The effects of dependent supplier-customer relationships on supplier's corporate innovation

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**THE EFFECTS OF DEPENDENT SUPPLIER-CUSTOMER
RELATIONSHIPS ON SUPPLIER'S CORPORATE
INNOVATION**

**ZHUORAN JIAO
NANYANG BUSINESS SCHOOL
2021**

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INNOVATION**

ZHUORAN JIAO

NANYANG BUSINESS SCHOOL

A thesis submitted to the Nanyang Technological University in partial
fulfilment of the requirement for the degree of Master of Business

2021

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Summary

Purpose – The purpose of this paper is to study the association between two dimensions of dependent supplier-customer relationships (supplier's dependence and customer's dependence) and supplier's corporate innovation. The paper also engages in the moderating effect of the relationship duration to interact with two dimensions of dependent supplier-customer relationships.

Methodologies – The main estimate model is fixed-effects Poisson regression. The alternative estimate models are random-effects Poisson regression and Poisson pseudo-maximum likelihood regressions.

Findings – The relationship duration cannot moderate the effect of supplier's dependence and customer's dependence on the quantity of innovation. However, the relationship duration positively moderates the effect of supplier's dependence on the quality of innovation while negatively moderates the effect of customer's dependence on the quality of innovation.

Implications – When suppliers aim to improve their innovative performance, they should maintain long-term relationships with major customers under high level of supplier's dependence while obviate long-term relationships with major customers under high level of customer's dependence

Keywords – Empirical research, supplier-customer relationships, corporate innovation, relationship duration.

Abstract

In the paper, I study the association between two dimensions of dependent supplier-customer relationships (supplier's dependence and customer's dependence) and supplier's corporate innovation. I also engage in the moderating effect of the relationship duration. Using panel data from the Compustat database and the NBER Patent database, I find that the main effects of supplier's dependence and customer's dependence on supplier's corporate innovation are contingent that are moderated by the relationship duration. Specifically, the relationship duration positively moderates the association between supplier's dependence and supplier's corporate innovation while negatively moderates the association between customer's dependence and supplier's corporate innovation. The findings highlight the importance of dependent supplier-customer relationships and the nature of dynamic changes in supplier-customer relationships. The paper contributes to firms in selecting appropriate strategies to leverage dependence when they take supplier-customer relationships as a source of innovation.

1. Introduction

Supplier-customer relationships are essential resources to gain competitive advantages that influence firms' strategic decisions in supply chain management (SCM). To achieve economic outcomes, firms strategically reduce their exchanged partners' numbers while increase the trading volume with selected partners in supplier-customer relationships (Choi and Krause, 2006; Kim, 2017). For example, the number of purchaser's managed suppliers in 1997 had declined over 50 percent from 1990 (Trent and Monczka, 1998) and this trend continued after the 21st century. The same rule applies to suppliers. By maintaining exchanges with fewer customers, suppliers develop closer relationships and jointly pursue improved opportunities with customers, which increase the percentage of long-term contracts (Trent and Monczka, 1998). Long-term agreements improve trust and reduce transaction costs between mutual parties (Williamson, 1973). Consequently, the trend results in dependent supplier-customer relationships because suppliers increase dependence on major customers and their operations intertwines with major customers (Ahuja, 2000). Meanwhile, increasing trading volume from suppliers increases major customer's dependence when suppliers sell more products and services to them. Literature has investigated the importance of dependent supplier-customer relationships in relating to firm's financial indicators (Lanier et al., 2010; Patatoukas, 2012; Lu and Shang, 2017), operational efficiencies (Flynn et al., 2010; Villena et al., 2011; Ak and Patatoukas, 2016; Huo et al., 2016), constraint absorption (Casciaro and Piskorski, 2005), opportunistic behaviors (Dong et al., 2015; Villena and Craighead, 2017), and information utilization (Narasimhan and Kim, 2001; Ried et al.; 2020).

However, the effects of supplier-customer relationships on corporate innovation deserve more attention because innovation is no longer determined by the firm itself but, increasingly, by the network in which a firm is embedded (Powell et al., 1996). Technological innovation is considered as a specific type of corporate investment, which builds a firm's long-term

competitive advantages and sustainable growth (Porter, 1992). Besides internal resources within the firm's boundaries, firms also leverage external resources from the embedded supply network to innovate their products and services (Sjoerdsma and van Weele, 2015). To access external resources, firms collaborate with their partners in supplier-customer relationships through financial sales and in turn, build their own technical capabilities (Yan et al., 2017). It is reported that 55%-65% of innovation is driven by supply network partners (Rao, 2018). For example, Procter & Gamble (P&G) engaged in innovation activities with its top 15 suppliers and achieved a 30% increase in the quantity of innovation projects with joint staffing between P&G and supplier researchers (Larry & Sakkab, 2006). Through its "partners to win" program, Around 70% of Unilever's innovations are linked to its strategic suppliers by mutually investing and co-innovate (Trebilcock, 2014). In terms of technology-intensive firms, Toyota's R&D centers from individual platforms selected their embedded suppliers to collaboratively work on innovative projects (Wyman, 2015). Google engaged in its partners in a distributed innovation network where everyone had the possibility to contribute to Android's development, pushing both hardware and software technology forward (Remneland-Wikhamn et al., 2020).

Focalizing on suppliers, they actively acknowledge and leverage their corporate innovation driven by their major customers. For example, Samsung Electronics Co. was the leading supplier of Apple Inc. as Samsung's products comprised 26 percent of the component cost of the iPhone in 2012 (Kim, 2020). When Apple sold its products, Samsung made profits from memory chips, displays, and batteries supplied to Apple (Martin and Mickle, 2017). Samsung made \$110 from each top-of-the-line \$1,000 iPhone X that Apple sold (Martin and Mickle, 2017). Meanwhile, Samsung learned from innovative features of the iPhone and iPad to apply to Samsung's own products, such as the Galaxy Note series (Kim, 2012). To protect its patent information, Apple accused Samsung of patent infringement in 2012 and invested more resources in component hedging, which refrained competitors from availing of Apple's new

technologies (Spence, 2015; Kendall, 2016). The example illustrates the case that a supplier leverages the relationship with one of its major customers to improve its own innovative performance. However, supplier's corporate innovation is not thoroughly studied as it is either conceptualized by hypotheses (Choi and Krause, 2006; Kumar et al., 2020) or empirically investigated by inconsistent results (Bellamy et al., 2014; Krolikowskia and Yuan, 2017; Kim, 2020). From the Samsung-Apple case, supplier's dependence and customer's dependence exist but little research addresses these two dimensions of dependence in one research setting. Therefore, the paper identifies supplier's dependence and customer's dependence simultaneously to describe dependent supplier-customer relationships and associates them with supplier's corporate innovation. Two dimensions are unidirectional that describe the extent of dependence on financial sales. To a supplier, the more outputs it sells to a customer, the more dependent it is on the customer; while to a customer, the more inputs it purchases from a supplier, the more dependent it is on the supplier (Pfeffer and Salancik, 2003). I propose the first research question:

Research question: How do supplier's dependence and customer's dependence in dependent supplier-customer relationships impact supplier's corporate innovation?

However, the effects may not be consistent as the relationship duration increases. Dynamic interactions in supplier-customer relationships indicate that costs and benefits to firms could change when the relationship evolves and matures (Irvine et al., 2016). Empirical research identifies the importance of the relationship duration on a firm's profitability (Kalwani and Narayandas, 1995; Irvine et al., 2016), productivity (Serpa and Krishnan, 2016), and commitment (Jap and Geneson, 2000) but lacks attention to innovation. Innovative activities require sufficient knowledge accumulation, mutual commitment, and long-term investments, which are not likely to achieve in the early stage of relationships. Suppliers who receive valuable information from customers increase innovative capabilities by meeting the demand

of targeted markets, which occur in the mature stage of supplier-customer relationships (Lin et al., 2010). Therefore, the paper investigates whether the relationship duration moderates the interplay between dependent supplier-customer relationships and supplier's corporate innovation. I propose the second research question:

Research question: Is there any moderating effect of the relationship duration on the interplay between supplier's dependence or customer's dependence and supplier's corporate innovation?

I use firm-level data from several archival sources that captures dyadic supplier-customer relationships and supplier's corporate innovation. For supplier's corporate innovation, I select two measures from the perspective of innovative outputs: quantity of innovation and quality of innovation, which are measured by patent counts and patent citations. Two measures jointly reflect that leading firms are making efforts to increase the quantity and value of their patents (Kim, 2020). For dyadic supplier-customer relationships, I select two independent variables: supplier's dependence ratio and customer's dependence ratio. Supplier-customer dyads denote the fundamental units in the supply network that flow through direct management and information (Stone et al., 1995). Organizational perspectives build dependence either unidirectionally or jointly in supplier-customer relationships, which describes a firm's dependence on external resources from others (Pfeffer and Salancik, 2003). However, dependence is a unidimensional construct that may contain supplier's dependence and customer's dependence simultaneously in a relationship (Huo et al., 2017). To mitigate the impact of supplier's and customer's respective industries, I measure the firm-level dependence ratio scaled by industry competitiveness. The moderating variable is the relationship duration that summarizes the overall number of years that suppliers and major customers have financial sales. The sample period is between 1980 and 2006.

The paper contributes to SCM and innovation literature in several ways. First, the paper synthesizes two dimensions of dependence in supplier-customer relationships. The literature identifies power imbalance and mutual dependence by aggregating two dimensions of dependence but little separates them into unidirectional dependence. The paper fills this gap by identifying two dimensions of dependence measured by firms' financial sales. Putting two dimensions together in a relationship, the paper depicts the essence of supplier-customer relationships as either competitive or cooperative that helps firms make strategic decisions in SCM issues (Kim, 2017). Second, the paper contributes to the innovation literature by depicting dependent supplier-customer relationships as a source of corporate innovation. Because suppliers accumulate technologies from major customers in exchanged transactions, the paper identifies the unidirectional dependence that provides a constructive signal to supplier's corporate innovation. Little research focuses on relating the power-dependence structure to supplier's corporate innovation. Third, the paper investigates the relationship duration between suppliers and major customers to investigate the dynamic change of dependent supplier-customer relationships. Little research focuses on the relationship duration in SCM and by interacting it with two dimensions of dependence, the paper sheds light on how dependent supplier-customer relationships dynamically benefit firms from the build-up stage to maturity.

