference in firm ages (history), and difference in CMMI level (or other similar certification). Finally, higher factor loadings (especially for human capital complementarity) would have led to better results.

Archival data can be used in future studies to characterize and operationalize skill relatedness in supply chain teams, e.g., using secondary data about occupational classifications and co-existence of skills across industries. The effect of such on supply chain innovation is worth studying. Furthermore, partners' decisions on exercising power and sharing knowledge are also ripe for future research. This includes characterizing a causal relationship between mediated (exercised) power and non-mediated (unexercised) power, and possible moderators for the relationships. It also includes characterizing strategic traits of knowledge that may affect the decision to share. Finally, a study on how economic benefit of social capital can be calculated would be very useful.

9. TABLES

Table II-1

Main Constructs and Their Scales' Sources

INDEPENDENT VARIABLES		
Construct	**Sub-constructs**	**Measure**
Dominant OC	OC Similarity	(Subramaniam & Youndt, 2005)
	OC Gap	Firms' size gap used as proxy
HC Related Diversity	HC Complementarity	(Fang, 2011; Subramaniam & Youndt, 2005)
	Total HC	Joint team Size used as proxy
Power Exercise	Reward power	(Handley & Benton Jr, 2012a, 2012b)
	Coercive Power	(Handley & Benton Jr, 2012a, 2012b)
	Legal Power	(Handley & Benton Jr, 2012a, 2012b)
Social Capital Valuation	____	(Cousins, Handfield, Lawson, & Petersen, 2006; Lawson, Tyler, & Cousins, 2008)
DEPENDENT VARIABLES		
Incremental Innovative Capability	____	(Subramaniam & Youndt, 2005)
Radical Innovative Capability	____	(Subramaniam & Youndt, 2005)

Table II-2

Control Variables and Justification for Inclusion

Control Variable	Support for Affecting Innovation
Length of Relationship	(Autry & Golicic, 2010; Krause, Handfield, & Tyler, 2007)
Buyer/ Supplier Absorptive Capacity	(Cohen & Levinthal, 1990)
Firm Size	(Cefis & Marsili, 2006; Katila & Ahuja, 2002)
Firm Age	(Cefis & Marsili, 2006; Gumusluoğlu & Ilsev, 2009; Motohashi, 2005)

Table II-3

Factor Loadings

Construct	Items	HC Comp	Inc. Inn	Org. Similarity	Rad. Inn. Capability	Rel Coe Pow	Rel Leg Pow	Rel Rew Pow	SC Valuation
HC Comp	**HCC2**	0.4297							
	HCC4	0.9989							
Incremental Innovative Capability	**IIC1**		0.6830						
	IIC3		0.7145						
	IIC4		0.8091						
	IIC5		0.7305						
OC Similarity	**OCS1**			0.7254					
	OCS2			0.7865					
	OCS3			0.8013					
Radical Innovative Capability	**RIC1**				0.8961				
	RIC2				0.8588				
	RIC3				0.8638				
Relative Coercive Power	**RCP1**					0.9309			
	RCP2					0.9006			
	RCP3					0.7702			
Legal Power	**LP1**						0.8107		
	LP2						0.9676		
	LP3						0.8410		
Relative Reward Power	**RRP1**							0.7167	
	RRP2							0.8705	
	RRP3							0.6841	
Social Capital Valuation	**TSCV1**								0.6636
	TSCV2								0.9223
	TSCV3								0.9374

Table II-4

Latent Variables' Composite Reliability and Cronbach Alpha

Latent Variable	Composite Reliability	Cronbachs Alpha
HC Comp	0.7140	0.5590
Inc. Inn	0.8246	0.7189
Org. Similarity	0.8152	0.6995
Radical Inn	0.9058	0.8445
Rel Coe Pow	0.9027	0.8452
Rel Leg Pow	0.9075	0.8692
Rel Rew Pow	0.8036	0.6439
SC Valuation	0.8847	0.8079

Table II-5

Average Variance Extracted Scores

Latent Variable	AVE
HC Comp	0.5913
Inc. Inn	0.5413
Org. Similarity	0.5956
Radical Inn	0.7622
Rel Coe Pow	0.7569
Rel Leg Pow	0.7669
Rel Rew Pow	0.5798
SC Valuation	0.7233

Table II-6

Discriminant Validity (Diagonal Items are Square Root of AVE)

	HC Comp	Inc. Inn	Org. Similarity	Radical Inn	Rel Coe Pow	Rel Leg Pow	Rel Rew Pow	SC Valuation
HC Comp	0.7690	0	0	0	0	0	0	0
Inc. Inn	-0.1959	0.7357	0	0	0	0	0	0
Org. Similarity	-0.2371	0.0768	0.7718	0	0	0	0	0
Radical Inn	-0.171	0.4223	0.1851	0.8730	0	0	0	0
Rel Coe Pow	-0.0488	-0.0812	-0.0801	-0.2515	0.8700	0	0	0
Rel Leg Pow	0.0407	0.1123	-0.0874	0.0011	0.1441	0.8757	0	0
Rel Rew Pow	0.0464	-0.1603	-0.0659	-0.2177	0.0983	-0.1547	0.7614	0
SC Valuation	-0.0042	0.3335	0.0858	0.1257	0.0039	0.1275	0.0478	0.8505

Table II-7

Discriminant Validity: Cross Loadings

	HC Comp	Inc. Inn	Org. Similarity	Rel Coe Pow	Radical Inn	Rel Leg Pow	Rel Rew Pow	SC Valuation
HCC2	0.4297	0.0414	-0.1100	-0.0482	-0.0088	0.1197	-0.0125	-0.0093
HCC4	0.9989	-0.2021	-0.2364	-0.0474	-0.1741	0.0355	0.0480	-0.0038
IIC1	-0.1367	0.6830	0.1712	-0.0561	0.3328	0.0756	-0.1715	0.2532
IIC3	-0.0862	0.7145	0.0319	-0.0565	0.1216	0.0615	-0.0897	0.2750
IIC4	-0.1280	0.8091	0.0404	-0.0751	0.3206	0.0832	-0.0681	0.3739
IIC5	-0.2080	0.7305	0.0030	-0.0514	0.4247	0.1034	-0.1449	0.1017
OCS1	-0.2014	0.0219	0.7254	-0.0257	0.0326	0.0580	-0.1263	0.0316
OCS2	-0.1938	0.0596	0.7865	-0.0166	0.0389	0.1164	-0.1414	-0.0215
OCS3	-0.1750	0.0724	0.8013	-0.1121	0.2667	-0.2589	0.0446	0.1511
RCP1	-0.0915	-0.0586	-0.1107	0.9309	-0.2781	0.1326	0.0639	0.0244
RCP2	0.0277	-0.1112	-0.0143	0.9006	-0.2105	0.1982	0.1184	0.0172
RCP3	-0.0666	-0.0309	-0.0873	0.7702	-0.1270	-0.0088	0.0817	-0.0670
RIC1	-0.2375	0.3818	0.2081	-0.1878	0.8961	-0.0005	-0.1561	0.1335
RIC2	-0.0836	0.3984	0.0976	-0.2652	0.8588	-0.0061	-0.1315	0.0979
RIC3	-0.1344	0.3188	0.1884	-0.1982	0.8638	0.0108	-0.2947	0.0985
LP1	0.0344	0.0435	-0.1281	0.1318	-0.0365	0.8107	-0.0699	0.1290
LP2	0.0215	0.1395	-0.0617	0.1368	-0.0071	0.9676	-0.1911	0.1035
LP3	0.0850	0.0475	-0.0881	0.1152	0.0581	0.8410	-0.0596	0.1419
RRP1	-0.0329	-0.0935	-0.0362	-0.0715	-0.1371	-0.1714	0.7167	-0.0518
RRP2	0.0411	-0.1320	-0.1287	0.1520	-0.2343	-0.1002	0.8705	0.0446
RRP3	0.0986	-0.1440	0.0616	0.1032	-0.0942	-0.1005	0.6841	0.1161
TSCV1	0.0955	0.1691	0.2125	-0.0174	0.0549	0.0234	0.1241	0.6636
TSCV2	-0.0658	0.3047	0.0518	0.0241	0.0827	0.1281	0.0317	0.9223
TSCV3	0.0015	0.3399	0.0295	-0.0042	0.1592	0.1398	0.0113	0.9374

Table II-8

Reliability and Validity Summary

Reliability			
Indicator Reliability	Outer loadings	All above 0.65 (except HCC)	Table II-3
Internal Consistency Reliability	Composite Reliability	All above acceptable cutoff 0.7	Table II-4
	Cronbach alpha	All above 0.6 cutoff[12]	Table II-4
Validity			
Convergent Validity	AVE numbers	All above the cutoff of 0.5 or higher (Bagozzi and Yi, 1988)	Table II-5
Discriminant Validity	AVE and latent variables correlations	Fornell and Larcker (1981) suggest that the "square root" of AVE of each latent variable should be greater than the correlations among the latent variables	Table II-6
	Cross loadings	No major cross loadings (< 0.2 from main loading)	Table II-7

[12] With the exception of Human Capital Complementarity as discussed in-text

Table II-9

R squared, Communalities and GoF

Endogenous Variable	R^2	Communality
Incremental Inn. Capability	0.3495	0.5384
Radical Inn. Capability	0.3639	0.7623
Goodness of Fit	**48.1%**	

Table II-10

Hypotheses Testing Results

Hypothesis	Path	Path Coefficient	T Statistics	2 Tailed p Value	1 Tailed p Value
H1	**Dominant Organizational Capital -> Incremental Innovativeness**	-0.236	1.392	0.1642	0.0821 *
H2	**Human Capital Related Diversity -> Radical Innovativeness**	-0.188	2.2458	0.0249 **	0.0125 **
H3a	**Power Exercise -> Incremental Innovativeness**	-0.060	0.5711	0.5681	0.2840
H3b	**Dominant Organizational Capital * Power Exercise -> Incremental Innovativeness**	-0.243	0.8427	0.3996	0.1998
H4a	**Power Exercise -> Radical Inn**	-0.184	1.963	0.0499 **	0.0250 **
H4b	**HRD * Power Exercise -> Radical Inn**	0.175	1.8625	0.0628 *	0.0314 **
H5a	**SC Valuation -> Inc. Inn**	0.287	3.6384	0.0003 ***	0.0001 ***
H5b	**SC Valuation -> Radical Inn**	0.194	2.3635	0.0183 **	0.0091 ***

***p < 0.01, **p < 0.05, *p < 0.1

Table II-11

Results for the Decomposed Model

Path	Path Coefficients	T Statistics	2 Tailed p Value	1 Tailed p Value
Total HC -> Radical Inn	-0.102	1.679	0.0935 *	0.0467 **
HC Comp -> Radical Inn	-0.17	1.308	0.1912	0.0956 *
Org Similarity -> Inc. Inn	0.061	0.435	0.6637	0.3318
OC Gap -> Inc. Inn	-0.239	2.819	0.0049 ***	0.0024 ***

***p < 0.01, **p < 0.05, *p < 0.1

10. FIGURES

Figure II-1

Model Summary

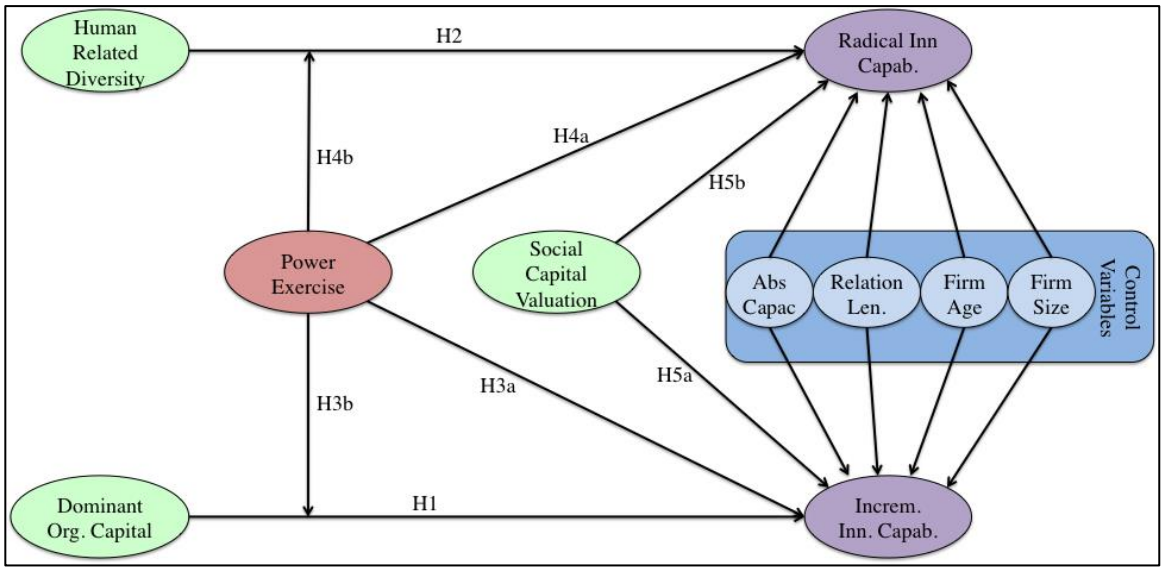


Figure II-2

The Two-Step Approach (Ciavolino & Nitti, 2009)