2. Literature Review

2.1. Corporate Innovation in Supply Chains

Corporate innovation acts as a firm-level enabler to develop unique products and services that helps a firm to gain competitive advantages (Bellamy et al., 2014). As a special type of corporate investment, technological innovation affects a firm's operational decisions (Chu et al., 2019). In supply chains, firms are exposed to other organizations through frequent interactions. Recognizing that other organizations are valuable sources of innovation, strategic

suppliers accrue technologies from external sources to improve their innovative performance by taking advantage of their power in supplier-customer relationships. Suppliers accrue more technologies from external sources of networks than what they obtain from internal innovation efforts (Kumar et al. 2020). For example, when a supplier's customer makes more R&D investments than the supplier itself, the potential to leverage the customer's R&D investments could be valuable vectors of innovation for the supplier. Therefore, supplier-customer relationships are believed as important sources of innovation that impact the supplier's own innovative performance.

The general process of innovation is that firms input necessary resources in R&D activities and may or may not obtain productive innovative outputs. Regarding to innovation process, literature investigates corporate innovation from two dimensions: innovative inputs (aka. innovation efforts) and innovative outputs (aka. innovation outcomes). One typical metric of innovative inputs is R&D intensity, which refers to the extent that a firm makes efforts in innovative activities (Kim and Zhu, 2018). Firms spend R&D expenditure developing new products and services to expect beneficial returns (Arora et al., 2004). However, R&D intensity is not a complete metric of corporate innovation because firms may not improve their innovative performance though they invest plentiful resources in R&D activities. To compensate for the drawback of R&D intensity, researchers consider estimating the consequence of a firm's innovation efforts (Kim and Zhu, 2018). Literature uses patent information as an important metric of innovative outputs (Trajtenberg et al., 1997; Miller et al., 2007; Choi and McNamara, 2018; Brunel, 2019). Patent information serves as a front-end metric of innovative activities that reflect advancements over existing technologies (Bellamy et al., 2014; Kumar et al., 2020). Patent protection is one of the most efficient ways to achieve technological evolution and competitive advantages (Hauser et al., 2006). Using the data of patent information, literature links innovative outputs to other firm-level performance in SCM.

For example, Bellamy et al. (2014) investigate the way that structural characteristics of supply networks affect innovative outputs. Brunel (2019) distinguishes domestic patents and foreign patents to measure domestic innovation and the adoption of foreign technologies separately. To leverage patent information appropriately, Ahuja et al. (2005) identify innovative outputs into two dimensions: quantity of innovation and quality of innovation. The quantity of innovation is measured by the number of patents that a firm applies or grants in a given period. It provides a fundamental overview of innovative output but inevitably remains biased and insufficient (Hall et al., 2001). The quality of innovation is measured by the number of patent citations that a patent is cited by other forward patents. It enables researchers to trace patent applications because forward patents are required to cite earlier similar or related patents with technical claims (Hagedoorn and Cloudt, 2003). Therefore, the paper uses two dimensions of innovative outputs to estimate corporate innovation through informative and composite perspectives.

2.2. Dependent Supplier-Customer Relationships

To gain competitive advantages, suppliers identify relationship management as one of their top issues in operations. Supplier-customer relationships are increasingly concentrated in decades, in which supplier's financial sales occur within a few major customers. Compared to minor customers who purchase a small number of products and services, major customers with a large number of financial sales are more likely to flow through direct and significant impacts on the supplier (Gulati, 1998), which refers to the phenomenon as "customer-base concentration". In contrast, indirect links usually cannot be recognized and controlled by the focal firm because they are out of the firm's managerial reach (Choi and Krause, 2006). As suppliers are more intertwined with major customers, major customers impact the supplier's performance by leveraging dependent supplier-customer relationships (Galbraith and Stiles,

1983). The intertwinement creates bilateral dependence in dyadic supplier-customer relationships, including supplier's dependence and customer's dependence.

Organizational perspectives build resource dependence theory (RDT) to describe the power-dependence structure in supplier-customer relationships. The central proposition of RDT is that organizations are dependent on other organizations for the provision of vital resources (Drees and Heugens, 2013) and thus constrained by a network of interdependence for these external resources (Hillman and Withers, 2009). Organizations own power by taking control of vital resources over other organizations who require these resources (Huo et al., 2017). Suppliers are dependent on external resources from powerful resource owners, which allows them to dominate dependent suppliers and maximize their own interests (Galbraith, 1952; Pfeffer and Salancik, 2003). In supplier-customer relationships, suppliers' increased volume of financial sales with major customers is regarded as essential resources owned by major customers, resulting in supplier's dependence on major customers. When interest-driven major customers own power over suppliers, they gain more bargaining power and occupy advantageous positions. Major customers could activate their power, exert adversarial tactics, and require relationship-specific investments (RSI) from power-disadvantaged suppliers (Gassenheimer and Ramsey, 1994; Crook and Combs, 2007). On the one hand, major customers utilize their bargaining power to squeeze dependent supplier's profits by identifying more opportunism, which is self-interest seeking with guile (Williamson, 1973). When power-advantaged major customers dominate in supplier-customer relationships, they perceive less supplier's opportunism while suppliers perceive more major customers' opportunism (Villena and Craighead, 2017). On the other hand, dependent suppliers require to make RSI to maintain relationships (Gu et al., 2017; Kim and Zhu, 2018), which requires suppliers to invest resources to its major customers as a commitment and are irreversible once suppliers switch to other customers (Huang et al., 2016). The sunk cost makes suppliers vulnerable to find alternatives

to replace current customers. For example, in product development, customers require suppliers to install unique fixturing, merchandise displays, and equipment to meet their demands (Jap and Ganesan, 2000). Meanwhile, power asymmetry is a perceptual construct (Fiol et al., 2001) that is intentionally activated by powerful major customers or exists in the eyes of interested suppliers. In the Samsung-Apples case, recognizing Samsung's dependence, Apple pressured Samsung from the lawsuit and forced Samsung to comply and supply under Apple's terms and regulations (Kim, 2012).

Nevertheless, increased volume of financial sales also acts as valuable resources for major customers, which in turn increases major customers' dependence on suppliers. Organizational perspectives believe that supplier-customer relationships are bilateral in which suppliers could also build switching costs and concomitant bargaining power as opposed to major customers (Crook and Combs, 2007). Emerson (1962) describes joint dependence as the aggregation of dyadic firms' dependence by summing two dimensions of unidirectional dependence, independent of power asymmetry—the variance of dyadic firms' dependence. The joint dependence shifts organizations' motivations away from the pursuit of shortsighted economic benefits to improve relationships through trust and reciprocity (Powell et al., 1990). Supplier's dependence and customer's dependence act independently as one could have an additional effect on the other (Casciaro and Piskorski, 2005). When customers are dependent on their suppliers, power-disadvantaged customers invest RSI in suppliers that increase their switching costs to alternative suppliers (Jap and Ganesan, 2000). From RDT, suppliers own bargaining power, withhold available resources, and expect more opportunistic behavior against major customers. From cooperative incentives, customers are willing to commit to bilateral efforts and make the relationship resilient and successful (Terpend and Krause, 2015). Ultimately, suppliers receive rewards from relationships and foster trust and commitment with dependent customers (Chen et al., 2004). In the Samsung-Apple case, because Samsung was the sole

supplier of Apple's processing chips, it leveraged component business to pressure Apple and countered Apple with its patent allegations (Martin and Mickle, 2017). Meanwhile, Apple looked to reduce its supply-chain reliance on Samsung by finding alternative suppliers.

2.3. Relationship Duration

The relationship duration between a supplier and its major customers recognizes the dynamic changes as they interact with each other consistently over periods. In the early stage of relationships, dependent firms make RSI to commit relationships with power-advantaged firms, which are of high risk due to irreversible switching costs (Gu et al., 2017). Power-advantaged firms utilize their bargaining power to create competitive environments among dependent firms and limit their access to vital resources, restricting their innovative capabilities (Kim and Zhu, 2018). Therefore, in the early stage, dependent suppliers confront severe uncertainties and competition because of their position in power disadvantages. As the relationship matures, suppliers obtain repeated sales and cross-selling opportunities from major customers instead of spending resources to attract new customers (Kotler and Armstrong, 1991). These activities cooperated with major customers are valuable sources of product ideas and test sites for product development, which ultimately become vectors of supplier's innovation (Jackson and Bund, 1985). In addition, goodwill trust emerges from repeated sales and long-term relationships that enhances inter-organizational performance along the entire supply chain (Lanier et al., 2010). Similarly, customer's dependence could motivate customer's willingness to maintain long-term relationships with suppliers that creates benefits to mutual sides (Lanier et al., 2010), including supply-chain integration (Vickery et al., 2003), firm's responsiveness (Chen et al., 2004), and firm's productivity (Serpa and Krishnan, 2016).

Marketing researchers describe how the relationship duration promotes firm-level performance in supply chains. Dwyer et al. (1987) develop an influential framework that posits

five series of predictable and stable stages in buyer-seller relationships: awareness, exploration, build-up, maturity, and dissolution. However, the temporality that distinguishes short-term and long-term causal effects in networks, including life cycle, technological and evolutionary logics, is metaphorical while not all theoretical stages have been empirically confirmed (Irvine et al., 2016; Kumar et al., 2020). Not all transaction activities move through into five stages respectively (Jap and Anderson, 2007). Empirical research identifies the relationship duration as the length of supplier-customer relationships from the build-up stage to the mature stage (Eggert et al., 2006; Serpa and Krishnan, 2016). When the relationship evolves to maturity, it lasts considerably long, reflecting that RSI could bring long-term benefits to suppliers (Jap and Anderson, 2007).

3. Hypotheses Development

3.1. The Effect of Supplier's Dependence and Relationship Duration on Innovation

Supplier's dependence (aka. customer concentration) refers to the extent that a supplier is dependent on its major customers in terms of financial sales (Patatoukas, 2012). It captures how major customers take control of vital resources that suppliers cannot readily access and find alternatives. From RDT, dependent suppliers are willing to develop their capability to grant vital resources and reduce uncertainties (Casciaro and Piskorski, 2005). However, major customers tend to resist suppliers' attempts in developing such capability because it will undermine their advantageous positions (Casciaro and Piskorski, 2005). Empirical research identifies supplier's dependence as a double-edged sword. Just-in-time (JIT) firms with a diffuse customer base (low supplier's dependence) have superior ROA responses relative to those with a concentrated customer base (Balakrishnan et al., 1996). For innovative inputs, supplier's dependence is negatively related to supplier's R&D investment (Kim and Zhu, 2018). However, other empirical research identifies positive signals of supplier's dependence on

supplier's accounting rates of return (Patatoukas, 2012), tax avoidance (Huang et al., 2016), and inventory efficiencies (Ak and Patatoukas, 2016). However, little research documents the effect of supplier's dependence on innovative outputs though researchers believe that supplier-customer relationships are essential sources of innovation. Depending on large-scale major customers, suppliers may have access to more external technologies that can be used to innovate their products and services. Meanwhile, suppliers should be careful about the risk that power-advantageous major customers squeeze supplier's benefits to pursue their own interests.

To extend previous results, I posit that the effect of supplier's dependence on supplier's corporate innovation is moderated by the relationship duration. Empirical research documents that firms benefit from the maturity of supplier-customer relationships. Kalwani and Narayandas (1995) find that suppliers in long-term relationships could achieve higher profitability through inventory utilization. Suppliers achieve higher potentials for financial sales (Jap and Anderson, 2007) and value creation in customer operations (Eggert et al., 2006) as the relationship duration increases. However, little research investigates the moderating effect of the relationship duration on corporate innovation though innovative outputs are characterized to require technology accumulation and R&D development in long-term relationships. Therefore, I make the following hypotheses.

Hypothesis 1: The relationship duration positively moderates the association between supplier's dependence and supplier's quantity of innovation.

Hypothesis 2: The relationship duration positively moderates the association between supplier's dependence and supplier's quality of innovation.

3.2. The Effect of Customer's Dependence and Relationship Duration on Innovation

Customer's dependence refers to the extent that a major customer is dependent on its supplier in terms of financial sales. It captures how suppliers take control of vital resources that major

customers cannot readily access and find alternatives. Though little research investigates customer's dependence when taking suppliers as focal firms, it may have the opposite effect on supplier's corporate innovation compared to supplier's dependence. When a supplier owns its customer's dependence and withholds more power, it dominates the relationship and invests their innovative activities with more freedom. Corporate innovation requires the supplier to invest in R&D activities continuously and maintain solid relationships with partners (Jap and Anderson, 2007). Under customer's dependence, the supplier is unlikely to terminate relationships because suppliers enjoy advantageous positions and cooperate on favorable terms with major customers. Meanwhile, customer's dependence is an important component of mutual dependence, calculated as the sum of supplier's dependence and customer's dependence. Mutual dependence enhances the likelihood of constraint absorption between partners (Casciaro and Piskorski, 2005), the performance of procurement relationships in manufacturers (Gulati and Sytch, 2007), the operational performance surveyed by managers (Huo et al., 2017), and supplier's financial performance (Kim, 2017).

Similar to supplier's dependence, I posit that the relationship duration is a positive moderator on the effect of customer's dependence. Maintaining long-term relationships is one of the most important purchasing strategies for firms in supply chains (Chen et al., 2004). Therefore, I make the following hypotheses.

Hypothesis 3: The relationship duration positively moderates the association between customer's dependence and supplier's quantity of innovation.

Hypothesis 4: The relationship duration positively moderates the association between customer dependence and supplier's quality of innovation.

Figure 1 shows the structure of the hypotheses.

Figure 1: Hypotheses.

4. Methodology

4.1. Data Collection

The data collection included two major databases: the Compustat database and the NBER patent database. The Compustat database reported U.S. public-traded firms' financial information, industry segment information, and major customer information. First, I retrieved suppliers' identifying information (e.g. GVKEY, CUSIP, and Standard Industrial Classification (SIC)) and financial information (e.g. total sales, total assets, and R&D expenditure) from the Compustat Fundamental Annual database. Because many supplier names were not in standard forms, I retrieved identifying information to inspect the accuracy of supplier's identifications. Second, I retrieved supplier's industry segment data from the Compustat Historical Segment database. Suppliers might have transactions in multiple industry segments that differed in the levels of competitiveness. The database included supplier's identifiable industry segments and respective sales. Third, I retrieved major customers' identifying information and supplier's sales to major customers from the Compustat Customer

Segment database. To build dyadic supplier-customer relationships, I referred to Andrea Frazzini's data library (http://people.stern.nyu.edu/afrazzin/data_library.htm) that consisted of well-established supplier-customer links (Atanassov, 2013). According to the statements of Financial Accounting Standards (SFAS) No. 131's major customer disclosure, public-traded firms from the Compustat database voluntarily disclosed their customers that accounted for more than 10 percent of their total sales. Though the statements required suppliers to identify major customers that accounted for at least 10 percent of their total sales, suppliers could voluntarily report other customers that possibly accounted for less than 10 percent of their total sales (Dhaliwal et al., 2016). Therefore, I manually inspected customers' purchases from suppliers to ensure that they conformed to the statements of SFAS No. 131.

The NBER patent database comprised detailed information of U.S. patents and forward citations between 1975 to 2006 from the United States Patent and Trademark Office (USPTO) (Hall et al., 2001; Bessen 2009). Each patent had its unique ID, assignee name, relative categories, and the number of patent citations. The database had a broad match of the assignee to the firm in the Compustat database using common identifying information (e.g. GVKEY and CUSIP), which helped me connect the Compustat database to the NBER patent database efficiently. The sample period was between 1980 and 2006 as the last year updated for the NBER patent database was 2006.

4.2. Dependent Variables

I measured supplier's corporate innovation from the perspective of innovative outputs by using two dependent variables: quantity of innovation and quality of innovation. The quantity of innovation was measured by the number of applied patents that a supplier applied each year. Compared to granted patents, the actual timing of applied patents was closer to the patented invention as inventors generally had a strong incentive to apply for patents instantly after

inventing (Hall et al., 2001). Furthermore, the year of granted patents depended on the review process from the patent office that might result in omitted bias in estimate. The number of applied patents was a direct measure of innovation that reflected advancements over existing technologies, especially for technology-intensive firms (Hall et al., 2001; Miller et al., 2007; Bellamy et al., 2014; Brunel, 2019). Firms expected to pioneer in emerging markets and technologies by filing more patent applications. For example, in 2016, ten of the world's largest car makers submitted 9,700 patent applications that increased nearly 110 percent from 2012 (Rogers, 2017). The quality of innovation was measured by the number of forward patent citations of applied patents that a supplier issued each year. A patent that received a relatively large number of citations contributed more to the economic value (Trajtenberg, 1990). Unlike the number of applied patents, the number of patent citations distributed weights to patents based on their quantities of forward citations that reflected their innovative importance (Hagedoorn and Cloudt, 2003). Generally, a firm's granted patents were heavily cited over the 3-year period after their application, which reflected the strength of the firm's past patents (Ahuja et al., 2005). For example, in 2016, General Motors narrowed their 1,000 patent filings to emerging technologies and advanced materials, down 3.4 percent from 2012, after they announced to look at patent quality instead of patent volume (Rogers, 2017). Overall, I operationalized innovative outputs in two dependent variables: the number of applied patents and the number of patent citations. I presented Table 1 to describe all variables, including their types, measures, and data sources.

Description of Variables

Construct	Variable	Variable Type	Measure	Data Source
Quantity of Innovation	Number of Applied Patents	Dependent	<i>Number of Applied Patents</i> _{<i>i,t+2</i>}	NBER Patent database
Quality of Innovation	Number of Patent Citations	Dependent	<i>Number of Applied Patents</i> _{<i>i,t+2</i>}	NBER Patent database
Supplier's Dependence	SDR	Independent	<i>Supplier's Dependence Ratio (SDR)</i> _{<i>it</i>} $= \frac{\sum_{j=1}^J \left(\frac{Sales_{ijt}}{Sales_{it}} \right)^2}{\sum_{s=1}^S \left(\frac{Sales_{ist}}{Sales_{it}} \times HHI_{st} \right)}$	Compustat
Customer's Dependence	CDR	Independent	<i>Customer's Dependence Ratio (CDR)</i> _{<i>it</i>} $= \frac{\sum_{j=1}^J \left(\frac{Sales_{ijt}}{COGS_{jt}} \right)^2}{\sum_{j=1}^J \left(\frac{Sales_{ijt}}{Sales_{it}} \times \left(\sum_{s=1}^S \left(\frac{Sales_{jst}}{Sales_{jt}} \times HHI_{st} \right) \right) \right)}$	Compustat
Relationship Duration	Relationship Duration	Moderator	<i>Duration</i> _{<i>it</i>}	Compustat
Supplier Size	Supplier Size	Control	<i>Supplier Size</i> _{<i>it</i>} = log (<i>Total Asset</i> _{<i>it</i>} + 1)	Compustat
Supplier Growth	Supplier Growth	Control	<i>Supplier Growth</i> _{<i>it</i>} = <i>Sales</i> _{<i>it</i>} / <i>Sales</i> _{<i>i,t-1</i>}	Compustat
Supplier Prior Performance	Supplier Prior Performance	Control	<i>SPP</i> _{<i>it</i>} = <i>Net Income</i> _{<i>it</i>} / <i>Total Assets</i> _{<i>it</i>}	Compustat
Supplier Debts Ratio	Supplier Debts Ratio	Control	<i>SDR</i> _{<i>it</i>} = <i>Total Debts</i> _{<i>it</i>} / <i>Total Assets</i> _{<i>it</i>}	Compustat
Supplier R&D Ratio	Supplier R&D Ratio	Control	<i>SRDR</i> _{<i>it</i>} = <i>Total R&D Expenditure</i> _{<i>it</i>} / <i>Total Assets</i> _{<i>it</i>}	Compustat
Industry Size	Industry Size	Control	<i>Industry Size</i> _{<i>st</i>} = log (<i>Total Asset</i> _{<i>st</i>} + 1)	Compustat
Industry Growth	Industry Growth	Control	<i>Industry Growth</i> _{<i>st</i>} = <i>Sales</i> _{<i>st</i>} / <i>Sales</i> _{<i>s,t-1</i>}	Compustat