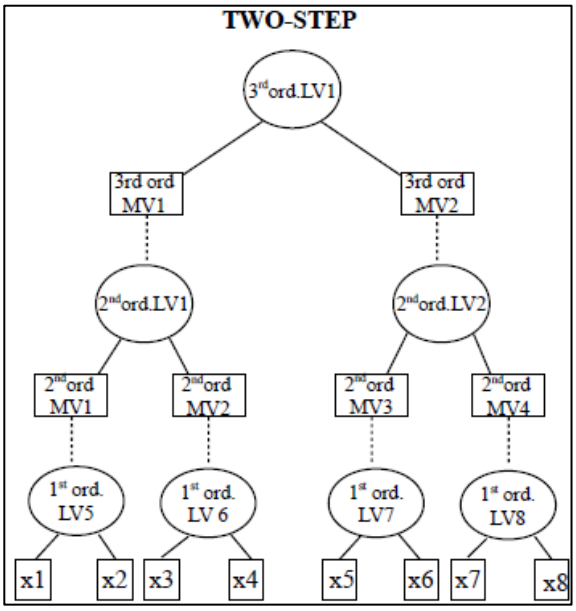


Figure II-3

PLS Analysis Stage I

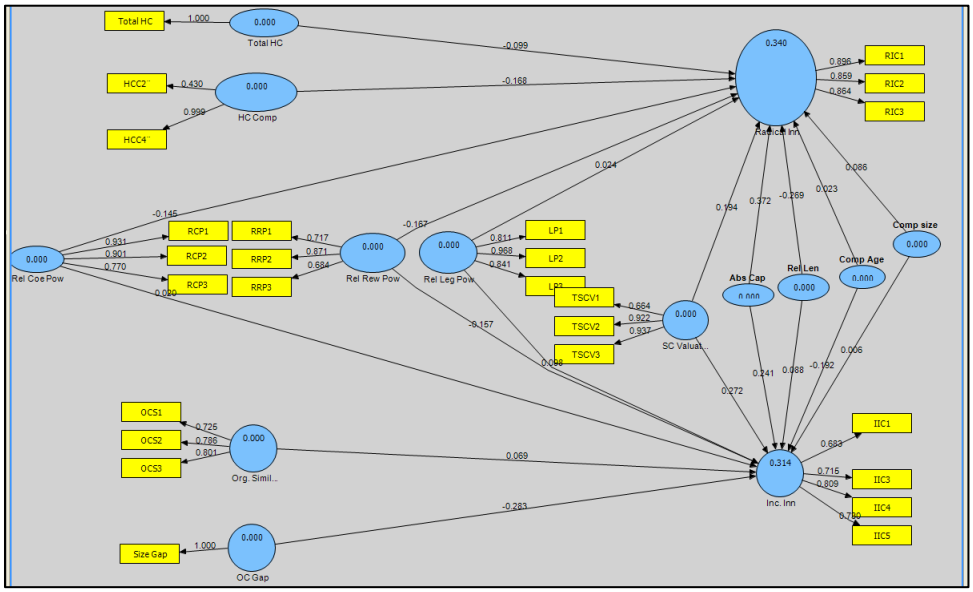


Figure II-4

Stage II: Path Coefficients

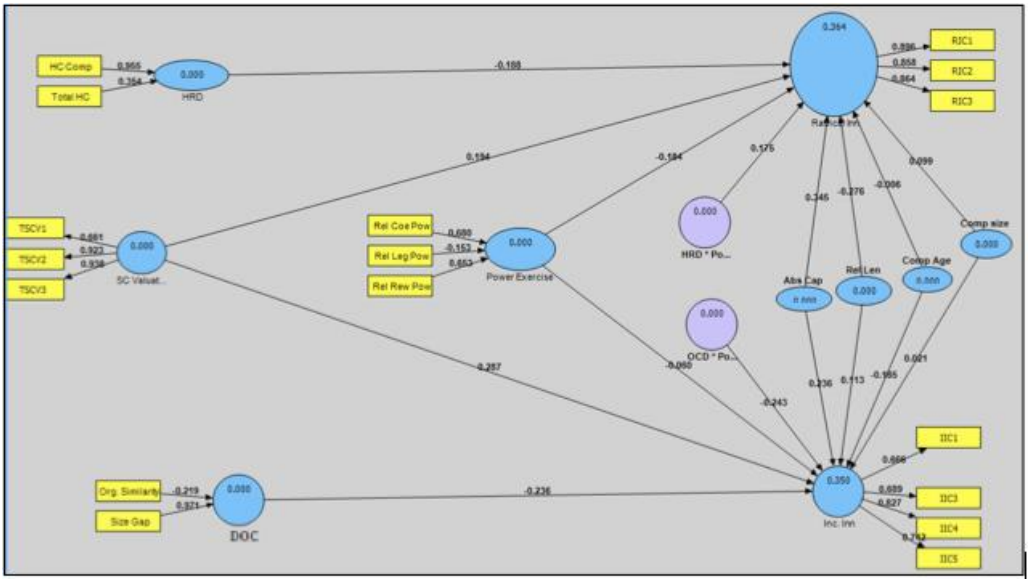


Figure II-5

Stage II: Bootstrap Results

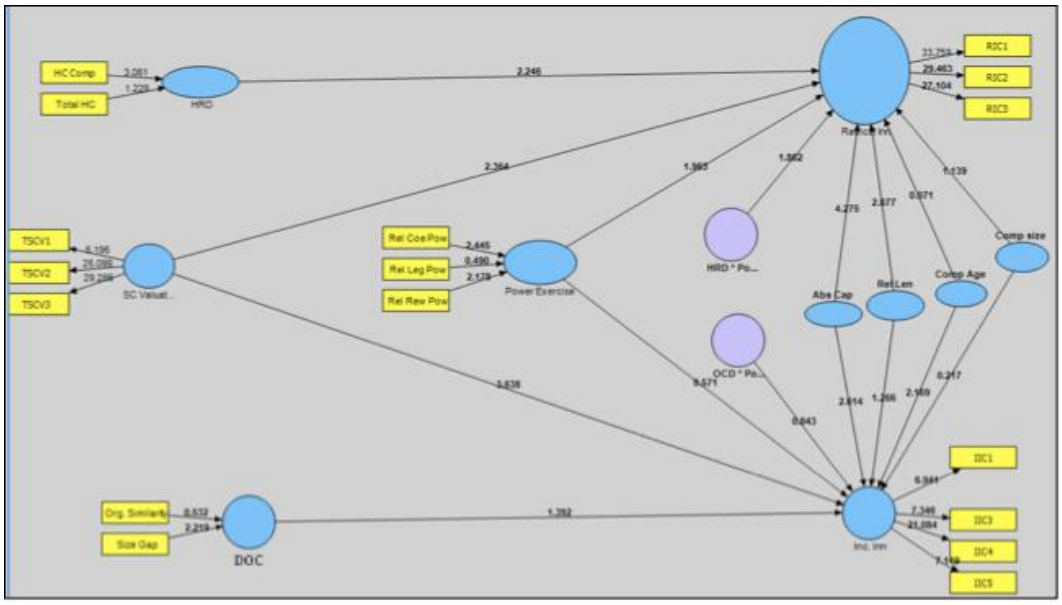
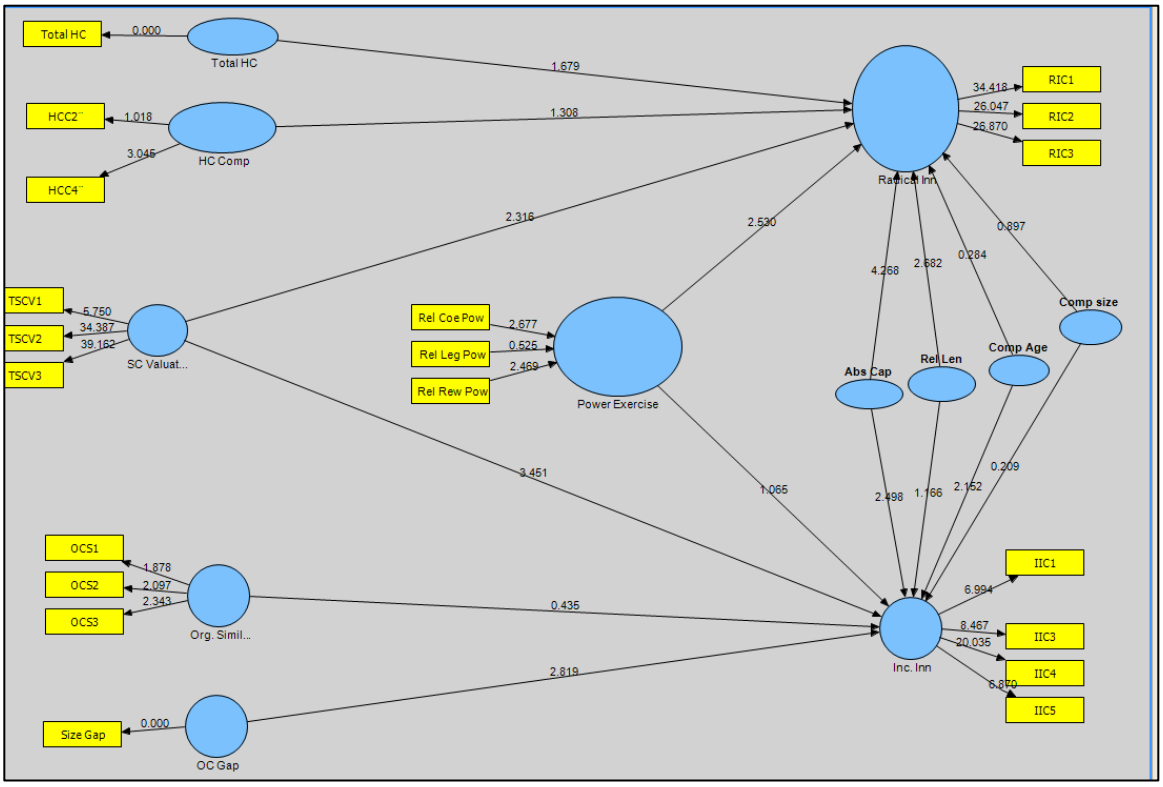


Figure II-6

Decomposed Model Bootstrap Results



APPENDICES

Appendix II-A

Invitation Letter

How can firms in a supply chain partnership increase their innovation capabilities through managing their knowledge? This is the focus of a research project being conducted at Wilfrid Laurier University, and we invite you to participate in a survey on this topic. It is hoped that the results of this study will help you identify the knowledge and power properties necessary in your supply chain partners to increase innovation. This survey is part of a more comprehensive study that examines the types of knowledge that supply chain partners should have to jointly make innovative products and processes. This research is carried out by doctoral student Eman Nasr at Wilfrid Laurier University, under the supervision of Dr. Kalyani Menon and Dr. Hamid Noori and is supported by Social Sciences and Humanities Research Council (SSHRC).

The survey should take around 15 minutes. It will ask questions regarding your relationships with a supplier that you are knowledgeable about and with whom there has been some recent joint work (or attempt for joint work) on product or process improvements. Questions will ask about knowledge issues related to your company and your supplier's company (ex. similarity of knowledge, processes and patents), discrepancy in power that may exist between the two of the companies, and joint abilities to innovate. You will not be required to identify your supplier. Response to survey questions will be taken as your consent that your response be used in this research. If you do not know the answer to an item, please leave this item blank. If you think you do not have the kind of information asked in this survey, please feel free to pass the survey along to the appropriate person in your company. If you choose to participate in this study, you will be sent a certificate of appreciation for contributing to academic research, signed by the director of PhD and Research-based programs in Wilfrid Laurier University. Upon completion of the study, you will also be provided a summary of results.

Your responses will be totally anonymous. Upon submitting your responses, you will be redirected to provide identification information required to customize and send the letter of appreciation. This identification will be kept completely separate from responses. Responses will only be used in aggregation (i.e. to compute statistics like average), with a total of around 200 full responses expected. Moreover, the data will be stored indefinitely on a password-protected computer. You have the right to decline to participate, withdraw from the study at any time, omit any question(s)/ procedure(s) you choose without penalty and without loss of benefits to which you are otherwise entitled. Please also note that the data will be collected using an online survey, the confidentiality and privacy of data cannot be guaranteed during web transmission. However, the survey provider is very well secured through Application-level, Network-level, and their Physical facilities. Because the survey provider is a U.S.-based company, data may be subject to the Patriot Act.

For any questions about the study, please contact the researcher, Eman Nasr, Wilfrid Laurier University, at phone: (519) 884-0710 extension 2846, or at nasr7080@mylaurier.ca; or one of her supervisors: Dr. Kalyani Menon (kmenon@wlu.ca), and, Dr. Hamid Noori (hnoori@wlu.ca). This research has been approved by the Research Ethics Board at Wilfrid Laurier University, approval number #3606. If you feel your rights as a participant in research have been violated during the course of this project, you may contact Dr. Robert Basso, Chair, University Research Ethics Board, Wilfrid Laurier University, (519) 884-1970 extension 5225, or rbasso@wlu.ca. For your records, please print a copy of the information provided herein.

Appendix II-B

Measurement Items

Human Capital Complementarity:

Please indicate the extent to which employees of the two companies (yours and your supplier's) have complementary expertise and skills by expressing your agreement with the following statements. Complementary skills are different, supplement one another, do not overlap, and co-exist in producing multiple products (1=Strongly Disagree, 3= Neither Agree Nor Disagree, 5=Strongly Agree)

- Employees of the two companies have complementary types of skills.
- Employees of the two companies are bright and creative in the same areas.
- Our employees have expertise in jobs and functions that complement those of supplier's employees.
- Employees of the two companies can develop new ideas and knowledge in exactly the same areas.

Organizational Capital Similarity

How do you compare your firm with the supplier on the following items? (1=Extremely different, 2=Moderately different, 3=slightly different, 4=slightly similar, 5= Moderately similar, 6=Extremely Similar)

- Organizational culture.
- Managerial structure and decision making process.
- Fields where we patent and license.
- Documentation style in manuals and databases.

Total Social Capital Valuation

Company Social Capital Valuation

My company perceives higher profitability when: (1=Strongly Disagree, 3= Neither Agree Nor Disagree, 5=Strongly Agree)

- The relationship with the supplier is characterized by close, personal interaction.
- The relationship with the supplier is characterized by mutual respect.
- The relationship with the supplier is characterized by mutual trust.

Supplier Social Capital Valuation

The supplier perceives higher profitability when: (1=Strongly Disagree, 3= Neither Agree Nor Disagree, 5=Strongly Agree)

- The relationship with our company is characterized by close, personal interaction.
- The relationship with our company is characterized by mutual respect.
- The relationship with our company is characterized by mutual trust.

Incremental Innovative Capability

The following items address small changes and refinements from joint projects with your supplier (incremental innovations). How would you rate your joint ability with the supplier to produce the following? (1=Very Low, 5=Very High)

- Improvements to prevailing product/ service lines.
- Small improvements on the current processes.
- Extensions to your existing expertise in prevailing products/services.
- Changes that enrich the way you currently compete.
- Extensions to technologies in scope or type of usage.

Radical Innovative Capability

The following items address highly pronounced changes from joint projects with your supplier (radical innovations). How would you rate your joint ability with the supplier to produce the following? (1=Very Low, 5=Very High)

- Significant changes that make your prevailing product/service lines obsolete.
- Innovations that fundamentally change your prevailing products/services.
- Innovations that make your existing expertise in prevailing products/services obsolete.

Supplier Reward and Coercive Power

Supplier Reward Power

How far would the supplier do the following to encourage your company to implement ideas suggested? (0=N/A, 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree)

- Supplier offers incentives to our firm when we are reluctant to cooperate with a new program.
- Supplier will favor us on other occasions if we go along with their requests.
- Supplier offers us rewards so we will go along with their wishes.

Supplier Coercive Power

- If we do not do as they ask, we will not receive very good treatment from the supplier.
- If we do not agree with the supplier's suggestions, they could make things difficult for us.
- The supplier makes it clear that failing to comply with their requests will result in penalties against us.

Company Reward and Coercive Power

Company Reward Power

How far would your company do the following to encourage the supplier to implement ideas suggested? (0=N/A, 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree)

- Our company offers incentives to the supplier when they are initially reluctant to cooperate with a new program.
- Our company will favor the supplier on other occasions if they go along with our requests.

- Our company offers the supplier rewards so they go along with our wishes.

Company Coercive Power

- If the supplier does not do as we ask, they will not receive very good treatment from us.
- If the supplier does not agree with our suggestions, we can make things difficult for them.
- Our company makes it clear that failing to comply with our requests will result in penalties against the supplier.

Legal Power

Please indicate to what extent you or your supplier refer to legal agreements by answering the following: (-2=Done much more by supplier; -1= Done slightly more by supplier; 0= Not done by any of us, Done by us and supplier equally; 1=Done slightly more by our firm; 2=Done much more by our firm)

- Referring to the terms of our contract to gain compliance on particular requests.
- Making a point to refer to our legal agreement when attempting to influence the other.
- Using sections of our formal agreement as a "tool" to get one to agree to the other's demands.

Appendix II-C: Descriptive Statistics

Variable #1 (Respondent Tenure)			
Count	105	*Skewness*	-0.09105
Mean	2.58095	*Skewness Standard Error*	0.23347
Mean LCL	2.30444	*Kurtosis*	1.48304
Mean UCL	2.85747	*Kurtosis Standard Error*	0.45392
Variance	1.4381	*Alternative Skewness (Fisher's)*	-0.09238
Standard Deviation	1.19921	*Alternative Kurtosis (Fisher's)*	-1.53236
Mean Standard Error	0.11703	*Coefficient of Variation*	0.46464
Minimum	1.	*Mean Deviation*	1.08662
Maximum	4.	*Second Moment*	1.4244
Range	3.	*Third Moment*	-0.15479
Sum	271.	*Fourth Moment*	3.00895
Sum Standard Error	12.28821	*Median*	3.
Total Sum Squares	849.	*Median Error*	0.01431
Adjusted Sum Squares	149.5619	*Percentile 25% (Q1)*	1.
Geometric Mean	2.25658	*Percentile 75% (Q2)*	4.
Harmonic Mean	1.92661	*IQR*	3.
Mode	4.	*MAD*	1.
Variable #2 (Company Size)			
Count	105	*Skewness*	-2.0979
Mean	4.5619	*Skewness Standard Error*	0.23347
Mean LCL	4.35735	*Kurtosis*	6.61781
Mean UCL	4.76646	*Kurtosis Standard Error*	0.45392
Variance	0.787	*Alternative Skewness (Fisher's)*	-2.12843
Standard Deviation	0.88713	*Alternative Kurtosis (Fisher's)*	3.85558
Mean Standard Error	0.08657	*Coefficient of Variation*	0.19446
Minimum	1.	*Mean Deviation*	0.65923
Maximum	5.	*Second Moment*	0.7795
Range	4.	*Third Moment*	-1.44381
Sum	479.	*Fourth Moment*	4.02112
Sum Standard Error	9.09036	*Median*	5.
Total Sum Squares	2,267.	*Median Error*	0.01059
Adjusted Sum Squares	81.84762	*Percentile 25% (Q1)*	5.
Geometric Mean	4.43175	*Percentile 75% (Q2)*	5.
Harmonic Mean	4.21969	*IQR*	0.E+0
Mode	5.	*MAD*	0.E+0
Variable #3 (Company Age)			
Count	105	*Skewness*	-1.06859
Mean	4.15238	*Skewness Standard Error*	0.23347
Mean LCL	3.87587	*Kurtosis*	2.79469
Mean UCL	4.42889	*Kurtosis Standard Error*	0.45392
Variance	1.4381	*Alternative Skewness (Fisher's)*	-1.08414
Standard Deviation	1.19921	*Alternative Kurtosis (Fisher's)*	-0.15604
Mean Standard Error	0.11703	*Coefficient of Variation*	0.2888
Minimum	1.	*Mean Deviation*	1.03329
Maximum	5.	*Second Moment*	1.4244
Range	4.	*Third Moment*	-1.8166
Sum	436.	*Fourth Moment*	5.67018
Sum Standard Error	12.28821	*Median*	5.
Total Sum Squares	1,960.	*Median Error*	0.01431
Adjusted Sum Squares	149.5619	*Percentile 25% (Q1)*	3.
Geometric Mean	3.90987	*Percentile 75% (Q2)*	5.
Harmonic Mean	3.56335	*IQR*	2.
Mode	5.	*MAD*	0.E+0

Appendix II-C (continued): Descriptive Statistics: Industry Distribution[13]

Industry Code	Industry Name	What it includes	Number of Points	Percentage
CON	Construction	Construction contractors (238), industrial building construction (236210)	5	4.76%
EEM	Electrical and Electronics Manufacturing	Computer and electronic product manufacturing (334), Electrical equipment, appliance and component manufacturing (335)	13	12.38%
FM	Food Manufacturing	Food (311), consumer packaged goods (one point)	8	7.62%
HM	Healthcare Manufacturing	Pharmaceutical and medicine manufacturing (325410), medical equipment manufacturing (339)	12	11.43%
IE	Information and Entertainment	Telecom (517), Gaming, tourism, restaurants	7	6.67%
MMM	Metal Manufacturing	Metal recycling, machinery manufacturing (333), primary metal manufacturing (331), fabricated metal manufacturing (332)	11	10.48%
OGM	Oil and Gas Manufacturing	Mining, quarrying, and oil and gas extraction (21), Power generation (221111)	10	9.52%
OTH	Other	Financial services, airline, maintenance, plumbing, aquaculture, transportation & warehousing, (professional, scientific and technical services (541), Shoe repair and retail, wholesale	15	14.29%
TM	Transportation Manufacturing	Transportation manufacturing (336)	11	10.48%
WP	Wood and Plastics	Plastic product manufacturing (3261), wood product manufacturing (321), textile manufacturing (313), paper manufacturing (322)	13	12.38%

[13] NAICS codes shown to the best of their availability

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CHAPTER III. Strategizing Niceness in Co-opetition: The Case of Knowledge Exchange in Supply Chain Innovation Projects

ABSTRACT

In this paper, we take a novel approach to address the dilemma of innovation sharing versus protection among supply chain partners. The paper conducts an exploratory study that introduces factors affecting a firm's optimum supply chain innovation strategy. We go beyond the conventional Prisoners' Dilemma, with its limiting assumptions of players' preferences and symmetry, to explore a larger pool of 2X2 games that may effectively model the problem. After classifying firm types according to collaboration motive and relative power, we use simulation to explore the effects of firm type, opponent type, and payoff structure on repeated innovation interactions (or, equivalently, long-term relations) and optimality of 'niceness'. Surprisingly, we find that opponent type is essentially irrelevant in long-term innovation interactions, and focal firm type is only conditionally relevant. The paper contributes further by introducing reciprocation of strategy type (nice versus mean), showing that reciprocation is recommended, while identifying and explaining the exceptions to this conclusion.

1. INTRODUCTION

Inter-firm knowledge sharing[14] is now an integral part of organizational strategy. Firms pursue opportunities to increase their stock of corporate knowledge (Samaddar & Kadiyala, 2006) while sharing the costs and risks of knowledge creation (Tether, 2002). Nevertheless, the threat that unintended knowledge spillovers will diminish competitive advantage still persists (Ding & Huang, 2010). In particular, when "fine-grained tacit knowledge" is to be shared, the increasing preference for informal, as opposed to legal, safeguards elevates this risk (Lee & Johnson, 2010; Nair, Narasimhan, & Bendoly, 2011). We take the case of supply chain knowledge sharing between the participative members as a particular case to further discuss this dilemma.

As supply chain knowledge exchanges have become increasingly indispensible (Eng, Chew, & Lee, 2014), a firm's decision to share part of its internal knowledge with other members of the chain may be encouraged, but nonetheless partners must be trusted not to leak the shared knowledge to the competition. Thus, the risk of horizontal leakage of knowledge (to competition) is inherent in vertical sharing (with supply chain partners). In this context, the unintended knowledge spillover problem becomes each firm's *deliberate* choice whether or not to leak its partner's knowledge to that partner's competition (e.g., a shared supplier may pass a manufacturer's development plans to competing manufacturers). Because the outcome depends on the decisions of all parties, this multi-decision-maker problem can be effectively modeled as a game (Nagarajan & Sošić, 2008). We, therefore, adopt a game-theoretic perspective in an exploratory study of supply chain knowledge exchanges, to address whether a firm should:

(1) readily share its knowledge with a partner; and/or

(2) use partner's knowledge in other linkages.

For the most part, the literature on knowledge sharing has dichotomized this challenge as the choice to be a "good partner" or not (Hamel, 1991), or, more pointedly, as the choice to cooperate or defect (Nair, Narasimhan, & Choi, 2009). This knowledge-sharing dilemma is also known as the "boundary paradox" (Quintas, Lefrere, & Jones, 1997).

[14] Knowledge sharing and knowledge exchange are used interchangeably.

We focus on a knowledge-sharing problem involving two firms (or players) in a supply chain. In our model, the firms have shared knowledge (e.g., innovation projects such as new product development), and each has the option of sharing it without the partner's consent or keeping it within the partnership. Because each player must choose one of two alternatives, the relationship between the two players can be modeled as a 2×2 game, in which each player chooses (simultaneously) whether to cooperate or defect. The best known of these games is Prisoners' Dilemma, but there are many others in which the players' values are different (Kilgour & Fraser, 1988; Rapoport & Guyer, 1978; Robinson & Goforth, 2005). In our view, the assumption of symmetric player motivations inherent in the Prisoners' Dilemma payoff structure limits the applicability of the model, and does not facilitate an understanding of the relationship of partners' preferences and actions.

Our aim in this paper is to highlight a broader class of symmetric and asymmetric 2×2 games that can model the knowledge-sharing dilemma among supply chain partners, in the context of joint innovation projects. Firms strive to involve supply chain partners in innovation activities in multiple ways including strategic commitment to price (Gilbert & Cvsa, 2003), subsidies provision (Kim, 2000), or direct exchanges of knowledge. We here focus on the latter to study decisions regarding incoming and outgoing knowledge flows, shedding light on how the different types of players (firms) interact by relaxing several of the assumptions of Prisoners' Dilemma. For this purpose, we consider the six player types suggested by Perlo-Freeman (2006: 5). *Cooperate-Defect (CD) Games* are 2×2 games in which

> *"... for each player X, there exists a strategy of the other player, which we call 'Co-operate', such that for each strategy for player X, he prefers the other player to choose Co-operate. We call the other strategy for each player 'Defect'."*

In other words, whatever X chooses, he/she prefers that partner Cooperate. Restricting attention to CD games enables us to classify firms along two dimensions:

(1) Collaboration motive: What is the firm's most preferred outcome?

(2) Relative power: Which outcome does the firm prefer to avoid the most?

The answers to these questions determine the player type. For example, a prisoner is a firm that prefers to defect (while partner cooperates, of course) and least prefers to cooperate (while partner defects). Thus we think of a prisoner as an aggressively

exploitative firm that most prefers to defect and least prefers to be suckered. The interaction of two prisoners is a Prisoners' Dilemma. The other five types are fully opportunistic, fearfully exploitative, fair, good and moral.

We see CD games as particularly relevant to the supply chain knowledge-sharing dilemma in the short term, as each firm always prefers that its partner cooperate (maintain secrecy) rather than defect (expose secrets). We build on Perlo-Freeman's definitions to characterize firms of different types and study their behaviors in one-time joint innovation projects.

To address long-term relationships, we investigate the effect of repetition of the game on firms' choices and outcomes using MATLAB simulation. We adopt Axelrod's (1984) classification of long-term strategies as 'nice' or 'mean' according to their approach to supply chain relations, trustful or distrustful. A 'nice' firm never defects, except when provoked (defected against), whereas a 'mean' firm may defect without provocation. In particular, we are interested in conditions when sequences of cooperation might occur, and when they are vulnerable to unprovoked defection.

The issue of provoked versus unprovoked defection carries a particular relevance to the supply chain, where communicating a policy of defection only when provoked would seem to signal fairness and trustworthiness, while the threat of unprovoked defection signals untrustworthiness. Managers tend to consider inter-firm relationships as polar opposites, either entirely cooperative or entirely competitive (Klein, Rai, & Straub, 2007). In this study, we explore the conditions under which being trustful (nice) versus distrustful (mean) is advisable (see Rousseau, Sitkin, Burt, & Camerer (1998) for a review of inter-firm trust).

This paper provides a relevant and timely expansion of the horizon of supply chain innovation games beyond Prisoners' Dilemma. We introduce a pool of possible knowledge interactions by firms showing how they could be strategized in a supply chain. We also build on Axelrod's (1984) findings on direct reciprocation (the famous TIT FOR TAT strategy) by introducing reciprocation of *strategy type*. One interesting finding is that the superiority of TIT FOR TAT is not universal, but depends on the relative gain from changing the opponent's action versus the cost of changing one's own. We identify seven payoff categories that help us explore the effect of different

motivations – gaining the greatest reward versus avoiding the worst punishment in exchange of knowledge between two firms in a supply chain.

2. BACKGROUND/ LITERATURE REVIEW

2.1 The Joint Innovation Dilemma

The joint innovation process (e.g., in supply chain) is a collaborative relationship in which organizations collectively implement a knowledge creation endeavor, sharing the expenses and the benefits of the newly created knowledge according to a mutually agreed rule (Samaddar & Kadiyala, 2006). In this process, participating firms contribute useful knowledge to this pool, building up a "knowledge repository" retrievable by all members (Cress & Martin, 2006). For the endeavor to succeed, participating firms must allocate and share adequate resources (Samaddar & Kadiyala, 2006).

The conventional wisdom regarding collaborative knowledge creation generally directs firms to be "good partners" by being open and contributing knowledge to the shared pool. Hamel (1991) was the first to question this advice, suggesting that inter-firm collaboration can develop into a "race to learn", in which a firm intends to "acquire" its partner's skills as opposed to merely accessing them. The idea was that "good partners" with high transparency and collaborative intent tend to be exploited by opportunistic partners with lower transparency and competitive intent (Hamel, 1991). Larsson, Bengtsson, Henriksson, and Sparks (1998) build on this analysis, using a game-theoretic perspective, by developing a collective learning framework that explains both negative and positive learning processes. The authors highlight the distributive dimension and its effect on the appropriation of joint learning by individual organizations.

Consequently, there is a trade-off between the integrative and distributive dimensions of collaborative knowledge creation (Larsson et al., 1998). Quintas et al. (1997) referred to this problem as "the boundary paradox"; where borders must be open for knowledge to flow, but core strategic knowledge, upon which survival depends, must be preserved. On similar grounds, Das and Teng (1998) define relational risk in terms of the probability that a partner does not cooperate, instead acting opportunistically and misusing the acquired knowledge.

Given the existence of both collaborative and competitive dimensions, joint innovation projects have often evolved into "mixed-motive" relations (Parkhe, 1993). In some cases, abundance of access to a firm's knowledge has *created* new competitors (Arruñada & Vázquez, 2006). In others, leakage effects allowed the imitators to profit *more* from innovations than the original commercializers (Teece, 1986). Once a firm shares valuable and strategic knowledge externally, its ability to control access to this knowledge is severely compromised (Anand & Goyal, 2009). There is an obvious imperative to manage organizational knowledge strategically in order to optimize its flow.

The literature suggests few ways to deal with the tension between sharing and protecting knowledge. Trust is one of the most significant ways of reducing partners' opportunistic behavior (Das & Teng, 1998; Norman, 2004; Zaheer, McEvily, & Perrone, 1998). Empirically, it has been shown that when firms build relational capital in conjunction with an integrative approach to managing conflict, they are able to simultaneously learn and protect (Kale & Singh, 2000). Other protection mechanisms include: (1) making company personnel aware of the need to protect certain knowledge and identifying the knowledge that needs protecting; (2) walling off critical knowledge from the joint project; and, (3) using contractual mechanisms that specifically identify proprietary data, as opposed to information that can be shared (Norman, 2001).

2.2 Prisoners' Dilemma: Knowledge Exchange, Co-opetition and Social Dilemmas

The simultaneous motivation to cooperate and compete with the same business partner has been labeled as "co-opetition" (Brandenburger & Nalebuff, 1995, 1996). Even though the literature has mostly, if not exclusively, referred to *horizontal* co-opetition (with direct competitors), we here acknowledge the presence of competitive forces with supply chain partners, who typically work also with competitors, and may leak strategic knowledge. Heide and Miner (1992) see buyer-supplier interactions as competitive and best represented by Prisoners' Dilemma, but they take an operational perspective (they define competition in terms of pricing decisions, inventory costs, and delivery terms) as opposed to the knowledge-based perspective we adopt here. The opportunity to create rents through simultaneous competition and cooperation has been

conceptually examined using a game-theoretic lens (Brandenburger & Nalebuff, 1995; Heide & Miner, 1992; Lado, Boyd, & Hanlon, 1997; Parkhe, 1993).