Table 1: Description of variables

4.3. Independent Variables and Moderating Variable

4.3.1. Supplier's Dependence Ratio (SDR)

Supplier's dependence ratio incorporated supplier's dependence on major customers scaled by supplier's industry competitiveness, as described below.

$$Supplier's Dependence Ratio (SDR)_{it} = \frac{\sum_{j=1}^J \left(\frac{Sales_{ijt}}{Sales_{it}} \right)^2}{\sum_{s=1}^S \left(\frac{Sales_{ist}}{Sales_{it}} \times HHI_{st} \right)}$$

The numerator $Customer\ Concentration_{it} = \sum_{j=1}^J \left(\frac{Sales_{ijt}}{Sales_{it}} \right)^2$ was the conventional measure of supplier's dependence that focused on firm-level customer concentration (Patatoukas, 2012). In the expression, $Sales_{ijt}$ represented supplier i 's sales to its major customer j in year t and $Sales_{it}$ represented supplier i 's total sales in year t . The expression of supplier's dependence captured two dimensions: the number of major customers and the relative importance of each major customer determined by the purchase from the supplier (Kim, 2017). The expression ranged from 0 to 1 where a larger number of customer concentration represented a concentrated customer base to the supplier, which in turn resulted in a higher level supplier's dependence. To an extreme, if a supplier had only one customer who purchased its all products and services, then the supplier's customer concentration reached the maximum value 1 as $Sales_{ijt}$ equalized to $Sales_{it}$ and $J = 1$.

The denominator $Supplier's\ Industry\ Competitiveness_{it} = \sum_{s=1}^S \left(\frac{Sales_{ist}}{Sales_{it}} \times HHI_{st} \right)$ captured the extent that a supplier's industry segments were competitive. To a supplier i , it might have financial sales in multiple industry segments. Thus, HHI_{st} represented a supplier's industry segment s 's industry concentration in year t calculated by Herfindahl-Hirschman Index (HHI), which was a whole number from 0 to 10,000. Higher HHI_{st} represented a concentrated industry segment that was less competitive (Kim, 2019). However, as one supplier might have business in multiple industry segments, I used supplier's financial sales in respective industry segments to weight HHI_{st} where $Sales_{ist}$ represented supplier i 's sales in industry segment s in year t and $Sales_{it}$ represented supplier i 's total sales in year t . Therefore, the denominator described the focal supplier's weighted industry competitiveness in a given year.

Putting together, SDR described the focal supplier's dependence on its major customers and accounted for the fact that a supplier with competitive industry segments was more dependent

on its major customers. Suppliers had more power to bargain and reduced their dependence on major customers when they dominated in a less competitive industry; in contrast, suppliers had fewer alternatives to bargain with major customers when they competed with other suppliers in a competitive industry.

4.3.2. Customer's Dependence Ratio (CDR)

Customer's dependence ratio incorporated major customer's dependence on suppliers scaled by major customer's industry competitiveness, as described below.

$$Customer's\ Dependence\ Ratio\ (CDR)_{it} = \frac{\sum_{j=1}^J \left(\frac{Sales_{ijt}}{COGS_{jt}} \right)^2}{\sum_{j=1}^J \left(\frac{Sales_{ijt}}{Sales_{it}} \times \left(\sum_{s=1}^S \left(\frac{Sales_{jst}}{Sales_{jt}} \times HHI_{st} \right) \right) \right)}$$

The numerator $Customer's\ Dependence_{it} = \sum_{j=1}^J \left(\frac{Sales_{ijt}}{COGS_{jt}} \right)^2$ was the measure of major customer's dependence that focalized on supplier i in year t . In the expression, $Sales_{ijt}$ also represented major customer j 's purchase from its supplier i in year t and $COGS_{jt}$ represented major customer j 's total purchase in year t . As one supplier might have several major customers in a given year, I captured the customer base's dependence on the supplier by summing over J major customers. Similarly, the expression was larger than 0. However, unlike supplier's customer concentration, the expression's maximum value could exceed 1 because customer's dependence captured customer base's dependence in summation.

The denominator $Supplier's\ Customer\ Base\ Industry\ Competitiveness_{it} = \sum_{j=1}^J \left(\frac{Sales_{ijt}}{Sales_{it}} \times \left(\sum_{s=1}^S \left(\frac{Sales_{jst}}{Sales_{jt}} \times HHI_{st} \right) \right) \right)$ captured the extent that a supplier's customer base industry segments were competitive. Similar to supplier's industry competitiveness, major customers might have business in multiple industry segments. Thus, I used major customer's financial sales in respective industry segments to weight HHI_{st} where $Sales_{jst}$ represented

major customer j 's sales in industry segment s in year t and $Sales_{jt}$ represented major customer j 's total sales in year t . Therefore, $\sum_{s=1}^S \left(\frac{Sales_{jst}}{Sales_{jt}} \times HHI_{st} \right)$ described the individual major customer's weighted industry competitiveness in a given year. However, because suppliers were focal firms in the variable building, to calculate a supplier's overall customer base industry competitiveness, I weighted the supplier's several major customers' industry competitiveness based on the supplier's sales to each major customer in a given year, which was the summing term $\sum_{j=1}^J \frac{Sales_{ijt}}{Sales_{it}}$.

Putting together, CDR described the major customer base's dependence on the focal supplier and accounted for the fact that a major customer base with competitive industry segments was more dependent on the supplier because major customers had less power to bargain with the supplier.

4.3.3. Relationship Duration

Though supplier-customer relationships were changing over time, the mature phase could last for a considerably long period (Jap and Anderson, 2007). Therefore, I used counted number of years that occurred financial sales between a supplier and its major customers to measure the relationship duration. In other words, it indicated the age of linkage between a supplier and its major customers. However, one supplier might correspond to several major customers in a given year, which resulted in several observations of the relationship duration. I distributed weights to these observations of the relationship duration based on the supplier's sales to each major customer in a given year.

4.4. Control Variables

I also controlled for a variety of firm and industry characteristics to account for extraneous effects (Bellamy et al., 2014; Kim, 2017; Krolikowskia and Yuan, 2017). Firm-level control variables included supplier size, supplier growth, supplier prior performance, supplier debts ratio, and supplier R&D ratio. Supplier size, measured by the natural log of the supplier's total assets plus one, indicated that a large supplier might have more resources in innovation. Supplier growth, measured by the ratio of supplier's sales in the current year over supplier's sales in the previous year, indicated that a supplier in high-speed growth might have more incentives in innovation. Supplier prior performance, measured by supplier's net income over total assets (aka. ROA), indicated that a profitable and efficient supplier might generate more innovative outcomes. Supplier debts ratio, measured by supplier's total debts over total assets, indicated that a supplier in healthy liability was more likely to innovate. Supplier R&D ratio, measured by supplier's R&D expenditure over total assets, indicated that a supplier who invested more resources in R&D activities might have more fruitful innovative outcomes. Industry-level control variables included industry size and industry growth. Industry size, measured by the natural log of the industry's total assets plus one, indicated that a large industry might provide access to more resources for included suppliers. Industry growth, measured by the ratio of industry's sales in the current year over industry's sales in the previous year, indicated that an industry in high-speed growth might contain more innovative opportunities for included suppliers.

4.5. Model Specification

I operationalized innovative output in two dependent variables: the number of applied patents and the number of patent citations. Two dependent variables had common characteristics of non-negative integer values with excess zeros. Therefore, ordinary least

squares (OLS) regression was not appropriate for the sample data because it assumed linearity, homoskedasticity, and normality (Greene, 2007). I used the fixed-effects Poisson regression to account for the characteristics of the sample data. First, the sample data was the panel data that was required to account for individual effects. I performed the Hausman test to determine between fixed-effects and random-effects and the result indicated that fixed-effects were appropriate for the sample data. Thus, I controlled for industry- and year- fixed effects. Second, an alternative model for the Poisson regression was the negative binomial regression that controlled for the overdispersion problem. However, the negative binomial regression could not control for individual fixed-effects, which resulted in severe covariate problems (Allison and Waterman, 2002; Silva and Tenreyro, 2010). Meanwhile, the degree of overdispersion in the sample data was acceptable that would not bias the results to a large extent. Therefore, I used the fixed-effects Poisson regression to estimate the sample data instead of the fixed-effects negative binomial regression.

The fixed-effects Poisson regression had the following form (Guimarães, 2008):

$$E(n_{it}) = \lambda_{it} = \exp(\alpha_i + \beta'x_{it}),$$

where n_{it} was the count variable for individual i in year t , β was a vector of unknown parameters, x_{it} was a vector of exogenous variables, and α_i were variables that account for all “fixed effects”. It was assumed that n_{it} followed a Poisson distribution with parameter λ_{it} and then the conditional likelihood function was given by

$$f_{Poi}(n_{it}) = \frac{\lambda_{it}^{n_{it}} e^{-\lambda_{it}}}{n_{it}!}.$$

In my estimate, n_{it} referred to dependent variables including the number of applied patents and the number of patent citations and x_{it} referred to each explanatory variable including independent, moderating, and control variables. To mitigate reverse causality and account for the lagged effect of innovation, all independent, moderating, and control variables were lagged by three years. Therefore, the two models took the following forms:

$$E(\text{Number of Applied Patents}_{i,t+3})$$

$$\begin{aligned} &= \exp (\alpha_i + \beta_0 + \beta_1(\text{SDR}_{it}) + \beta_2(\text{CDR}_{it}) + \beta_3(\text{Duration}_{it}) \\ &+ \beta_4(\text{SDR}_{it} \times \text{Duration}_{it}) + \beta_5(\text{CDR}_{it} \times \text{Duration}_{it}) \\ &+ \beta_6(\text{Supplier Size}_{it}) + \beta_7(\text{Supplier Growth}_{it}) \\ &+ \beta_8(\text{Supplier Prior Performance}_{it}) + \beta_9(\text{Supplier Debts Ratio}_{it}) \\ &+ \beta_{10}(\text{Supplier R\&D Ratio}_{it}) + \beta_{11}(\text{Industry Size}_{it}) \\ &+ \beta_{12}(\text{Industry Growth}_{it})) \end{aligned}$$

$$E(\text{Number of Patent Citations}_{i,t+3})$$

$$\begin{aligned} &= \exp (\alpha_i + \beta_0 + \beta_1(\text{SDR}_{it}) + \beta_2(\text{CDR}_{it}) + \beta_3(\text{Duration}_{it}) \\ &+ \beta_4(\text{SDR}_{it} \times \text{Duration}_{it}) + \beta_5(\text{CDR}_{it} \times \text{Duration}_{it}) \\ &+ \beta_6(\text{Supplier Size}_{it}) + \beta_7(\text{Supplier Growth}_{it}) \\ &+ \beta_8(\text{Supplier Prior Performance}_{it}) + \beta_9(\text{Supplier Debts Ratio}_{it}) \\ &+ \beta_{10}(\text{Supplier R\&D Ratio}_{it}) + \beta_{11}(\text{Industry Size}_{it}) \\ &+ \beta_{12}(\text{Industry Growth}_{it})) \end{aligned}$$

5. Estimate

5.1. Descriptive Statistics

I run all analyses in Stata 15. First, I reported descriptive statistics of the sample data. Table 2 presented the means, standard deviations, minimums, and maximums of all variables. Overall, there were 4,117 observations in the sample data. The mean of SDR and CDR were comparably small because industry competitiveness was a whole number ranging from 0 to 10,000. Four variables (number of applied patents, number of patent citations, supplier debts ratio, and supplier R&D ratio) included excess zeros, indicating that suppliers might not issue patents, default on debts, and invest in R&D activities in a given year. The mean of supplier prior performance was negative because suppliers were likely to have negative income in a given

year. I excluded outliers in the sample data to ensure that all variables were in reasonable ranges.

Table 3 presented pairwise correlations of independent, moderating, and control variables. All correlation coefficients were below 0.5, indicating multicollinearity was not a major concern in the estimate.

Descriptive Statistics

Variables	Observations	Mean	Std. Dev.	Min	Max
Number of Applied Patents	4117	3.2040	39.0340	0	1482
Number of Patent Citations	4117	11.1715	99.4806	0	2739
SDR	4117	0.0020	0.0146	0.0000	0.5224
CDR	4117	0.0003	0.0096	0.0000	0.4852
Relationship Duration	4117	1.9950	1.5513	1	14
Supplier Size	4117	4.6103	1.9166	0.3119	10.8840
Supplier Growth	4117	2.0782	33.9584	0.0393	2087.7500
Supplier Prior Performance	4117	-0.0883	0.6709	-22.0375	21.7891
Supplier Debts Ratio	4117	0.0915	0.2336	0.0000	7.9597
Supplier R&D Ratio	4117	0.0703	0.1457	0.0000	2.0520
Industry Size	4117	8.1480	2.3568	0.2708	12.0135
Industry Growth	4117	1.0665	0.1130	0.3402	2.1241

Table 2: Descriptive statistics

Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) SDR	1.0000									
(2) CDR	-	1.0000								
(3) Relationship Duration	-	-	1.0000							
(4) Supplier Size	-	0.040*	0.134*	1.0000						
(5) Supplier Growth	-	0.0010	0.0180	0.0110	1.0000					
(6) Supplier Prior Performance	-	0.0030	0.056*	0.135*	0.0010	1.0000				
(7) Supplier Debts Ratio	-	0.0160	0.0100	0.180*	0.0080	0.164*	1.0000			
(8) Supplier R&D Ratio	-	0.0050	0.109*	0.173*	0.0040	0.334*	0.040*	1.0000		
(9) Industry Size	-	0.0040	0.0220	0.443*	0.0110	0.0300	0.223*	0.139*	1.0000	
(10) Industry Growth	-	0.0170	0.0010	0.049*	0.0160	0.0190	0.043*	0.0200	0.087*	1.0000

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

Table 3: Pairwise correlations

5.2. Main Estimate

The results of the fixed-effects Poisson regression were presented in Table 4. Noted that the numbers of observations for the two models in Table 4 were smaller than those in Table 2. Some observations were dropped in the estimate because there were all zero values or there was only one observation per group. Model 1-4 tested the effects of dependent supplier-customer relationships on the quantity of innovation measured by the number of applied patents. Model 1 was the base model that only included control variables. Among all control variables, supplier growth, supplier prior performance, and supplier debts ratios were insignificant. Supplier size and industry size had positive effects on the number of applied patents. Conversely, supplier R&D ratio and industry growth had negative effects on the number of applied patents. Model 2 and Model 3 included the main effects of SDR and CDR, respectively. The results indicated that neither SDR nor CDR was significant solely. Model 4 was the full model including independent variables, moderating variables, and their interaction terms. Model 4 indicated that $SDR_{it} \times Duration_{it}$ was insignificant, which did not support Hypothesis 1. It also indicated that $CDR_{it} \times Duration_{it}$ was insignificant, which did not support Hypothesis 3. Interestingly, the relationship duration could not moderate the effect of supplier's dependence and customer's dependence on the quantity of innovation.

Models 5-8 tested the effects of dependent supplier-customer relationships on the quality of innovation measured by the number of patent citations. Model 5 was the base model. Among all control variables, supplier growth and industry size were insignificant. Supplier size, supplier prior performance, and supplier R&D ratio had positive effects on the number of patent citations. Conversely, supplier debts ratio and industry growth had negative effects on the number of patent citations. Model 6 and Model 7 included the main effects of SDR and CDR, respectively, in which SDR had a negative sole effect on the number of patent citations. Model 8 was the full model that indicated a significantly positive effect of $SDR_{it} \times Duration_{it}$

that supported Hypothesis 2 but a significantly negative effect of $CDR_{it} \times Duration_{it}$ that did not support Hypothesis 4. Interestingly, as the relationship duration increased, the negative effect of supplier's dependence on quality of innovation was positively moderated while the positive effect of customer's dependence on quality of innovation was negatively moderated by the relationship duration.

Fixed-Effects Poisson Regression Model

Dependent Variables	Number of Applied Patents $t+3$				Number of Patent Citations $t+3$			
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6	(7) Model 7	(8) Model 8
SDR		-.0382 (1.3709)		.1856 (10.9214)		-2.0603* (1.1008)		-42.5642*** (4.3245)
CDR			.8992 (1.1633)	-1.6247 (2.4495)			-.0636 (.4111)	2.5916** * (.8476)
Relationship Duration				.0709*** (.0215)				.0256*** (.0086)
SDR * Relationship Duration				-.0992 (5.4363)				20.3187*** (2.0978)
CDR * Relationship Duration				2.7866 (2.4735)				-2.9582** (.7898)
Supplier Size	.1300** (.0622)	.1300** (.0623)	.1288** (.0622)	.1655*** (.0634)	.1147*** (.0238)	.1157*** (.0238)	.1148*** (.0238)	.0972*** (.0260)
Supplier Growth	.0091 (.0354)	.0090 (.0355)	.0090 (.0355)	.0081 (.0356)	-.0262 (.0165)	-.0264 (.0165)	-.0262 (.0165)	-.0096 (.0169)
Supplier Prior Performance	-.0585 (.0438)	-.0585 (.0438)	-.0584 (.0438)	-.0581 (.0436)	.2725*** (.0594)	.2714*** (.0594)	.2723*** (.0594)	.3278*** (.0608)
Supplier Debts Ratio	.0287 (.2917)	.0290 (.2919)	.0193 (.2922)	.0382 (.3015)	-1.3763* (.4636)	-1.3551* (.4624)	-1.374** (.4636)	-1.0561* (.4505)
Supplier R&D Ratio	-1.0075*** (.3900)	-1.0075* (.3900)	-1.0065* (.3899)	-.8509** (.3939)	1.1024** (.1472)	1.1074** (.1472)	1.1023** (.1472)	1.3424** (.1516)
Industry Size	.1429*** (.0385)	.1428*** (.0386)	.1437*** (.0385)	.1615*** (.0388)	.0161 (.0155)	.0161 (.0155)	.0162 (.0155)	.0189 (.0156)
Industry Growth	-.8699*** (.2110)	-.8697** (.2112)	-.8824** (.2115)	-.8543** (.2128)	-1.6404* (.0869)	-1.6379* (.0869)	-1.6389* (.0875)	-1.5706* (.0885)
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1212	1212	1212	1212	961	961	961	961
AIC	3343	3345	3345	3340	17964	17961	17966	17832

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 4: Fixed-effects Poisson regression model with 3-year lags – innovative outputs (1980-2006)

5.3. Moderating Effects

From Table 4, the main effects of independent variables were contingent with insignificant coefficients, which were moderated by the relationship duration. To have a closer look at moderating effects, I graphed the plots of two interaction terms. I graphed the predicted dependent variables with changes in each correspondent variables, using high and low values

of correspondent variables with one standard deviation below and above the mean. Particularly, I only included the plot of $SDR_{it} \times Duration_{it}$ and the number of patent citations and the plot of $CDR_{it} \times Duration_{it}$ and the number of patent citations. I excluded the plot of $SDR_{it} \times Duration_{it}$ and the number of applied patents and the plot of $CDR_{it} \times Duration_{it}$ and the number of applied patents because regression results were insignificant in Table 4.