More specifically, co-opetitive knowledge sharing interactions have been seen as instances of social dilemmas (Cabrera & Cabrera, 2002; Quigley, Tesluk, Locke, & Bartol, 2007). "Social dilemmas are situations in which each member of a group has a clear and unambiguous incentive to make a choice that -- when made by all members -- provides poorer outcomes for all than they would have received if none had made the choice" (Dawes & Messick, 2000). In such collaborative interactions, a better-for-all outcome may not be fully attainable because of individual temptations to pursue "selfish" goals while free riding on others' contributions (Y. Wu, Loch, & Ahmad, 2011). The dilemma, therefore, represents a tension between individual and collective rationality, where individual rationality leads to collective irrationality (Kollock, 1998; Wang, Gwebu, Shanker, & Troutt, 2009). Unfortunately, the solution to games involving social dilemmas includes at least one deficient equilibrium, i.e., there is always another outcome that is better for everyone (Kollock, 1998).

Prisoners' dilemma is the two-person social dilemma that has received the most attention in the context of knowledge sharing (Kollock, 1998). "The essence of the dilemma is that each individual actor has an incentive to act according to competitive, narrow self-interest even though all actors are collectively better off (i.e., receive higher rewards) if they cooperate" (Cable & Shane, 1997). Prisoners' Dilemma neatly illustrates the rationale of innovation-related co-opetition from a game-theoretic perspective (Ritala & Hurmelinna-Laukkanen, 2009). In most, if not all, co-opetitive situations, it is advantageous for each partner to "defect" and pursue individual interests at the expense of others (Hennart, 1991; Kogut, 1989). Firms may defect by withholding knowledge, not fulfilling promises, stealing a partner's proprietary technology, or hiring the partner's key personnel (Parkhe, 1993). The complexity of the problem is exacerbated by the further difficulty to observe defections, i.e., partner deciding to withhold rather than share knowledge (Gächter, von Krogh, & Haefliger, 2010).

2.3 Repeated/ Iterated Prisoners' Dilemma

Iterated Prisoners' Dilemma represents multiple firm interactions on joint innovation projects. The main significance of the iterated Prisoners' Dilemma is the fact

that repeated interaction exposes one's strategy, which may overcome the dominance of defection, producing mutual cooperation. Players are mindful of the fact that observed actions will be reciprocated and are therefore motivated to signal cooperative behavior (Z. Wu, Choi, & Rungtusanatham, 2010). In an iterated prisoners' dilemma, decisions in one round affect decisions (and outcomes) of subsequent rounds, altering the utility of each cooperation/ defection decision (Rokkan, Heide, & Wathne, 2003). The most influential work on the iterated prisoners' dilemma is Axelrod's *The Evolution of Cooperation* (1984). In this work, Axelrod reports on two tournaments, in which subject matter experts were invited to submit strategies for an iterated Prisoners' Dilemma tournament. The winning strategy, TIT-FOR-TAT, carries the main message of his work: It is beneficial to be seen to reciprocate the actions of the partner, be they cooperation or defection.

Furthermore, Axelrod delivers three more suggestions on how to do well in an iterated prisoners' dilemma, namely: (1) Realize that the aim is not to destroy the opponent, and therefore refrain from comparing payoffs or being envious, (2) Be mindful of opponent's adaptation by refraining from overly complex strategies that cannot be distinguished from randomness, and finally, (3) Be "nice." Axelrod made the striking claim that the single best predictor of the performance of a strategy is its "niceness", i.e., whether it could ever defect first. This result will be challenged and further investigated in this chapter.

Although Axelrod's work was "far and away the most influential study of strategic solutions to social dilemmas" (Kollock, 1998), it did receive a number of criticisms. The reciprocal altruism represented by TIT-FOR-TAT was found to perform very badly in noisy environments and to be extremely vulnerable to disturbances (Molander, 1985). Even though Axelrod never claimed TIT-FOR-TAT to be a universally superior strategy regardless of opponent or conditions, critics still argued that other strategies, including those that allow for mutations, forgiveness, and different kinds of reciprocity, frequently work better (Brams & Kilgour, 2012; Molander, 1985; Nowak, 2006; Sigmund, 2010). Below we confirm that TIT-FOR-TAT performs well, but not necessarily best, in an iterated context. As will be shown later, our simulation results confirm that other strategies score higher on average.

2.4 A Gap in the Literature: Beyond Prisoners' Dilemma

Very few studies have gone beyond Prisoners' Dilemma to acknowledge the representativeness of other 2X2 games (e.g., Chicken and Stag Hunt games) to the knowledge-sharing dilemma. Scholars have sometimes recognized the potential of these other games but there has been little further analysis (Parkhe, 1993; Ritala & Hurmelinna-Laukkanen, 2009). Kollock (1998), for instance, states that the three games of: Prisoner's Dilemma, Chicken and Assurance (Stag Hunt) are the key two-person social dilemma games, and even argues that the latter is a more accurate model of some social dilemmas. The dynamics of these games have been less explored; here we take a step toward filling this void by applying them in the context of joint innovation practices in supply chains.

The most notable work on a wider pool of relevant games that apply to the context of collective action (including knowledge-sharing relations) is a working paper by Perlo-Freeman (2006) on what he calls the 'Co-operate-Defect' games, as defined in the introduction. In such games, a player always prefers that the opponent Cooperate rather than Defect.

The attractiveness of the aforementioned games lies in their relevance to several contexts including supply chain joint innovations, in which firms always prefer their partner to 'cooperate'. Perlo-Freeman finds that players in 'cooperate-defect' games can be classified into six types based on their preference orderings: prisoner, chicken, deterrer, appeaser, warrior and pacifist. The author further argues that there is no particular reason to assume that players in a game face identical priorities and constraints (i.e., players are not necessarily the same type), so asymmetric games are equally worthy of attention. In our study, we follow Perlo-Freeman's recommendations and consider the whole pool of 'cooperate-defect' games (symmetric and asymmetric) when two firms in a supply chain opt to practice joint innovation.

3. THEORETICAL FOUNDATIONS

3.1 Player Types Framework

Our notation for a cooperate-defect game is shown in Table III-1. The focal player (focal firm for which optimum decisions are studied) is the row chooser. The focal player

decides whether to cooperate or defect. In the context of joint supply chain innovation, cooperation may be viewed as sharing knowledge readily with the project partner and protecting partner's knowledge from reaching its competitors, while defecting is the opposite. The focal player's utilities (payoffs) are as follows:

R: reward (payoff from mutual cooperation)

S: sucker's payoff (from unilateral cooperation)

T: temptation (payoff from unilateral defection)

P: punishment (from mutual defection)

The focal player's opponent is the column chooser. Each player must choose either to cooperate (C) or defect (D). Payoffs must satisfy two conditions (1) $S < R$, and, (2) $P < T$; i.e., focal player prefers opponent cooperation regardless of focal player's choice. This gives rise to six preference orderings, introduced by Perlo-Freeman (2006):

1. Prisoner: $T > R > P > S$
2. Chicken: $T > R > S > P$
3. Appeaser: $R > T > P > S$
4. Deterrer: $R > T > S > P$
5. Warrior: $T > P > R > S$
6. Pacifist: $R > S > T > P$

We think of Perlo-Freeman's six preference orderings as defining six player types with the descriptive names given above. In the context of joint supply chain, they can be classified along the two dimensions of collaboration motive and power. The first dimension, collaboration motive, refers to the preferred outcome from the interaction with a supply chain partner. Three motives are identified:

(1) Race to learn: ($T > R > S$ & P) (orderings 1 and 2), where the focal player's main goal is to induce the opponent to cooperate, yielding either the temptation payoff, which it prefers, or the mutual reward. Such firms are exploitative in the short term. That is, if they do not perceive/ plan for future projects with the partner, they tend to defect in a current knowledge exchange.

(2) Mutual cooperation: ($R > T > S$ & P) (orderings 3 and 4), where the focal player's main goal is truly looking for a two-way cooperation, and if not that then the temptation payoff. Such firms are cooperative in the short term. That is, if they do not

perceive/ plan for future projects with the partner, they tend to cooperate in a current knowledge exchange.

(3) Extreme motives: (either $P > R$ or $S > T$) (orderings 5 and 6), where one of the less preferred outcomes, with payoff S or P, is second in the preference ordering. Such a firm's behavior is determined, even in the long term, regardless of the opponent's choices. That is, the motivation (to cooperate in case of S > T, or to defect in case S > T) is strong enough to dictate the same decision in both short-term and long-term knowledge exchanges.

The second dimension relates to a firm's relative power between the two supply chain partners. Power is a key concept that introduces new motivations to a game (Wolf & Shubik, 1974). It can be defined in terms of several aspects including, the ability to reward or punish an opponent, the cost of exercising rewards or punishments (Wolf & Shubik, 1974), or in terms of opponent replaceability (Kumar, Scheer, & Steenkamp, 1995, 1998). We adopt the latter definition, which is most appropriate to supply chains, where power can be seen as inversely proportional to switching cost (ease and cost of replacing a partner) (Kumar et al., 1998). This is indicated by what a firm would mostly avoid from an interaction, which by assumption must be S or P. If a firm's least possible utility is P, it cannot afford to lose a deal and would rather be suckered, it signals low power, or a high need for its partner. On the other hand, if a firm's least possible utility is S, it would rather lose the deal than be suckered, signaling higher power and less need for its partner. A framework for firm types is shown in Figure III-1.

It is worth emphasizing that the firm types explained above are commonly encountered in supply chain innovation projects. A prisoner, or an aggressively exploitative partner, can be viewed as a jointly innovating firm in a *race-to-patent*. Such a firm benefits from developing a new product with a partner, but gets even greater return for exclusive patent privileges, and drives away its partner's rights ($T > R$). A two-prisoner interaction (i.e., prisoners' dilemma) represents a two-way race for patent on a jointly developed technology or product, where the greatest payoff is for exclusive rights, followed by shared rights, with total loss of patent rights to partner coming as the worst outcome. An example is Sears Inc., which was benefiting well (by getting reward R) from the exclusive right to sell its supplier's shared product innovation, the "Bionic

Wrench" of "LoggerHead Tools". The company, yet, sought higher temptation payoff (T) from defecting by giving the idea to its offshore tool manufacturer, Craftsman (Collins, 2012).

A chicken, or aggressively exploitative partner, has the same motivations, except that it has much higher dependence on its opponent, making loss of the deal more destructive than giving up patent privilege altogether. In the above example, LoggerHead Tools illustrates a chicken being unable to replace Sears' large orders and missing resources to drag out the lawsuit, leading it to tolerate a defecting partner rather than lose the deal and suffer bankruptcy (Collins, 2012).

Both appeaser and deterrer, equally good and fair partners, enter into a joint project looking for the expanded pool of knowledge and expanded rewards. The difference is that the former's low power means that it nonetheless benefits by contributing more knowledge to the partnership, even if the opponent misuses it ($S > P$). The latter, however, places higher proprietorship value on its knowledge, that it would rather lose the partnership than find that its knowledge has been leaked away ($P > S$).

On the other hand, a warrior, or a fully opportunistic partner, is a very powerful firm that can never be defeated. It wants only deals in which it can suck away partner's knowledge. An example is the largest turbine manufacturer in China, Sinovel Wind Group Co. Ltd., which stopped doing business with one of its suppliers, American Superconductor Corp. (AMSC) after "stealing" intellectually protected technology related to wind turbines (Ailworth, 2011). This signals the *extreme* preference for temptation, followed by ending the deal (T and P are the greatest payoffs) as opposed to any cooperative outcome. Finally, a Pacifist, or moral partner, always benefits from cooperating. This could be a company that prefers losing patent privilege to facing infringement penalties ($S > T$). Such a scenario is common when opponents are well protected legally by intellectual property rights such as the series of lawsuits between Samsung and Apple Inc. (Carare, 2013; Duhigg & Lohr, 2012).

3.2 One Shot Game

How do the player types above behave in a one-shot interaction (equivalently one-time innovation project or at least one in which there is no intent of a future interaction)? Nash equilibrium analysis produces Figure III-2. Only 5 games end up with mutual

cooperation (indicated by the green squares). As expected, a Warrior always defects, and a Pacifist always cooperates, because of their unconditional preference for defection and cooperation, respectively. Similarly, a Prisoner will always defect and an Appeaser will always cooperate in a one-time interaction, as their dominant strategies dictate. As we will show, however, there is a great difference between dominant and unconditionally preferred strategies in the repeated game context. In 16 games there is defection at least from one side, or as part of a mixed strategy. This motivates our subsequent study on the effect of repeated interaction on the one-shot equilibria.

3.3 Repeated Interactions

In a repeated game, a player can be induced to avoid an otherwise dominant strategy. For example, Axelrod (1981, 1984) suggested that in repeated Prisoners' Dilemma players (whom we call prisoners) can be induced to cooperate, despite their one-shot dominant strategy of defection.

Similar to the logic behind a prisoner's behavior, a chicken would prefer to signal cooperative intent in a repeated interaction to induce its partner to cooperate, to avoid the worst outcome. A deterrer can be easily induced by partner's actions, as it prefers to mimic them. Therefore, it is expected that a deterrer will tend to match its partner's actions. Although an appeaser has a dominant strategy of cooperation, still finds $T > S$, so it may try to take advantage. Finally, as suggested by Perlo-Freeman (2006), the unconditionally preferred behaviors of warrior and pacifist cannot be overcome, even in a repeated game. This makes the behavior of the first four types more compelling to test, with the latter pair representing a *null* hypothesis.

In the pool of 10 games among the four *inducible* players, prisoner, chicken, deterrer, and appeaser, we are particularly interested in whether repetition of the games would stimulate cooperative behavior, especially as, in 8 of these games, equilibrium involves defection (Figure III-2). As a first step, we would like to characterize long-term "cooperative behavior" in testable terms, namely as "niceness". Nice strategies are defined by Axelrod (1984) as strategies that never defect first. In a repeated (long-term) interaction, a firm that is pursuing a "nice" strategy defects only in response to opponent's defection. Alternatively, a firm that employs unprovoked defection, even if it is only occasional, is pursuing a "mean" strategy.

Under what conditions is niceness advisable in repeated innovation interactions? The answer may involve several factors, including player type, opponent type, opponent strategy, payoff structure and length of relationship (number of game iterations). In the next section, we will test these factors to assess when nice strategies are superior to their mean counterparts. Simulating the different player types, strategies, and payoff structures will enable us to reach several managerial recommendations regarding cooperative behavior in repeated innovation projects.

4. THE SIMULATION STUDY

Simulation is widely recognized as an "effective pragmatic" research methodology for studying supply chain management issues, especially for problems that are more complex, require detailed analysis, or involve random elements (Nair et al., 2009; Swaminathan, Smith, & Sadeh, 1998). Given the infinitely many possibilities for long-term interaction strategies, as well as the fact that randomness is involved in some of those strategies, simulation is a reasonable and feasible platform for this study. Our aim is to determine what behaviors of prisoner, chicken, appeaser, and deterrer maximize their returns in a repeated-game environment, in games that may or may not be symmetric (i.e., players of the same type). These four player types seem to be most realistic, interesting, and relevant to the supply chain context. Extreme motive relations where firms are completely unadaptable to partner's actions are far from being common, especially in long-term relations. In addition, their lack of adaptability makes them less appealing for long-term analysis.