Figure 2 was the plot of $SDR_{it} \times Duration_{it}$ and the number of patent citations. The blue “Low Duration” line and the red “High Duration” line distinguished the moderating effects of the relationship duration on the predicted number of patent citations. The slope of each line depicted the effect of SDR on the predicted number of patent citations from the low value to the high value. Figure 2 indicated that the high value of the relationship duration positively reinforced the association between SDR and the number of patent citations while the low value of the relationship duration negatively weakened the association between SDR and the number of patent citations. Figure 3 was the plot of $CDR_{it} \times Duration_{it}$ and the number of patent citations. The blue line and the red line distinguished high and low levels of the relationship duration in the same way. Figure 3 indicated the high value of the relationship duration negatively weakened the association between CDR and the number of patent citations while the low value of the relationship duration had nearly no effect on the association between CDR and the number of patent citations. From the two figures, we not only learned why the main effects were insignificant to some extent, but also saw moderating effects of the relationship duration intuitively.

Figure 2: Moderating effect of the relationship duration on supplier's dependence ratio

Figure 3: Moderating effect of the relationship duration on customer's dependence ratio

5.4. Robustness Checks

I conducted additional estimates to ensure the results were robust to alternative settings, methodologies, and models. First, I set all independent, moderating, and control variables to

be lagged by two years instead of three years. According to the data from USPTO, the average time from the date of patent application filing to the date of grant was 2.5 years (Bellamy et al., 2014). Setting 2-year lags could mitigate the concern that some applied patents and their forward citations were filed by USPTO in a shorter period. Results of the fixed-effects Poisson regression with 2-year lags were indicated in Table 5. For the quantity of innovation, the relationship duration had an insignificantly moderating effect on SDR but had a significantly positive moderating effect on CDR, which did not support Hypothesis 1 but supported Hypothesis 3. For quality of innovation, the relationship duration had significantly positive moderating effects on SDR and CDR, which supported Hypothesis 2 and Hypothesis 4. Overall, I found similar results for the effects of SDR but different results for the effects of CDR between 2-year lags and 3-year lags. Interestingly, an important characteristic of patent information was timeliness. The inconsistent results indicated that setting different time lags between firm-level characteristics and innovative outputs might have different analytical results.

Fixed-Effects Poisson Regression Model

Dependent Variables	Number of Applied Patents $t+2$				Number of Patent Citations $t+2$			
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6	(7) Model 7	(8) Model 8
SDR		1.9165*		-3.3017		.8441*		-
		(1.0183)		(8.5865)		(.5030)		(3.6504)
CDR			2.2814**	-1.768			1.2767**	-6.1383***
			(.9887)	(2.3652)			(.3513)	(.7344)
Relationship Duration				.0084				-.0052
				(.0157)				(.0078)
SDR * Relationship Duration				2.6257				29.6206**
				(4.2868)				(1.8062)
CDR * Relationship Duration				4.6267*				8.9016***
				(2.5111)				(.8079)
Supplier Size	.0397	.0364	.0350	.0304	.2363***	.2352***	.2337***	.1448***
	(.0482)	(.0482)	(.0482)	(.0486)	(.0225)	(.0225)	(.0225)	(.0242)
Supplier Growth	.0344	.0356	.0349	.0376	.0961***	.0968***	.0957***	.1177***
	(.0274)	(.0274)	(.0274)	(.0275)	(.0147)	(.0148)	(.0147)	(.0148)
Supplier Prior Performance	-.0363	-.0375	-.0362	-.0359	-.0032	-.0034	-.0015	.0353
	(.0296)	(.0297)	(.0296)	(.0297)	(.0368)	(.0369)	(.0369)	(.0381)
Supplier Debts Ratio	-.1917	-.1983	-.2118	-.2038	-.5519***	-.5533***	-.6210***	-.3498*
	(.1441)	(.1453)	(.1475)	(.1477)	(.1973)	(.1974)	(.2009)	(.2007)
Supplier R&D Ratio	1.2356**	1.2313**	1.2316**	1.2379**	1.6794**	1.6753**	1.6758**	1.8017***
	(.3149)	(.3146)	(.3148)	(.3147)	(.1378)	(.1378)	(.1377)	(.1400)
Industry Size	-.0299	-.0242	-.0287	-.0228	-.1405***	-.1396***	-.1422***	-.1451***
	(.0327)	(.0329)	(.0328)	(.0331)	(.0144)	(.0145)	(.0145)	(.0147)
Industry Growth	-.0540	-.0678	-.0664	-.0900	.4214***	.4179***	.3990***	.3565***
	(.1609)	(.1611)	(.1609)	(.162)	(.0807)	(.0807)	(.0810)	(.0822)
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1349	1349	1349	1349	1104	1104	1104	1104
AIC	798.40	798.24	798.93	792.45	4252.74	4253.56	4253.08	4172.62

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 5: Fixed-effects Poisson regression model with 2-year lags – innovative outputs (1980-2006)

Second, instead of using the Poisson regression, I used the Poisson pseudo-maximum likelihood regressions (PPML) with high-dimensional fixed effects (HDFE) (Correia et al.,

2019a). Compared to the Poisson regression, there was no need to specify a distributional assumption for the dependent variable in PPML. PPML could be applied to any dependent variable with nonnegative values without the need to explicitly specify a distribution for the dependent variable. Therefore, PPML was safe in the presence of nonnegative data with excess zeros as it correctly detected and dropped separated observations in the estimate (Correia et al., 2019b). Another advantage was that PPML allowed controlling for multiple fixed effects that could account for multiple sources of heterogeneity. It was useful in large panel-type datasets with increasing combinations of fixed effects and individual slopes. Results of PPML were indicated in Table 6. However, most results were insignificant so I would not take Table 6 as a main reference compared to the main estimate in Table 4.

Poisson Pseudo-Maximum Likelihood Regressions with High-Dimensional Fixed Effects

Dependent Variables	Number of Applied Patents $t+3$				Number of Patent Citations $t+3$			
	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6	(7) Model 7	(8) Model 8
SDR		8.8088** *		5.3685		7.5487** *		-31.1544
		(3.1196)		(7.5212)		(2.0944)		(34.4326)
CDR			2.072* (1.1287)	-4.5846* (2.7667)			3.6215* (1.9194)	1.7431 (2.9635)
Relationship Duration				-1.181** (.0514)				-1.1342*** (.0483)
SDR * Relationship Duration				2.3338 (4.5019)				20.2764 (17.0741)
CDR * Relationship Duration				6.5768** (3.1284)				1.6662 (3.5856)
Supplier Size	1.000*** (.0326)	1.0035** * (.0329)	.9999*** (.0326)	1.0126** * (.0323)	.8973*** (.0660)	.9012*** (.0660)	.8971*** (.0660)	.9177*** (.0618)
Supplier Growth	-.0001 (.0013)	-.0001 (.0013)	-.0001 (.0013)	-.0001 (.0015)	.0012* (.0007)	.0012* (.0007)	.0012* (.0007)	.0012* (.0007)
Supplier Prior Performance	.1151** (.0562)	.1152** (.0566)	.1150** (.0561)	.1237** (.0581)	.3806*** (.0740)	.3816*** (.0739)	.3805*** (.0740)	.3927*** (.0767)
Supplier Debts Ratio	2.3667** * (.6539)	2.3472** * (.6535)	2.3783** * (.6562)	2.3647** * (.6691)	3.9578** * (.9329)	3.9261** * (.932)	3.9979** * (.9258)	3.8258** * (.9646)
Supplier R&D Ratio	2.5098** * (.4458)	2.5064** * (.4441)	2.5089** * (.4456)	2.4334** * (.4438)	2.2563** * (.4384)	2.2575** * (.4375)	2.2549** * (.4383)	2.1104** * (.4340)
Industry Size	.3056** (.1367)	.3067** (.1357)	.3056** (.1369)	.2723** (.1220)	.0937 (.1293)	.0945 (.1275)	.0919 (.1298)	.0548 (.1188)
Industry Growth	-.8964 (1.1245)	-.8939 (1.1259)	-.8961 (1.1221)	-.8051 (1.0774)	-2.254 (1.3862)	-2.244 (1.3895)	-2.2807* (1.3802)	-1.9854 (1.268)
Constant	-6.486*** (1.688)	6.5369** * (1.6845)	6.4856** * (1.6895)	6.1127** * (1.5855)	.0640 (1.7176)	.0138 (1.7202)	.1080 (1.7179)	.3337 (1.6717)
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	3289	3289	3289	3289	3283	3283	3283	3283
Pseudo R ²	.7456	.7460	.7456	.7490	.6338	.6342	.6341	.6407

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 6: Poisson pseudo-maximum likelihood (PPML) regressions model with high-dimensional fixed effects

(HDFE) – innovative outputs (1980-2006)

Third, I run the Poisson regression with random effects though the Hausman test suggested that fixed-effects were more appropriate in the sample data. The results were similar to the model in section 5.2.