In particular, we are interested in whether player prospects are affected by repetition of interaction. We use MATLAB to code the playing of the games, and twenty strategies chosen to be as representative as possible. The selection of strategies was informed by a general search on the terms 'Iterated Prisoners Dilemma' and 'Repeated Prisoners Dilemma'. The criteria for selection included that the strategy has been clearly explained in the literature, that it can be classified as 'nice' or 'mean', that it can be matched with an essentially identical strategy of the other classification, and that if is not too complex to code. Although whether a behavior is successful in a game depends on the payoffs, it is yet zero-independent and scale-independent (adding a constant to every

payoff or multiplying all payoffs by the same positive number should not change the results). However, it may well depend on the relative gaps between the payoffs, which we call the payoff structure.

We simulated several payoff structures according to the magnitude of differences among the focal player's payoffs: *S*, *P*, *R* and *T*. The structure is described in terms of the differences between consecutive payoffs, starting with the lowest. Gaps can be either 'small', S, or 'big', B, giving rise to seven broad categories of payoff patterns, SSS or BBB, where differences are equal (we call this one EQUI), SBB, BSB, BBS, BSS, SBS, and SSB. We carried out several simulations in which the ratio of B to S ranged from 2 to 400. Although in some cases, our results depended on the payoff pattern, the specific value of the ratio of B to S did not seem to affect our results significantly.

The main game adapts each set of payoffs to each of the four player types: prisoner, chicken, deterrer and appeaser, according to the player's preference ordering. Each player then plays a sequence of games with every player type, using each of the 20 strategies defined in Table III-2. The result is shown in terms of the ranking of the 20 strategies for each player, from best to worst. For each player, three rankings are shown: (1) rankings of all strategies against the 10 nice opponents only; (2) rankings of strategies against the 10 mean strategies only; and, (3) ranking of strategies against all 20 opponent strategies. Modules are subsequently programmed to assess the following:

(1) Which factors, firm type, opponent type, and/or payoff structure, determine the optimum innovation strategy for firms in long-term interactions?

(2) In what way can determinants from (1) dictate niceness in innovation strategies?

Results of the above questions are discussed in section 5.

4.1 Exploring Determinants of Optimum Strategy

To assess whether opponent type affects advisability of strategies, we simulated the 10 games allowing each player type to play 600 iterations with each opponent type. This simulation was carried out for each of the seven payoff structures. Note that exact values for each payoff structure were chosen arbitrarily, as is typical in studies on iterated

prisoner dilemma -- see Axelrod (1984)[15]. Further analysis also proved that within a payoff structure, differences are insignificant (see sub-section 4.2). Kendall's τ (Kendall rank correlation coefficient) was then calculated to make 24 comparisons. Kendall's τ was used as it is a non-parametric, easily calculable, and a fair measure of rank correlation (Kendall, 1938). For example, a prisoner is ranked when playing against the following: another prisoner (PP ranking), chicken (PC ranking), deterrer (PD ranking) and appeaser (PA ranking). Six comparisons are performed to compare each pair of the four prisoner rankings. The same test was performed for the other three players, resulting in 24 comparisons. For all 24 comparisons, rankings are highly correlated with no statistically significant differences. We, therefore, conclude that, all other things being equal, opponent type does not matter in strategy rankings across all player types and all payoff structures.

The same procedure was repeated across payoff structures to compare how player types perform using different strategies against the same opponent type. For example, the four player types were ranked when playing against a prisoner providing: PP ranking, CP ranking, DP ranking, and AP ranking. Six comparisons are performed to compare each two of the four prisoner rankings. The same procedure was applied to the other three players, resulting in 24 comparisons.

4.2 Exploring Determinants of Niceness

This module of the simulation investigates whether nice strategies are superior to their mean counterparts, and what the conditions for their superiority are. The module plays three games to capture rankings for each player across the seven categories of payoff structures (Note that from 4.1 opponent type does not cause any significant difference in rankings so only three games as opposed to ten were simulated). Two payoff structures were simulated within each of the categories to determine whether exact payoff values matter within a category. Rankings are then recorded for each player, throughout several iterations, 300, 400, 500 and 600, to ensure robustness of findings. Firstly, a test was carried out to compare rankings of each pair of payoff values within a

[15] A similar argument applies to the choice of number of iterations. This is commonly arbitrary in the literature. In the context of long term innovation endeavors, 600 interactions readily cover what companies consider to be 'long-term'.

category of payoffs. Kendall's τ was used to make the comparison. No difference was significant (see Table III-A1 in Appendix).

The lack of significant difference between payoff values within a category of payoffs justifies restricting our analysis to one set of payoffs in each category. Therefore, the nice versus mean comparison was carried out for one set of payoffs within each payoff category (and across player types) to test for the superiority of nice strategies over their mean counterparts, when playing against (1) only nice strategies, (2) only mean strategies, and (3) a mix of nice and mean strategies. To do so, we performed a Mann–Whitney–Wilcoxon test (a non-parametric two-sided rank sum test) to compare whether nice strategies tend to achieve greater payoffs than their mean counterparts.

5. ANALYSIS OF THE RESULTS

There is no evidence that the rankings of a player's strategies depend on the type of the opponent. In other words, all else being equal, a prisoner (i.e., an aggressively exploitative partner), for instance, has essentially the same strategy rankings whether it plays against another prisoner, a chicken, a deterrer or an appeaser, as long as comparison is made over the same set of strategies (see Table III-A2 in Appendix). This implies that, although in a one-shot interaction actions and outcome are sensitive to opponent type (Figure III-2), in a repeated interaction, advisable actions for a player do not depend on opponent type.

Secondly, by taking a close look at the comparison results among player types (see Table III-A3 in Appendix), it is evident that different player types perform essentially the same in all payoffs except three: SSB, BSS, or BSB. These three payoff structures share the property of having a (relative) middle S, which means that there is a relatively small difference between *T* and *R* on one side (outcomes from opponent cooperating), and, *S* and *P* on the other (outcomes from opponent defecting). This means that within these payoff structures a player gains relatively little by 'training' the opponent to be cooperative. In this case, correlations among rankings of different players (when playing with same opponent) are negative and/or not significant. This implies that, when there is relatively little value in inducing the opponent to cooperate, each player type will be advised differently. Otherwise, the high value from inducing cooperation

unifies advisable strategies across different player preferences. These results suggest that both player type and payoff structure are determinants for optimum innovation strategy.

Moreover, we notice from test results on player type that negative correlations and/or lack of significance are consistent along all three middle S payoff structures when comparison is made between prisoner and appeaser, or between chicken and deterrer. This result is quite intuitive, given that these are the two maximally different pairs, in terms of payoff preference (see Figure III-3). On one hand, a prisoner has *high* power and a *Race to Learn* motivation, whereas an appeaser has *low* power and a *Mutual Cooperation* motivation. On another hand, a chicken has *low* power and a *Race to Learn* motivation, while a deterrer has *high* power and a *Mutual Cooperation* motivation. It is not surprising that rankings are maximally different across each of these two pairs. Below we discuss the results of the module, which investigates whether nice strategies are superior to mean ones.

5.1 General Results: Reciprocation of Strategy Type

Testing the hypothesis that nice strategies are superior to their mean counterparts (at the 0.05 level), we made the following general observations:

1. Nice strategies yield a significantly greater expected payoff compared to their mean counterparts against a nice opponent, regardless of opponent type.
2. Nice strategies do not yield significantly greater expected payoff compared to their mean counterparts against mean opponents, regardless of opponent type.
3. Nice strategies yield a significantly greater expected payoff compared to their mean counterparts against a (balanced) combination of nice and mean strategies, regardless of opponent type.

According to these results, inasmuch as it can be perceived, a player should reciprocate his/ her opponent's *strategy type* as opposed to actions (see Axelrod (1984) on TIT FOR TAT). Even though this reciprocation result contrasts with the underlying assumption of several economic models, conventional game-theoretic models in particular, stating that agents are self-interested, it extends results of *action fairness* or *fair play*. Experiments suggest that cooperative behavior in Sequential Prisoners' Dilemma reflects what is known as "positive reciprocation" (Clark & Sefton, 2001). Moreover, in models of "reciprocal altruism", where cooperation is a best response to

cooperation, and defection a best response to defection, the one-shot equilibrium involves matching (Andreoni & Miller, 1993). Our findings extend results from the literature about reciprocation of partner's action in both repeated and sequential prisoners' dilemma (Axelrod, 1984; Clark & Sefton, 2001; Cooper, DeJong, Forsythe, & Ross, 1996; Eckel & Grossman, 1996; Fehr & Gächter, 1998) by suggesting reciprocation of strategy type (niceness) as a generalized result not applying solely for prisoners but extended to the four player types studied herein. In other words, a firm observing a nice strategy from its innovation partner should also adopt a nice strategy to maximize return. Table III-3 shows samples of typical results for the general reciprocation rule.

5.2 Exception: Relative Versus Absolute Gains from Inducement

The reciprocation results, discussed above, have two main exceptions, depending on the payoff structure. In these two exceptions, a player may abuse nice opponents by pursuing a mean strategy, or may pursue a nice strategy against mean opponents. Table III-4 shows these exceptions, in which previously significant results (at the 0.05 level) are replaced by weakly significant or insignificant *p*-values; previously non-significant results are replaced by either strongly or weakly significant values of p ($p < 0.1$).

These exceptions can be attributed to the relative gain from inducing opponent's cooperation, that is, the benefit of changing one's opponent's actions relative to changing one's own. In the three payoff structures of SSB, BSB, and BSS, it makes relatively little difference whether the opponent cooperates or defects. In this case, the player cares less to induce the opponent to cooperate and may, therefore, pursue a mean strategy even with nice opponents. However, in other payoff structures where it makes a relatively large difference whether the opponent cooperates or defects (namely BBS, SBB and SBS), a player may accommodate its (mean) opponent by pursuing nice strategies.

For the former exception, results that originally showed nice strategies to be significantly better than their mean counterparts now show either weak significance ($0.05 < p < 0.1$) or insignificance. And for the latter exception, results that originally showed that nice strategies are not significantly superior to their mean counterparts now show either strong or weak significance ($p < 0.1$). Table III-4 shows the details of exceptions.

If we take a closer look at Table III-4, we observe a pattern in the (first) "Nice Abuse Exception" regarding player types. A prisoner will always be advised to abuse its

mean opponent when the relative gain rule applies, while an appeaser is never advised to follow such a strategy. This result seems quite intuitive, given the fact that a prisoner is both exploitative and powerful, and may therefore be abusive, while an appeaser is cooperative and powerless, and is not expected to be abusive (see Framework in Figure III-1). As for the other two players, deterrer and chicken, each is either exploitative or powerful, and may be well advised to abuse nice opponents in a single payoff structure. In the SSB payoff, a chicken's biggest (relative) gain is from obtaining *T* by defecting against a cooperative strategy. While in the BSS payoff, a deterrer gains relatively little by moving from unilateral defection (*T*) to mutual cooperation (R), and would, therefore, not be advised to make the move.

In the second exception, the gain from inducing a change in opponent's behavior is substantial (SBB, SBS, and BBS). The substantial middle jump of payoffs from S and P on one side to R and T on the other side motivates niceness, even against mean strategies, hoping to prompt cooperation. A player would try hard to induce cooperation by defecting opponents, ending up with either *R* or *T*. In this case, we say that a player's payoff may depend more on the opponent's action than the player's own action. In the BBS payoff, however, players can still achieve relatively high gains with mean (defective) opponents through changing their own actions and moving between *S* and *P*.

5.3 The Prisoner Base-Case Exception

According to the above conclusions, the base case in which payoffs are equidistant (SSS) should support the general result on strategy reciprocation (5.1). However, we still observe some (weak) evidence that nice strategies are superior to mean, and only for prisoner types. Although this observation is not in line with the relative gains rule, it does confirm the findings of Axelrod (1984), who used equidistant payoffs and concluded that nice strategies perform better than mean ones. We here contend, however, that this is a specific conclusion applicable to prisoners, and does not necessarily apply to other firm types.

6. MANAGERIAL IMPLICATIONS

The results presented in this paper provide several insights regarding strategies of managing joint innovations in supply chains, under several conditions including: (1)

intent of each firm from the joint innovation relation, (2) relative power of each firm, in terms of partner replaceability, and, (3) relative motivations of gaining most reward versus avoiding worst punishment (payoff structure). Together, (1) and (2) define what we call firm "type", which may play a key role in determining the best strategies to pursue in supply chain innovation relations. In these risky venues, where firms' strategic knowledge is at stake, firms may be aggressively exploitative, fearfully exploitative, good, fair, moral or fully opportunistic.

Exploring advisable long-term strategies for a focal firm, one surprising result was the fact that partner's intent and power (i.e., partner type) does not affect the focal firm's advisable strategies. In contrast to one-shot interactions, in long-term interactions, opponent innovation *strategy* is what matters, regardless of its type or preferences from collaboration (Table III-5 summarizes results). On the other hand, the importance of intent and power of the focal firm itself in driving its decisions of what strategy to adopt, is contingent on its motivation to signal cooperative behavior and induce it in its partner. When there is relatively high gain from signaling cooperative behavior, firm type is less important and the different firm types are similarly advised as to what strategies to adopt. However, when the gain from signaling cooperativeness is relatively low, firm types are advised differently and may pursue diverse strategies. This latter conclusion of diversity in advisable strategies is most pronounced among maximally different types of firms, i.e., ones that are different in both power (high versus low) and collaboration intent (mutual cooperation versus race to learn).

Firms that engage in repetition of innovation interactions can induce cooperative behavior, or niceness, in four "inducible" partner types: the fearfully exploitative, the aggressively exploitative, the fair, and the good partners. Our results support the conventional wisdom regarding action reciprocation (by, for example, TIT FOR TAT) and reciprocal altruism by introducing reciprocation of strategies. Companies are advised to pursue cooperative strategies that never defect first, i.e., *nice* strategies, only when opponents pursue similarly cooperative strategies. Otherwise, companies may be well advised to consider defecting.

The above recommendation, however, is subject to conditions related to relative gains from attempting to change partner's actions (See Figure III-4). A firm may abuse a

"good partner" when the relative gain from inducement is insignificant, and it may be nice to be a "bad partner" when the relative gain from inducement is significant. The generalizability of abuse, however, is still subject to the firm's power and the nature of its collaboration motive. Finally, it is worth noting that relative gains from different combinations of actions can be placed into seven broad categories, where differences in behavior within each category are not significant, but differences in behavior across categories are significant.

7. CONCLUSION AND FUTURE DIRECTIONS

This paper presents an exploratory study that highlights a pool of symmetric and asymmetric 2X2 games that can effectively model the knowledge-sharing dilemma among supply chain partners that jointly innovate. We study how the different types of players (firms) interact by classifying them along two dimensions: collaboration motive and relative power. We then proceed using a simulation to study repeated innovation interactions (equivalently long-term relations), exploring the effects of firm type, opponent type, and strategy type (nice versus mean). Our results show the complete irrelevance of opponent type, and the contingent relevance of focal firm type on advisable strategies in long-term innovation interactions. We also extend the literature on action reciprocation (e.g., TIT-FOR-TAT) by promoting reciprocation of strategy type (nice versus mean), naming and explaining three conditions as exceptions to this reciprocation.

While this research provides some interesting results, our work provides opportunities for further future extension. Firstly, information about opponent's real motive from collaboration may be unavailable or at least not accurate. In other words, companies may not know about their partner's preferences, their real gains or losses from losing deals, losing knowledge, or abusing knowledge, or from mutual cooperation. Secondly, dichotomizing cooperation decisions may be unrealistic in cases where it is difficult to define cooperation as a yes or no question (Larsson et al., 1998). Moreover, we recognize that we considered only 20 strategies in an infinite universe -- considering more may lead to more robust conclusions. Finally, real supply chains involve multiple actors, as opposed to dyads, and other motivations such as reputation building and altruism may figure into decisions.

Our study can, therefore, be extended along several dimensions. One extension is to consider the "shadow of the future" or the probability of the game ending at any iteration. In a supply chain, this can represent the value of dealing with the same partner again, or the likelihood of repeated projects. Moreover, we characterized cooperative behavior using only niceness, but other features, such as forgiveness, can be studied as another dimension of cooperation. Furthermore, the fact that some interactions may involve elements of negotiation and can be represented as cooperative games also applies to supply chains, in which payoff division from joint projects are agreed upon and use of partner's knowledge can be negotiated (for example, in an intellectual property agreement).

Another extension may expand the level of analysis to the network, acknowledging both the presence of several partners in a supply chain and the possible evolution of strategies in the determination of which one survives as the fittest. Finally, supply chain decisions involve several relational elements, such as care for the other, or 'warm glow altruism' (Kreps, Milgrom, Roberts, & Wilson, 1982). Altruism is particularly relevant to the supply chain context as payoffs are likely interdependent. Further experiments can study the effect of social capital and length of previous relationships with partners on supply chain cooperation.

8. TABLES

Table III-1

Payoff Matrix For Focal (row) Player

		Opponent	
		Cooperate	Defect
Focal Player	Cooperate	*R*	*S*
	Defect	*T*	*P*

Table III-2

Strategy Definitions

Strategy Name	Explanation	Strategy Name	Explanation
TIT-FOR-TAT	Cooperate in the first round, then mimic opponent's action in previous round.	MISTRUST	Starts with defection. If defected against, it responds with a defect. Otherwise, it cooperates.
ALLC	Always cooperate.	ALLD	Always defect.
REVISED DOWNING	Same as DOWNING, but starts with two rounds of cooperation.	DOWNING	The DOWNING player defects on the first two rounds, then decides which move to make on the basis of the opponent's track record: It reviews the game record, determining how often in the past the opponent has responded to defection with defection and how often it has responded to cooperation with defection. It then assumes that the opponent will continue to respond to future acts of cooperation and defection with cooperation and defection in the same proportions. Finally, DOWNING computes whether it is more profitable to cooperate or to defect, given the opponent's response policy, and makes the appropriate move. (In cases where the strategy would be cooperating for the first time, it assumes that the probability that an opponent will respond to cooperation with cooperation is fifty percent.)
SOFT MAJORITY	Starts with cooperate. Plays the way the opponent has played in the majority of the previous rounds. A tie goes to cooperate.	HARD MAJORITY	Starts with defect. Plays the way the opponent has played in the majority of the previous rounds. A tie goes to defect.
PAVLOV	Starts with cooperation. Then cooperates if both players made the same move previously, defects otherwise.	MEAN PAVLOV	Starts with defection. Then cooperates if both players made the same move previously, defects otherwise.
WILLIAM ADAMS	It starts with a threshold of four defections. Once the threshold is crossed, it defects and then adjusts the threshold by cutting it in half. It continues calculating the threshold after it is less than one because it then becomes the probability this rule cooperates after a defection.	MEAN WILLIAM ADAMS	Same like WILLIAM ADAMS but this one starts with 4 unprovoked defections
CCD	Alternates cooperate, cooperate, defect, regardless of what the opponent does.	DDC	Alternates defect, defect, cooperate, regardless of what the opponent does
JOSS	Starts with cooperation. If defected against, respond with a defect. Otherwise, cooperate 90% of the time, i.e., TFT plus 10% unprovoked defect.	MISTRUST 10	Starts with defection. If defected against, respond with a defect. Otherwise, cooperate 90% of the time, i.e., MISTRUST plus 10% unprovoked defect.

Table III-2 (continued)

Strategy Definitions

Strategy Name	Explanation	Strategy Name	Explanation
CHAMPION	Cooperates during the first ten rounds, uses the TFT strategy during the next fifteen rounds, and subsequently switches to a more complicated strategy: It cooperates if the other player cooperated in the preceding round, but otherwise computes a ``cooperation rate'' -- the number of rounds in which the other player cooperated, divided by the current round number. If this cooperation rate is 3/5 or more, CHAMPION continues to cooperate; otherwise, it selects a random number in the range from 0 to 1 and defects unless this number is less than or equal to the cooperation rate.	MEAN CHAMPION	Defects during the first ten rounds, uses the TFT strategy during the next fifteen rounds, and subsequently switches to a more complicated strategy: It cooperates if the other player cooperated in the preceding round, but otherwise computes a ``cooperation rate'' -- the number of rounds in which the other player cooperated, divided by the current round number. If this cooperation rate is 3/5 or more, CHAMPION continues to cooperate; otherwise, it selects a random number in the range from 0 to 1 and defects unless this number is less than or equal to the cooperation rate.
GRIM (FRIEDMAN)	Starts with cooperation and stays with it until defected against once, it then defects for the rest of the (iterations).	HARRINGTON	Plays cooperatively for the first thirty-six iterations, then defects without provocation. If its opponent makes its first defection on the same move, this strategy assumes it is playing itself unless the opponent defects again. If it thinks it is playing a strategy identical to itself, it cooperates. However, if it is not playing itself, it attempts to take advantage of the opponent. It decides randomly when it should probe the other strategy for weakness. If the opponent appears to be a consistent defector (more than 70% defects), Harrington's strategy will respond with continual defection.

Table III-3

Typical Results: Reciprocation Rule

Payoff Structure	Player Type	Opponent Strategy	MWW	Rule
EQUI	Prisoner	Nice	0.0022	General Rule 1
		Mean	0.1405	General Rule 2
		Overall	0.0022	General Rule 3
	Chicken	Nice	0.0013	General Rule 1
		Mean	0.1212	General Rule 2
		Overall	0.0013	General Rule 3
	Deterrer	Nice	0.0028	General Rule 1
		Mean	0.1405	General Rule 2
		Overall	0.0028	General Rule 3
	Appeaser	Nice	0.0017	General Rule 1
		Mean	0.2123	General Rule 2
		Overall	0.0017	General Rule 3
SSB	Prisoner	Nice	0.1405	**Nice Abuse Exc.**
		Mean	1.0000	General Rule 2
		Overall	0.1405	**Nice Abuse Exc.**
	Chicken	Nice	0.0640	**Nice Abuse Exc.**
		Mean	0.7913	General Rule 2
		Overall	0.0640	**Nice Abuse Exc.**
	Deterrer	Nice	0.0028	General Rule 1
		Mean	0.1620	General Rule 2
		Overall	0.0028	General Rule 3
	Appeaser	Nice	0.0028	General Rule 1
		Mean	0.2123	General Rule 2
		Overall	0.0028	General Rule 3
SBS	Prisoner	Nice	0.0013	General Rule 1
		Mean	0.1041	General Rule 2
		Overall	0.0013	General Rule 3
	Chicken	Nice	0.0022	General Rule 1
		Mean	0.0757	**Mean Treat Exc.**
		Overall	0.0022	General Rule 3
	Deterrer	Nice	0.0022	General Rule 1
		Mean	0.1212	**Mean Treat Exc.**
		Overall	0.0022	General Rule 3
	Appeaser	Nice	0.0028	General Rule 1
		Mean	0.0757	**Mean Treat Exc.**
		Overall	0.0028	General Rule 3

Table III-4

Exceptions

Exception	Payoff Structure	Iterations			
		300	400	500	600
Nice Abuse Exception	SSB	P, C ** N&O	P INS N&O C ** N&O	P INS N&O C ** N&O	P,C INS N&O
	BSS	P,D ** N&O	P INS N&O D ** N&O	P,D INS N&O	P,D INS N&O
	BSB	P ** N&O	P,C ** N&O	P, C ** N&O	P, C ** N&O
Mean Treat Exception	SBB	P ** MEAN	C ** MEAN	P ** MEAN	
	SBS	P,C,D ** MEAN	C,A ** MEAN	P,C,D ** MEAN	P,D,A ** MEAN
	BBS		A ** MEAN		C ** MEAN
Prisoner Base-Case Exception	SSS (EQUI)	P ** MEAN	P ** MEAN	P ** MEAN	P ** MEAN
	BBB (EQUI)	P ** MEAN			P ** MEAN

P: prisoner, C: chicken, D: deterrer, A: appeaser
INS: $p > 0.1$
** weakly significant $0.05<p<0.1$
N&O: results with nice strategies and overall combination of nice and mean strategies
MEAN: results with mean strategies

Table III-5

Results Summary

Factor	Results		Implications
Partner type	Not significant		A firm's long term strategy of cooperation does not depend on short term preferences of partner firm
Firm type	Conditionally significant	Significant when there is high value in inducing partner's cooperation	When there is high value in inducing partner's cooperation, a firm's long term strategy of cooperation depends on its own short term preferences
		Insignificant when there is little value in inducing partner's cooperation	When there is little value in inducing partner's cooperation, a firm's long term strategy of cooperation does not depend on its own short term preferences
Partner Strategy Type (nice versus mean)	Significant		A firm's long-term strategy of cooperation always depends on partner's niceness.

9. FIGURES

Figure III-1

2-Dimensional Framework for Firm Types

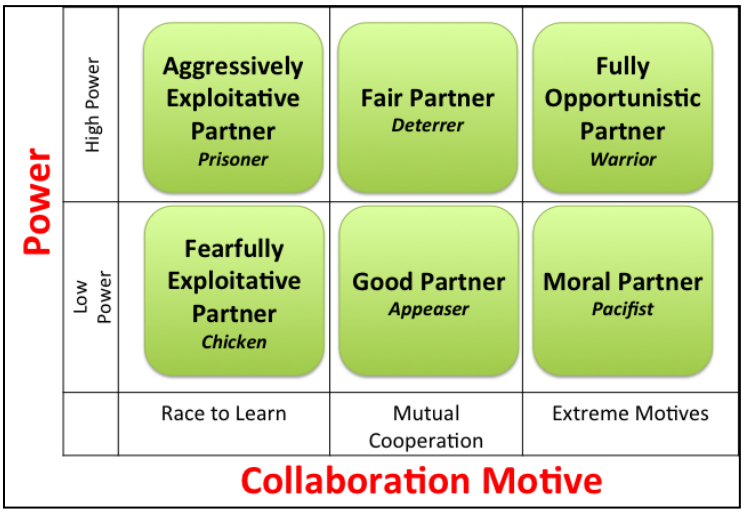

Figure III-2

One-Shot Equilibrium for 2X2 C-D Games

	Prisoner	Chicken	Deterrer	Appeaser	Warrior	Pacifist
Prisoner	DD					
Chicken	CD	CD, DC & a mixed strategy				
Deterrer	DD	Mixed Strategy	2 NE:CC & DD			
Appeaser	CD	CD	CC	CC		
Warrior	DD	DC	DD	DC	DD	
Pacifist	CD	CD	CC	CC	CD	CC

Figure III-3

Maximally Different Player Types (Shown in Double Arrows)

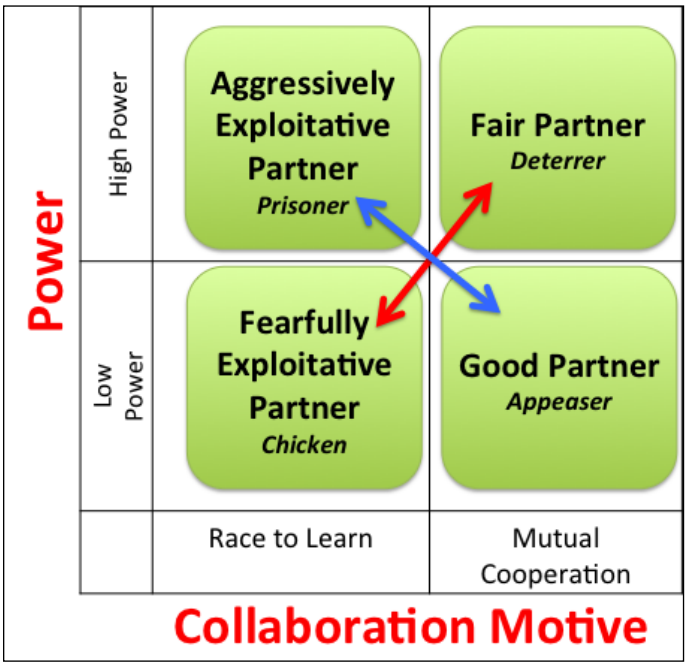

Figure III-4

Joint Effect of Partner's Strategy Type and Cooperation Value

Partner Strategy Type	**Nice**	**COOPERATION Zone** **Firm shall reciprocate** **Nice-Nice**	**ABUSE Zone** **Firm may not reciprocate** **Mean-Nice**
	Mean	**TOLERANCE Zone** **Firm shall not reciprocate** **Nice-Mean**	**RIVALRY Zone** **Firm may reciprocate** **Mean-Mean**
		High	**Low**
		Value of inducing cooperation	

APPENDICES

Table III-A1

Comparison of Rankings within Payoff Categories

	SSS												BBB											
	Prisoner			Chicken			Deterrer			Appeaser			Prisoner			Chicken			Deterrer			Appeaser		
	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All
kendall's τ	0.77573	0.66138	0.77573	0.88421	0.88421	0.88421	0.82105	0.62797	0.82105	0.91293	0.94737	0.91293	0.67019	0.78628	0.67019	0.94459	0.83158	0.94459	0.88421	0.81053	0.88421	0.96842	0.87072	0.96842
p value	2.1E-06	5.6E-05	2.1E-06	3.7E-11	3.7E-11	3.7E-11	4.6E-09	0.00013	4.6E-09	2.4E-08	3.3E-14	2.4E-08	4.3E-05	1.6E-06	4.3E-05	7.6E-09	2.3E-09	7.6E-09	3.7E-11	9.1E-09	3.7E-11	8.4E-16	1E-07	8.4E-16

	SSB												SBS											
	Prisoner			Chicken			Deterrer			Appeaser			Prisoner			Chicken			Deterrer			Appeaser		
	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All
kendall's τ	0.90526	0.97884	0.90526	0.94737	0.86316	0.94737	0.92632	0.96842	0.92632	0.94737	0.95515	0.94737	0.93684	0.97895	0.93684	0.91579	0.96842	0.91579	0.91293	0.94737	0.91293	0.88127	1	0.88127
p value	5E-12	2.3E-09	5E-12	3.3E-14	2.2E-10	3.3E-14	5E-13	8.4E-16	5E-13	3.3E-14	5.1E-09	3.3E-14	1.4E-13	-4E-16	1.4E-13	1.6E-12	8.4E-16	1.6E-12	2.4E-08	3.3E-14	2.4E-08	7.1E-08	-4E-16	7.1E-08