6. Discussion and Conclusion

6.1. Theoretical Implications

This paper studies the association between two dimensions of dependent supplier-customer relationships (supplier's dependence and customer's dependence) and supplier's corporate innovation. It also engages in the moderating effect of the relationship duration. The results of Hypothesis 1 and Hypothesis 2 partially indicate that the relationship duration positively moderates the association between supplier's dependence and supplier's corporate innovation, which are significant for the quality of innovation but insignificant for the quantity of innovation. My findings confirm that supplier's dependence on major customers in terms of financial sales is contingent, which positively reinforces supplier's corporate innovation in long-term relationships. In the early stage of the relationship, suppliers confront unfavorable contracts, make RSI to maintain relationships, and retain low commitment from major customers, weakening their innovative performance capabilities. However, as the relationship duration increases, supplier-customer relationships become mature. Mature relationships increase major customers' commitment to the supplier, ultimately improving trust, information exchange, and joint actions between two parties (Uzzi, 1996). Suppliers reduce transaction costs and leverage innovative technologies from powerful major customers on their corporate innovation. Meanwhile, unlike other performance, corporate innovation requires long-term investments in R&D activities and engages in more uncertainties than firms' general operations. When the supplier and major customers initially build relationships, the suppliers are unlikely to assimilate innovative technologies from customers. The supplier requires time to test its

innovative practices from supplier-customer relationships. Overall, the relationship duration is a positive signal to supplier's corporate innovation when suppliers are dependent on major customers in terms of financial sales.

Surprisingly, the results of Hypothesis 3 and Hypothesis 4 partially indicate that the relationship duration negatively moderates the association between customer's dependence and supplier's corporate innovation, which are significant for the quality of innovation but insignificant for the quantity of innovation. One possible explanation is that from RDT, power-advantageous firms are likely to create competitive environments among dependent firms (Kim and Zhu, 2018). Suppliers take advantageous positions when major customers are dependent on them in terms of financial sales. As the relationship duration increases, suppliers may have fewer incentives to innovate products and services but focus on other strategies, such as profitability, publicity, and sustainability. These strategies are achieved only when suppliers have enough power against major customers because they do not need to innovate to ingratiate major customers and survive in competitive markets. Another possible explanation is that power-advantageous suppliers have more access to external information that may be used in corporate innovation under customer's dependence. In other words, major customers have limited technologies that suppliers can learn as suppliers have already "milked" from their own channels of information (Serpa and Krishnan, 2018). Both two possible explanations account for the surprising findings. On the other hand, the association between customer's dependence and supplier's corporate innovation may not be linear as literature has identified a curvilinear association between characteristics of supplier-customer relationships and supplier performance (Choi and Krause, 2006; Serpa and Krishnan, 2018; Kim, 2019). In this study, I focus on the moderating effect of the relationship duration that makes suppliers less active in corporate innovation when major customers are dependent on suppliers in terms of financial sales.

6.2. Managerial Implications

Corporate innovation is an essential firm-level operation that impacts firms' long-term developments, especially in research-intensive industries. The puzzle is how suppliers leverage their relationships with major customers to improve their innovative performance. From RDT, a firm succeeds in corporate development when it minimizes its dependence on other resource providers (Pfeffer and Salancik, 2003). Depending on a few major customers, suppliers are like "putting all eggs in one basket" and constrained by powerful customers in unfavorable terms, relationship maintenance, and low profitability. It seems that taking more power over customers and generating customer's dependence would help the supplier outperform corporate innovation. However, major customers are also potential innovative resources because they usually have larger scales than suppliers. Large-scale major customers have more access to external information and technologies that suppliers might learn when they interact through financial sales (Sjoerdsma and van Weele, 2015). As perspectives regard dependent supplier-customer relationships as a double-edged sword, suppliers are confused about how to benefit from the dilemma. This paper captures the relationship duration as an essential indicator that clarifies the contingency of dependent supplier-customer relationships. The temporality in supply chains and changes across stages reflect in supplier's innovative outcomes. For example, Nokia's cellphone supply network changed from a few individual suppliers to multi-technology commodity clusters from 2000 to 2010 (Larsen et al., 2018). Nokia's case remained an open question for researchers whether the evolution was good or not. When the supplier is dependent on major customers, the supplier should maintain long-term relationships with major customers in order to accumulate technologies from major customers for their innovation. When major customers are dependent on the supplier, suppliers should obviate long-term relationships with these power-disadvantageous customers because they are valueless to the supplier in terms of innovative

resources. Asymmetric dependence indicates that power imbalance between the supplier and major customers instructs suppliers to take correspondent actions for their own benefits. In addition, suppliers should also be aware of the complexity of dependent supplier-customer relationships as dependence is usually not unilateral in reality. It is possible that the supplier and major customers are mutually dependent on each other or their relationship durations are interrupted for some reason. Therefore, suppliers should be careful when they respond to dependent supplier-customer relationships.

6.3. Limitations and Future Research

Admittedly, the paper finds important implications, it has several limitations that direct future research. First, power and dependence in supplier-customer relationships yield multi-dimensional relations that may be even intangible. In this paper, I use financial resources described as supplier's sales to customers or customer's purchases from the supplier to build the power-dependence structure in supplier-customer relationships. However, supplier's and customer's dependence do not limit to financial resources, which could be recognized as material flows, technological diversity, shared culture, and congruent goals (Villena et al., 2011; Kumar et al., 2020). Additionally, the intangibility of the power-dependence structure limits the potential when we use secondary data. Future research may use survey methodology to investigate different dimensions of the power-dependence structure in supplier-customer relationships.

Second, I use the number of applied patents and the number of patent citations to measure supplier's corporate innovation. However, patent information has its limitations. Not all inventions are strategized to patent as opposed to relying on secrecy or other means of appropriability (Hall et al. 2001). Because of the broad universe of inventions, there is no systematic data relating to inventions beyond patent information. Additionally, I capture firm-

level product and service innovation measured by commercial patents. However, innovation in supply chains may be achieved as other types of innovation, such as process and administrative innovation, independent of product and service innovation (Kumar et al., 2020). Little literature investigates the process and administrative innovation though they drive a new trend to connect innovation to other areas, such as process optimization and environmental protection. Furthermore, I do not distinguish incremental and radical innovation in my study but these two dimensions of innovation novelty could bring firms benefits in different cycles and effects (Yan et al., 2017). It is interesting to address these limitations in future research.

6.4. Conclusion

In the paper, I study the association between two dimensions of dependent supplier-customer relationships (supplier's dependence and customer's dependence) and supplier's corporate innovation. I also engage in the moderating effect of the relationship duration. The findings highlight the importance of dependent supplier-customer relationships and the nature of dynamic changes in relationships. The paper contributes to suppliers in selecting appropriate strategies to leverage dependence when they take supplier-customer relationships as a source of innovation.

Reference

- Ahuja, G. (2000). Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative science quarterly*, 45(3), 425-455.
- Ahuja, G., Coff, R. W., & Lee, P. M. (2005). Managerial foresight and attempted rent appropriation: Insider trading on knowledge of imminent breakthroughs. *Strategic Management Journal*, 26(9), 791-808.
- Ak, B. K., & Patatoukas, P. N. (2016). Customer-base concentration and inventory efficiencies: Evidence from the manufacturing sector. *Production and Operations Management*, 25(2), 258-272.
- Allison, P. D., & Waterman, R. P. (2002). Fixed-effects negative binomial regression models. *Sociological methodology*, 32(1), 247-265.
- Arora, A., Fosfuri, A., & Gambardella, A. (2004). *Markets for technology: The economics of innovation and corporate strategy*. MIT press.
- Atanassov, J. (2013). Do hostile takeovers stifle innovation? Evidence from antitakeover legislation and corporate patenting. *The Journal of Finance*, 68(3), 1097-1131.
- Balakrishnan, R., Linsmeier, T. J., & Venkatachalam, M. (1996). Financial benefits from JIT adoption: Effects of customer concentration and cost structure. *Accounting Review*, 183-205.
- Bellamy, M. A., Ghosh, S., & Hora, M. (2014). The influence of supply network structure on firm innovation. *Journal of Operations Management*, 32(6), 357-373.
- Bessen, J. (2009). NBER PDP project user documentation: Matching patent data to Compustat firms. *Version: Beta, May*.
- Brunel, C. (2019). Green innovation and green Imports: Links between environmental policies, innovation, and production. *Journal of environmental management*, 248, 109290.
- Casciaro, T., & Piskorski, M. J. (2005). Power imbalance, mutual dependence, and constraint absorption: A closer look at resource dependence theory. *Administrative science quarterly*, 50(2), 167-199.
- Chen, I. J., Paulraj, A., & Lado, A. A. (2004). Strategic purchasing, supply management, and firm performance. *Journal of operations management*, 22(5), 505-523.
- Choi, T. Y., & Krause, D. R. (2006). The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation. *Journal of operations management*, 24(5), 637-652.
- Choi, S., & McNamara, G. (2018). Repeating a familiar pattern in a new way: The effect of exploitation and exploration on knowledge leverage behaviors in technology acquisitions. *Strategic Management Journal*, 39(2), 356-378.
- Chu, Y., Tian, X., & Wang, W. (2019). Corporate innovation along the supply chain. *Management Science*, 65(6), 2445-2466.
- Correia, S., Guimarães, P., & Zylkin, T. (2019). ppmlhdf: Fast Poisson estimation with high-dimensional fixed effects, *arXiv. org*.
- Correia, S., Guimarães, P., & Zylkin, T. (2019). Verifying the existence of maximum likelihood estimates for generalized linear models. *arXiv preprint arXiv:1903.01633*.
- Crook, T. R., & Combs, J. G. (2007). Sources and consequences of bargaining power in supply chains. *Journal of Operations Management*, 25, 546-555.
- Dhaliwal, D., Judd, J. S., Serfling, M., & Shaikh, S. (2016). Customer concentration risk and the cost of equity capital. *Journal of Accounting and Economics*, 61(1), 23-48.
- Dong, Y., Skowronski, K., Song, S., Venkataraman, S., & Zou, F. (2020). Supply base innovation and firm financial performance. *Journal of Operations Management*.
- Drees, J. M., & Heugens, P. P. (2013). Synthesizing and extending resource dependence theory: A meta-analysis. *Journal of Management*, 39(6), 1666-1698.