	BSS												SBB											
	Prisoner			Chicken			Deterrer			Appeaser			Prisoner			Chicken			Deterrer			Appeaser		
	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All
kendall's τ	0.93404	0.97884	0.93404	0.94459	0.97895	0.94459	0.9657	0.96825	0.9657	0.93404	0.96842	0.93404	0.73351	0.91579	0.73351	0.87368	0.95789	0.87368	0.94737	0.94737	0.94737	0.96842	0.95789	0.96842
p value	1.1E-08	2.3E-09	1.1E-08	7.6E-09	-4E-16	7.6E-09	3.5E-09	3.4E-09	3.5E-09	1.1E-08	8.4E-16	1.1E-08	7.5E-06	1.6E-12	7.5E-06	9.2E-11	6.7E-15	9.2E-11	3.3E-14	3.3E-14	3.3E-14	8.4E-16	6.7E-15	8.4E-16

	BSB												BBS											
	Prisoner			Chicken			Deterrer			Appeaser			Prisoner			Chicken			Deterrer			Appeaser		
	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All	Vs Nice	Vs Mean	Vs All
kendall's τ	0.93684	0.96825	0.93684	0.95789	0.87368	0.95789	0.93684	0.97895	0.93684	0.96842	0.97895	0.96842	0.89182	0.81794	0.89182	0.94737	0.90526	0.94737	0.89474	0.85263	0.89474	0.91293	0.90526	0.91293
p value	1.4E-13	3.4E-09	1.4E-13	6.7E-15	9.2E-11	6.7E-15	1.4E-13	-4E-16	1.4E-13	8.4E-16	-4E-16	8.4E-16	4.9E-08	5.8E-07	4.9E-08	3.3E-14	5E-12	3.3E-14	1.4E-11	5E-10	1.4E-11	2.4E-08	5E-12	2.4E-08

Table III-A2

Opponent Type Result Summary

		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.698	0.663	0.681	0.828	0.779	0.832	0.66	0.765	0.663	0.712	0.611	0.723	0.839	0.839	0.818	0.716	0.639	0.663	0.828	0.884	0.926	0.934	0.874	0.926
Equi	p value	2E-05	1E-05	3E-05	4E-07	6E-08	2E-09	6E-05	3E-06	1E-05	1E-05	7E-05	1E-05	3E-07	3E-07	6E-07	1E-06	1E-04	1E-05	4E-07	4E-11	5E-13	1E-08	9E-11	5E-13
		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.902	0.725	0.807	0.947	0.979	1	0.937	0.735	0.884	0.85	0.725	0.807	0.923	0.905	0.902	0.884	0.735	0.884	0.842	0.642	0.821	0.947	0.884	0.905
SSB	p value	3E-08	1E-05	8E-07	3E-14	2E-09	-0	1E-13	7E-06	4E-11	2E-07	1E-05	8E-07	2E-08	3E-08	3E-08	4E-11	7E-06	4E-11	1E-09	3E-05	5E-09	3E-14	4E-11	5E-12
		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.853	0.842	0.863	0.916	0.947	0.968	0.874	0.832	0.874	0.916	0.853	0.874	0.958	0.863	0.947	0.916	0.821	0.884	0.902	0.916	0.895	0.937	0.937	0.958
SBS	p value	5E-10	1E-09	2E-10	2E-12	3E-14	8E-16	9E-11	2E-09	9E-11	2E-12	5E-10	9E-11	7E-15	2E-10	3E-14	2E-12	5E-09	4E-11	3E-08	2E-12	1E-11	1E-13	1E-13	7E-15
		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.934	0.895	0.945	0.958	0.968	0.997	0.945	0.913	0.937	0.955	0.884	0.937	0.947	0.976	0.987	0.945	0.892	0.934	0.881	0.979	0.947	0.955	0.979	0.989
BSS	p value	1E-08	1E-11	8E-09	7E-15	8E-16	1E-09	8E-09	2E-08	1E-08	5E-09	4E-11	1E-13	7E-09	2E-09	2E-09	8E-09	5E-08	1E-08	7E-08	-0	3E-14	5E-09	-0	-0
		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.684	0.789	0.684	0.558	0.926	0.895	0.432	0.884	0.768	0.453	0.716	0.621	0.684	0.779	0.726	0.747	0.937	0.874	0.786	0.926	0.832	0.516	0.895	0.853
SBB	p value	5E-06	3E-08	5E-06	4E-04	5E-13	1E-11	0.007	4E-11	1E-07	0.005	1E-06	5E-05	5E-06	6E-08	8E-07	3E-07	1E-13	9E-11	2E-06	5E-13	2E-09	0.001	1E-11	5E-10
		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.863	0.63	0.8	0.947	0.818	0.958	0.913	0.64	0.86	0.853	0.723	0.842	0.934	0.862	0.923	0.892	0.776	0.892	0.863	0.705	0.811	0.955	0.947	0.968
BSB	p value	2E-10	1E-04	2E-08	3E-14	6E-07	7E-15	2E-08	1E-04	1E-07	5E-10	1E-05	1E-09	1E-08	1E-07	2E-08	5E-08	2E-06	5E-08	2E-10	2E-06	9E-09	5E-09	3E-14	8E-16
		PP-PC			PP-PD			PP-PA			PC-PD			PC-PA			PD-PA			CP-CC			CP-CD		
	correlation	0.874	0.705	0.8	0.916	0.863	0.979	0.947	0.779	0.874	0.895	0.695	0.8	0.926	0.905	0.926	0.884	0.768	0.874	0.902	0.916	0.863	0.955	0.905	0.968
BBS	p value	9E-11	2E-06	2E-08	2E-12	2E-10	-0	3E-14	6E-08	9E-11	1E-11	3E-06	2E-08	5E-13	5E-12	5E-13	4E-11	1E-07	9E-11	3E-08	2E-12	2E-10	5E-09	5E-12	8E-16

Table III-A2 (cont'd)

Opponent Type Result Summary

		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.807	0.947	0.895	0.821	0.863	0.916	0.926	0.874	0.905	0.811	0.863	0.863	0.905	0.874	0.947	0.916	0.895	0.937	0.884	0.853	0.937	0.947	0.874	0.905
Equi	p value	8E-07	3E-14	1E-11	5E-09	2E-10	2E-12	5E-13	9E-11	5E-12	9E-09	2E-10	2E-10	5E-12	9E-11	3E-14	2E-12	1E-11	1E-13	4E-11	5E-10	1E-13	3E-14	9E-11	5E-12
		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.947	0.653	0.853	0.832	0.737	0.789	0.853	0.779	0.884	0.916	0.684	0.863	0.895	0.884	0.895	0.842	0.905	0.937	0.832	0.916	0.958	0.884	0.853	0.874
SSB	p value	3E-14	2E-05	5E-10	2E-09	5E-07	3E-08	5E-10	6E-08	4E-11	2E-12	5E-06	2E-10	1E-11	4E-11	1E-11	1E-09	5E-12	1E-13	2E-09	2E-12	7E-15	4E-11	5E-10	9E-11
		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.916	0.863	0.863	0.934	0.916	0.895	0.966	0.905	0.968	0.895	0.863	0.884	0.863	0.832	0.895	0.895	0.916	0.937	0.8	0.832	0.895	0.905	0.874	0.937
SBS	p value	2E-12	2E-10	2E-10	1E-08	2E-12	1E-11	3E-09	5E-12	8E-16	1E-11	2E-10	4E-11	2E-10	2E-09	1E-11	1E-11	2E-12	1E-13	2E-08	2E-09	1E-11	5E-12	9E-11	1E-13
		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.871	1	0.958	0.905	0.979	0.958	0.968	0.979	0.989	0.916	0.979	0.947	0.926	0.955	0.968	0.958	0.902	0.968	0.926	0.923	0.926	0.968	0.916	0.937
BSS	p value	1E-07	-0	7E-15	5E-12	-0	7E-15	8E-16	-0	-0	2E-12	-0	3E-14	5E-13	5E-09	8E-16	7E-15	3E-08	8E-16	5E-13	2E-08	5E-13	8E-16	2E-12	1E-13
		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.579	0.811	0.758	0.501	0.842	0.705	0.649	0.842	0.8	0.789	0.895	0.821	0.979	0.821	0.895	0.874	0.832	0.905	0.884	0.853	0.937	0.853	0.779	0.842
SBB	p value	2E-04	9E-09	2E-07	0.002	1E-09	2E-06	7E-05	1E-09	2E-08	3E-08	1E-11	5E-09	-0	5E-09	1E-11	9E-11	2E-09	5E-12	4E-11	5E-10	1E-13	5E-10	6E-08	1E-09
		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.947	0.674	0.895	0.85	0.695	0.8	0.874	0.821	0.874	0.923	0.684	0.905	0.905	0.842	0.905	0.853	0.821	0.968	0.895	0.905	0.968	0.884	0.832	0.874
BSB	p value	3E-14	8E-06	1E-11	2E-07	3E-06	2E-08	9E-11	5E-09	9E-11	2E-08	5E-06	5E-12	5E-12	1E-09	5E-12	5E-10	5E-09	8E-16	1E-11	5E-12	8E-16	4E-11	2E-09	9E-11
		CP-CA			CC-CD			CC-CA			CD-CA			DP-DC			DP-DD			DP-DA			DC-DD		
	correlation	0.915	0.926	0.863	0.874	0.905	0.874	0.966	0.989	0.979	0.892	0.895	0.874	0.863	0.6	0.832	0.884	0.905	0.979	0.884	0.663	0.811	0.895	0.568	0.832
BBS	p value	2E-08	5E-13	2E-10	9E-11	5E-12	9E-11	3E-09	-0	-0	5E-08	1E-11	9E-11	2E-10	1E-04	2E-09	4E-11	5E-12	-0	4E-11	1E-05	9E-09	1E-11	3E-04	2E-09

Table III-A2 (cont'd)

Opponent Type Result Summary

		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.916	0.895	0.926	0.926	0.811	0.895	0.937	0.874	0.947	0.913	0.884	0.926	0.958	0.895	0.968	0.892	0.926	0.937	0.979	0.874	0.958	0.913	0.884	0.958
Equi	p value	2E-12	1E-11	5E-13	5E-13	9E-09	1E-11	1E-13	9E-11	3E-14	2E-08	4E-11	5E-13	7E-15	1E-11	8E-16	5E-08	5E-13	1E-13	-0	9E-11	7E-15	2E-08	4E-11	7E-15
		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.895	0.926	0.895	0.947	0.926	0.958	0.916	0.863	0.926	0.853	0.895	0.947	0.863	0.905	0.958	0.895	0.842	0.916	0.905	0.916	0.905	0.968	0.926	0.947
SSB	p value	1E-11	5E-13	1E-11	3E-14	5E-13	7E-15	2E-12	2E-10	5E-13	5E-10	1E-11	3E-14	2E-10	5E-12	7E-15	1E-11	1E-09	2E-12	5E-12	2E-12	5E-12	8E-16	5E-13	3E-14
		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.937	0.895	0.958	0.905	0.874	0.937	0.884	0.926	0.926	0.905	0.947	0.989	0.875	0.863	0.884	0.895	0.895	0.937	0.928	0.916	0.937	0.897	0.832	0.895
SBS	p value	1E-13	1E-11	7E-15	5E-12	9E-11	1E-13	4E-11	5E-13	5E-13	5E-12	3E-14	-0	1E-07	2E-10	4E-11	1E-11	1E-11	1E-13	2E-08	2E-12	1E-13	5E-08	2E-09	1E-11
		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.916	0.895	0.958	0.905	0.979	0.937	0.895	0.937	0.958	0.989	0.989	0.989	0.895	0.937	0.968	0.884	0.947	0.968	0.937	0.979	0.989	0.905	0.947	0.958
BSS	p value	2E-12	1E-11	7E-15	5E-12	-0	1E-13	1E-11	1E-13	7E-15	-0	-0	-0	1E-11	1E-13	8E-16	4E-11	3E-14	8E-16	1E-13	-0	-0	5E-12	3E-14	7E-15
		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.863	0.884	0.895	0.947	0.895	0.947	0.926	0.926	0.926	0.832	0.916	0.916	0.884	0.895	0.937	0.842	0.884	0.863	0.895	0.905	0.905	0.947	0.937	0.958
SBB	p value	2E-10	4E-11	1E-11	3E-14	1E-11	3E-14	5E-13	5E-13	5E-13	2E-09	2E-12	2E-12	4E-11	1E-11	1E-13	1E-09	4E-11	2E-10	1E-11	5E-12	5E-12	3E-14	1E-13	7E-15
		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.884	0.916	0.874	0.937	0.874	0.958	0.905	0.863	0.947	0.874	0.926	0.937	0.895	0.884	0.947	0.905	0.853	0.905	0.905	0.853	0.916	0.958	0.916	0.947
BSB	p value	4E-11	2E-12	9E-11	1E-13	9E-11	7E-15	5E-12	2E-10	3E-14	9E-11	5E-13	1E-13	1E-11	4E-11	3E-14	5E-12	5E-10	5E-12	5E-12	5E-10	2E-12	7E-15	2E-12	3E-14
		DC-DA			DD-DA			AP-AC			AP-AD			AP-AA			AC-AD			AC-AA			AD-AA		
	correlation	0.958	0.937	0.979	0.853	0.611	0.811	0.871	0.863	0.905	0.955	0.979	0.989	0.871	0.874	0.905	0.895	0.884	0.895	0.958	0.989	1	0.916	0.895	0.895
BBS	p value	7E-15	1E-13	-0	5E-10	7E-05	9E-09	1E-07	2E-10	5E-12	5E-09	-0	-0	1E-07	9E-11	5E-12	1E-11	4E-11	1E-11	7E-15	-0	-0	2E-12	1E-11	1E-11

Table III-A3

Player Type Result Summary

		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.6	0.427	0.442	0.607	0.554	0.674	0.6	0.449	0.558	0.691	0.558	0.6	0.811	0.853	0.821	0.786	0.642	0.779	0.607	0.375	0.491	0.649	0.501	0.649
Equi	p value	1E-04	0.009	0.006	2E-04	7E-04	8E-06	1E-04	0.006	4E-04	2E-05	4E-04	1E-04	9E-09	5E-10	5E-09	2E-06	3E-05	6E-08	2E-04	0.023	0.003	7E-05	0.002	7E-05
		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.913	0.747	0.916	-0.48	-0.15	-0.36	-0.47	-0.15	-0.34	-0.41	-0.15	-0.29	-0.4	-0.08	-0.27	0.989	0.937	0.958	0.966	0.737	0.842	-0.42	-0.35	-0.33
SSB	p value	2E-08	3E-07	2E-12	0.003	0.386	0.028	0.004	0.386	0.04	0.011	0.386	0.074	0.014	0.631	0.098	-0	1E-13	7E-15	3E-09	5E-07	1E-09	0.011	0.034	0.047
		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.926	0.811	0.895	0.937	0.947	0.968	0.923	0.768	0.853	0.884	0.779	0.863	0.976	0.895	0.937	0.913	0.8	0.842	0.947	0.905	0.937	0.937	0.958	0.947
SBS	p value	5E-13	9E-09	1E-11	1E-13	3E-14	8E-16	2E-08	1E-07	5E-10	4E-11	6E-08	2E-10	2E-09	1E-11	1E-13	2E-08	2E-08	1E-09	3E-14	5E-12	1E-13	1E-13	7E-15	3E-14
		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.206	-0.36	-0.14	0.905	0.913	0.966	0.216	-0.36	-0.14	0.195	-0.33	-0.14	0.947	0.979	0.958	0.185	-0.33	-0.14	0.195	-0.35	-0.16	0.923	0.966	0.958
BSS	p value	0.217	0.027	0.399	3E-08	2E-08	3E-09	0.194	0.027	0.399	0.243	0.047	0.422	3E-14	-0	7E-15	0.27	0.047	0.422	0.243	0.032	0.351	2E-08	3E-09	7E-15
		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.863	0.863	0.916	0.474	0.695	0.632	0.463	0.579	0.611	0.547	0.726	0.653	0.558	0.695	0.653	0.989	0.863	0.958	0.937	0.979	0.968	0.505	0.632	0.621
SBB	p value	2E-10	2E-10	2E-12	0.003	3E-06	4E-05	0.004	2E-04	7E-05	5E-04	8E-07	2E-05	4E-04	3E-06	2E-05	-0	2E-10	7E-15	1E-13	-0	8E-16	0.001	4E-05	5E-05
		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.905	0.789	0.874	-0.43	-0.36	-0.37	-0.46	-0.28	-0.34	-0.4	-0.23	-0.31	-0.39	-0.16	-0.27	0.947	0.926	0.947	0.945	0.653	0.884	-0.48	-0.42	-0.37
BSB	p value	5E-12	3E-08	9E-11	0.007	0.028	0.024	0.004	0.086	0.04	0.014	0.165	0.064	0.016	0.351	0.098	3E-14	5E-13	3E-14	8E-09	2E-05	4E-11	0.003	0.009	0.024
		PP-CP			PP-DP			PP-AP			CP-DP			CP-AP			DP-AP			PC-CC			PC-DC		
	correlation	0.663	0.505	0.537	0.916	0.916	0.968	0.674	0.495	0.526	0.726	0.547	0.547	0.968	0.968	0.989	0.737	0.537	0.537	0.779	0.505	0.611	0.958	0.958	0.979
BBS	p value	1E-05	0.001	6E-04	2E-12	2E-12	8E-16	8E-06	0.002	8E-04	8E-07	5E-04	5E-04	8E-16	8E-16	-0	5E-07	6E-04	6E-04	6E-08	0.001	7E-05	7E-15	7E-15	-0

-ve correlation
insignificant p

Table III-A3 (cont'd)

Player Type Result Summary

		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	0.67	0.396	0.586	0.621	0.6	0.589	0.684	0.789	0.821	0.895	0.726	0.768	0.726	0.411	0.526	0.558	0.453	0.642	0.621	0.432	0.568	0.642	0.663	0.611
Equi	p value	4E-05	0.016	4E-04	5E-05	1E-04	1E-04	5E-06	3E-08	5E-09	1E-11	8E-07	1E-07	8E-07	0.011	8E-04	4E-04	0.005	3E-05	5E-05	0.007	3E-04	3E-05	1E-05	7E-05
		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	-0.42	-0.25	-0.31	-0.44	-0.42	-0.36	-0.44	-0.33	-0.34	0.979	0.884	0.895	0.937	0.839	0.926	-0.44	-0.18	-0.31	-0.42	-0.13	-0.28	-0.38	-0.08	-0.27
SSB	p value	0.011	0.128	0.064	0.006	0.009	0.028	0.006	0.047	0.04	-0	4E-11	1E-11	1E-13	3E-07	5E-13	0.006	0.27	0.064	0.009	0.436	0.086	0.02	0.631	0.098
		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	0.937	0.905	0.937	0.947	0.926	0.926	0.926	0.958	1	0.958	0.905	0.926	0.947	0.811	0.916	0.926	0.968	0.968	0.937	0.811	0.874	0.916	0.842	0.905
SBS	p value	1E-13	5E-12	1E-13	3E-14	5E-13	5E-13	5E-13	7E-15	-0	7E-15	5E-12	5E-13	3E-14	9E-09	2E-12	5E-13	8E-16	8E-16	1E-13	9E-09	9E-11	2E-12	1E-09	5E-12
		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	0.195	-0.34	-0.17	0.263	-0.32	-0.12	0.937	0.955	0.989	0.242	-0.32	-0.13	0.174	-0.41	-0.13	0.921	0.892	0.934	0.185	-0.41	-0.14	0.206	-0.35	-0.09
BSS	p value	0.243	0.04	0.319	0.113	0.055	0.501	1E-13	5E-09	-0	0.146	0.051	0.461	0.299	0.014	0.436	2E-08	5E-08	1E-08	0.27	0.014	0.399	0.217	0.034	0.586
		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	0.495	0.621	0.663	0.526	0.653	0.611	0.537	0.642	0.653	0.989	0.884	0.958	0.937	0.916	0.958	0.379	0.611	0.547	0.421	0.526	0.505	0.421	0.653	0.589
SBB	p value	0.002	5E-05	1E-05	8E-04	2E-05	7E-05	6E-04	3E-05	2E-05	-0	4E-11	7E-15	1E-13	2E-12	7E-15	0.02	7E-05	5E-04	0.009	8E-04	0.001	0.009	2E-05	1E-04
		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	-0.48	-0.37	-0.35	-0.44	-0.37	-0.38	-0.44	-0.38	-0.36	0.979	0.884	0.874	0.916	0.779	0.884	-0.49	-0.29	-0.36	-0.46	-0.22	-0.33	-0.43	-0.14	-0.31
BSB	p value	0.003	0.024	0.034	0.006	0.024	0.02	0.006	0.02	0.028	-0	4E-11	9E-11	2E-12	6E-08	4E-11	0.002	0.074	0.028	0.004	0.186	0.047	0.007	0.422	0.064
		PC-AC			CC-DC			CC-AC			DC-AC			PD-CD			PD-DD			PD-AD			CD-DD		
	correlation	0.747	0.526	0.611	0.779	0.526	0.611	0.926	0.979	1	0.789	0.526	0.611	0.695	0.505	0.547	0.947	0.947	0.989	0.674	0.505	0.547	0.705	0.495	0.537
BBS	p value	3E-07	8E-04	7E-05	6E-08	8E-04	7E-05	5E-13	-0	-0	3E-08	8E-04	7E-05	3E-06	0.001	5E-04	3E-14	3E-14	-0	8E-06	0.001	5E-04	2E-06	0.002	6E-04

-ve correlation
insignificant p

Table III-A3 (cont'd)

Player Type Result Summary

		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
Equi	correlation	0.768	0.832	0.832	0.853	0.705	0.758	0.579	0.442	0.586	0.674	0.516	0.554	0.684	0.411	0.575	0.611	0.568	0.568	0.663	0.779	0.758	0.947	0.726	0.811
	p value	1E-07	2E-09	2E-09	5E-10	2E-06	2E-07	2E-04	0.006	4E-04	8E-06	0.001	7E-04	5E-06	0.011	5E-04	7E-05	3E-04	3E-04	1E-05	6E-08	2E-07	3E-14	8E-07	9E-09
		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
SSB	correlation	-0.36	-0.05	-0.23	0.937	0.926	0.958	0.937	0.853	0.905	-0.45	-0.27	-0.33	-0.42	-0.16	-0.26	-0.45	-0.19	-0.34	-0.42	-0.07	-0.27	0.968	0.884	0.937
	p value	0.028	0.773	0.165	1E-13	5E-13	7E-15	1E-13	5E-10	5E-12	0.005	0.098	0.047	0.009	0.351	0.113	0.005	0.26	0.04	0.009	0.677	0.098	8E-16	4E-11	1E-13
		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
SBS	correlation	0.968	0.916	0.937	0.926	0.779	0.884	0.926	0.842	0.926	0.926	0.968	0.958	0.884	0.842	0.926	0.958	0.853	0.926	0.958	0.979	0.979	0.937	0.853	0.947
	p value	8E-16	2E-12	1E-13	5E-13	6E-08	4E-11	5E-13	1E-09	5E-13	5E-13	8E-16	7E-15	4E-11	1E-09	5E-13	7E-15	5E-10	5E-13	7E-15	-0	-0	1E-13	5E-10	3E-14
		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
BSS	correlation	0.947	0.979	0.989	0.185	-0.35	-0.11	0.211	-0.36	-0.14	0.966	0.895	0.937	0.274	-0.33	-0.12	0.216	-0.36	-0.12	0.916	0.947	0.979	0.259	-0.35	-0.09
	p value	3E-14	-0	-0	0.27	0.034	0.542	0.209	0.028	0.422	3E-09	1E-11	1E-13	0.098	0.047	0.501	0.194	0.028	0.501	2E-12	3E-14	-0	0.119	0.034	0.586
		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
SBB	correlation	0.463	0.611	0.547	0.937	0.895	0.958	0.968	0.895	0.926	0.453	0.568	0.568	0.474	0.474	0.568	0.442	0.611	0.558	0.463	0.558	0.621	0.937	0.905	0.937
	p value	0.004	7E-05	5E-04	1E-13	1E-11	7E-15	8E-16	1E-11	5E-13	0.005	3E-04	3E-04	0.003	0.003	3E-04	0.006	7E-05	4E-04	0.004	4E-04	5E-05	1E-13	5E-12	1E-13
		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
BSB	correlation	-0.4	-0.08	-0.27	0.968	0.884	0.947	0.934	0.821	0.895	-0.51	-0.34	-0.38	-0.49	-0.24	-0.35	-0.44	-0.24	-0.36	-0.42	-0.17	-0.33	0.937	0.884	0.947
	p value	0.014	0.631	0.098	8E-16	4E-11	3E-14	1E-08	5E-09	1E-11	0.002	0.04	0.02	0.003	0.146	0.034	0.006	0.146	0.028	0.009	0.319	0.047	1E-13	4E-11	3E-14
		CD-AD			DD-AD			PA-CA			PA-DA			PA-AA			CA-DA			CA-AA			DA-AA		
BBS	correlation	0.958	0.979	1	0.705	0.516	0.537	0.789	0.526	0.589	0.968	0.884	0.926	0.786	0.516	0.6	0.8	0.579	0.621	0.955	0.989	0.989	0.776	0.568	0.632
	p value	7E-15	-0	-0	2E-06	0.001	6E-04	3E-08	8E-04	1E-04	8E-16	4E-11	5E-13	2E-06	0.001	1E-04	2E-08	2E-04	5E-05	5E-09	-0	-0	2E-06	3E-04	4E-05

-ve correlation
insignificant p

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Dissertation Conclusion

This dissertation addresses hopes of promising opportunities and fears from substantial risks of supply chain innovation, utilizing three methodological approaches in three distinct papers. The first paper synthesizes the literature to develop the theory of Process Innovation Propagation (PIP). PIP creates a new profitability channel as a novel innovation appropriation mechanism that capitalizes on supply chain partnerships and positive tuning of expert and market power advantages. The second paper uses a survey technique to empirically test supply chain knowledge properties hypothesized to drive radical and incremental innovative capabilities, with moderating roles of reward, punishment and legal influences. Lastly, paper three conducts a simulation, designed within a game theoretic framework, to explore the effects of firm and partner preferences, strategy type (defective versus cooperative), and payoff structure on the optimum strategy for repeated innovation interactions. The dissertation carries significant implications and managerial insights in four supply chain directions: partner selection, decision making, reciprocal exchanges, and power tuning.

Partner Selection

Supply chain partners should be selected according to the type of joint innovation activity, be it transfer (propagation) or creation. PIP partners, for instance, must enjoy a high degree of strategic fit for the propagation to be successful. A propagator assesses potential receivers based on the similarity of organizational strategies to that of its business, the degree of interdependence, and the extent of incentive alignment between the companies. Process innovations aim at enhancing one or more competitive priorities, whose similarity across firms, increases the innovation's relevance to the receiving firm. Moreover, a higher degree of interdependence places more stake for each firm with the other, making the exchange more beneficial for the propagator, and more appealing for the receiver. Incentive alignment translates into higher synergies from collaboration, and more protection against opportunism.

On the other hand, partners for joint projects aimed at the *creation* of radical and incremental innovations should be assessed based on the properties of their organizations' intellectual capital. Firstly, managers should avoid partners with large size

discrepancy when developing incremental ideas. Such partners are expected to employ maximally different organizational procedures, patenting strategies and innovation processes. Disparity in size leads to high gaps in institutionalized knowledge properties, which is the basis of incremental innovations, impeding the applicability of the change to parties involved. When cooperating in radical innovation projects, managers should avoid excessive skill diversity and largely sized teams, which may entail conflicts and coordination problems.

Decision Making

Results of this dissertation research help managers take better decisions regarding their long term supply chain innovation strategies, innovation selection for propagation, and tuning governance structure for more effective knowledge exchanges. A firm's decision of whether to defect or not in long term innovation relations necessitates knowledge about partner's power stance and intent from the collaboration. Companies are advised to pursue cooperative strategies that never defect first, i.e., *nice* strategies, only when opponents pursue similarly cooperative strategies. Otherwise, companies may be well advised to consider defecting. This advice, however, is subject to conditions related to relative gains from attempting to change partner's actions. A firm may abuse a cooperative partner when the relative gain from inducement is insignificant, and it may be nice to a defective partner when the relative gain from inducement is significant.

The PIP theory developed herein guides the decision on the right innovations to share with supply chain partners for better performance. The theory characterizes specificity and tacitness as elements of vertical transferability, which have opposite effects on the effectiveness of propagation. Managers are advised to share less specific, but more tacit innovations along the supply chain. Innovations that are less bound to the type of business are easier to transfer vertically, without affecting imitation. The challenge of transferring tacit innovations, on the other hand, can be solved within the supply chain by increasing and enhancing interactions among people of the two organizations, while keeping competitors away from imitation. Managers are furthermore advised to decrease formality of governance with the degree of radicalness of the propagated change.

Reciprocity

This dissertation highlights reciprocity as a very important exchange rule that is increasingly driving outcomes from innovation relationships. Companies are advised to reciprocate and expect reciprocation from partners. The decision to pursue a cooperative or a defective innovation strategy is, at least partially, determined according to the partner's strategy type. This suggests that, in extension to (short-term) reciprocation of actions, such as the famous game theory's TIT-FOR-TAT, long term strategies may also be reciprocated.

Moreover, managers are advised to acknowledge the economic value behind social ties and relationship quality with supply chain partners. Managers who recognize the tangible value of cultivating supply chain social capital plant the seed of open sharing and partner knowledge protection, expecting reciprocation. As partners reciprocate actions, the wheel goes on and the supply chain's repository of shared knowledge is maximized and protected from competing chains.

Power Tuning

Power is an inevitable pillar of the inherently interdependent supply chain relationships. Despite its perceived negativity, power can be tuned in positive ways that can help otherwise passive companies to adopt successful innovations passed by PIP. Innovation owners are recommended to make every attempt to persuade supply chain members to adopt their innovations, capitalizing on their advantage as experts in the field when propagating downstream, or on their market power advantage when propagating upstream.

Active power exercise, on the other hand, harms the generation of radically new ideas, and does not help incremental ones. Supply chain joint endeavors aimed at the *creation* of ideas must not employ any influential strategies. New idea development requires a fair degree of freedom and flexibility to match the uncertainty of the creation process, even for small improvements/ changes. Organizations with power advantage that are inclined to use it are advised to refrain from doing so, realizing the losses in joint innovative capabilities that will result.

This work is not claimed to comprehensively capture supply chain innovation hopes and fears. As the innovation process continues to evolve, more threats and

opportunities will arise, raising different research questions and opening up new venues for research on the subject. It did, however, highlight several concerns in the area including: capitalizing on supply chain partners' capabilities and knowledge, appropriating maximum returns on successful innovations, devising innovation strategies with supply chain partners, power tuning for optimum innovation performance, and, finally, dealing with the knowledge sharing dilemma and risk of compromising competitive knowledge.