- Dwyer, F. R., Schurr, P. H., & Oh, S. (1987). Developing buyer-seller relationships. *Journal of marketing*, 51(2), 11-27.
- Eggert, A., Ulaga, W., & Schultz, F. (2006). Value creation in the relationship life cycle: A quasi-longitudinal analysis. *Industrial Marketing Management*, 35(1), 20-27.
- Emerson, R. M. (1962). Power-dependence relations. *American sociological review*, 31-41.
- Fiol, C. M., O'Connor, E. J., & Aguinis, H. (2001). All for one and one for all? The development and transfer of power across organizational levels. *Academy of Management Review*, 26(2), 224-242.
- Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of operations management*, 28(1), 58-71.
- Galbraith, J. K. (1952). *A theory of price control* (Vol. 17). Cambridge: Harvard University Press.
- Galbraith, C. S., & Stiles, C. H. (1983). Firm profitability and relative firm power. *Strategic Management Journal*, 4(3), 237-249.
- Gassenheimer, J. B., & Ramsey, R. (1994). The impact of dependence on dealer satisfaction: A comparison of reseller-supplier relationships. *Journal of Retailing*, 70, 253.
- Greene, W. (2007). Functional form and heterogeneity in models for count data (Vol. 2). *Now Publishers Inc.*
- Gu, T., Sanders, N. R., & Venkateswaran, A. (2017). CEO incentives and customer-supplier relations. *Production and Operations Management*, 26(9), 1705-1727.
- Guimarães, P. (2008). The fixed effects negative binomial model revisited. *Economics Letters*, 99(1), 63-66.
- Gulati, R. (1998). Alliances and networks. *Strategic management journal*, 19(4), 293-317.
- Gulati, R., & Sytch, M. (2007). Dependence asymmetry and joint dependence in interorganizational relationships: Effects of embeddedness on a manufacturer's performance in procurement relationships. *Administrative science quarterly*, 52(1), 32-69.
- Hagedoorn, J., & Cloudt, M. (2003). Measuring innovative performance: is there an advantage in using multiple indicators?. *Research policy*, 32(8), 1365-1379.
- Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). The NBER patent citation data file: Lessons, insights and methodological tools (No. w8498). *National Bureau of Economic Research*.
- Hauser, J., Tellis, G. J., & Griffin, A. (2006). Research on innovation: A review and agenda for marketing science. *Marketing science*, 25(6), 687-717.
- Hillman, A. J., Withers, M. C., & Collins, B. J. (2009). Resource dependence theory: A review. *Journal of management*, 35(6), 1404-1427.
- Huang, H. H., Lobo, G. J., Wang, C., & Xie, H. (2016). Customer concentration and corporate tax avoidance. *Journal of Banking & Finance*, 72, 184-200.
- Huo, B., Flynn, B. B., & Zhao, X. (2017). Supply chain power configurations and their relationship with performance. *Journal of Supply Chain Management*, 53(2), 88-111.
- Irvine, P. J., Park, S. S., & Yıldızhan, Ç. (2016). Customer-base concentration, profitability, and the relationship life cycle. *The Accounting Review*, 91(3), 883-906.
- Jackson, B. B., & Bund, B. (1985). *Winning and keeping industrial customers: The dynamics of customer relationships*. Free Press.
- Jap, S. D., & Anderson, E. (2007). Testing a life-cycle theory of cooperative interorganizational relationships: Movement across stages and performance. *Management science*, 53(2), 260-275.

- Jap, S. D., & Ganesan, S. (2000). Control mechanisms and the relationship life cycle: Implications for safeguarding specific investments and developing commitment. *Journal of marketing research*, 37(2), 227-245.
- Kalwani, M. U., & Narayandas, N. (1995). Long-term manufacturer-supplier relationships: do they pay off for supplier firms?. *Journal of marketing*, 59(1), 1-16.
- Kendall, B. (2016), "Supreme court hears apple-Samsung patent case", *Wall Street Journal*, October 12.
- Kim, D. Y. (2020). Beyond direct relationships The curvilinear relationship between supplier dependence and innovation. *Journal of Manufacturing Technology Management*, 31(2), 392-412.
- Kim, M. (2012), "Analysis: friend and foe; Samsung, Apple won't want to damage parts deal", *Reuters*, August 27.
- Kim, Y. H. (2017). The effects of major customer networks on supplier profitability. *Journal of Supply Chain Management*, 53(1), 26-40.
- Kim, D. Y., & Zhu, P. (2018). Supplier dependence and R&D intensity: The moderating role of network centrality and interconnectedness. *Journal of Operations Management*, 64, 7-18.
- Kotler, Philip and Gary Armstrong (1991). *Principles of Marketing*, 5th ed. Englewood Cliffs, NJ: Prentice-Ha.
- Krolikowski, M., & Yuan, X. (2017). Friend or foe: Customer-supplier relationships and innovation. *Journal of Business Research*, 78, 53-68.
- Kumar, S., Narayanan, S., & Salvador, F. (2020). Innovation in supply networks—A research framework and roadmap.
- Lanier Jr, D., Wempe, W. F., & Zacharia, Z. G. (2010). Concentrated supply chain membership and financial performance: Chain-and firm-level perspectives. *Journal of Operations Management*, 28(1), 1-16.
- Larry, H., & Sakkab, N. (2006). *Connect and develop: Inside Procter & Gamble's new model for innovation*. Harvard Business Review, 84, 58-67.
- Larsen, M. M., Seppälä, T., & Ali-Yrkkö, J. (2018). *The changing geography and ownership of value creation: Evidence from mobile telecommunications*. Industry and Innovation, 25, 675-698.
- Lin, R. J., Chen, R. H., & Chiu, K. K. S. (2010). Customer relationship management and innovation capability: an empirical study. *Industrial Management & data Systems*
- Lu, G., & Shang, G. (2017). Impact of supply base structural complexity on financial performance: Roles of visible and not-so-visible characteristics. *Journal of Operations Management*, 53, 23-44.
- Martin, T.W. and Mickle, T. (2017), "Why apple rival Samsung also wins if iPhone X is a hit", *Wall Street Journal*, October 2.
- Miller, D. J., Fern, M. J., & Cardinal, L. B. (2007). The use of knowledge for technological innovation within diversified firms. *Academy of Management journal*, 50(2), 307-325.
- Narasimhan, R., & Kim, S. W. (2001). Information system utilization strategy for supply chain integration. *Journal of business logistics*, 22(2), 51-75.
- Patatoukas, P. N. (2012). Customer-base concentration: Implications for firm performance and capital markets: 2011 american accounting association competitive manuscript award winner. *The accounting review*, 87(2), 363-392.
- Pfeffer, J., & Salancik, G. R. (2003). *The external control of organizations: A resource dependence perspective*. Stanford University Press.
- Porter, M. E. (1992). Capital disadvantage: America's failing capital investment system. *Harvard business review*, 70(5), 65.

- Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative science quarterly*, 116-145.
- Powell, W. W., Staw, B., & Cummings, L. L. (1990). Neither market nor hierarchy.
- Rao, S. (2018). *Making the right choices for supplier-enabled innovation success*, Washington, DC: Supply Chain Dive.
<https://www.supplychaindive.com/news/supplier-enabled-innovation-procurement/520166/>. Accessed April 18, 2020.
- Remneland-Wikhamn, B., Ljungberg, J. A. N., Bergquist, M., & Kuschel, J. (2020). *Open innovation, generativity and the supplier as peer: The case of iphone and android*. In Digital Disruptive Innovation (pp. 485-515).
- Ried, L., Eckerd, S., Kaufmann, L., & Carter, C. (2021). Spillover effects of information leakages in buyer–supplier–supplier triads. *Journal of Operations Management*, 67(3), 280-306.
- Rogers, C. (2017), “A shape-shifting car? Patent filings point to auto industry’s future”, Wall Street Journal, September 18.
- Serpa, J. C., & Krishnan, H. (2018). The impact of supply chains on firm-level productivity. *Management Science*, 64(2), 511-532.
- Silva, J. S., & Tenreiro, S. (2010). On the existence of the maximum likelihood estimates in Poisson regression. *Economics Letters*, 107(2), 310-312.
- Sjoerdsma, M., & van Weele, A. J. (2015). Managing supplier relationships in a new product development context. *Journal of Purchasing and Supply Management*, 21(3), 192-203.
- Spence, E. (2015), “Tim Cook defused Steve Jobs’ thermonuclear war, then he took down android”, *Forbes*, January 31.
- Stoner, J., Freeman, E., Gilbert, D., 1995. *Management*. Prentice Hall, Englewood Cliffs, NJ.
- Terpend, R., & Krause, D. R. (2015). Competition or cooperation? Promoting supplier performance with incentives under varying conditions of dependence. *Journal of Supply Chain Management*, 51(4), 29-53.
- Trajtenberg, M. (1990). A penny for your quotes: patent citations and the value of innovations. *The Rand journal of economics*, 172-187.
- Trajtenberg, M., Henderson, R., & Jaffe, A. (1997). University versus corporate patents: A window on the basicness of invention. *Economics of Innovation and new technology*, 5(1), 19-50.
- Trebilcock, R. (2014). *Unilever Partners To Win*. (September 24th ed.). Peerless Meida.
https://www.scmr.com/article/unilever_partners_to_win. Accessed April 18, 2020.
- Trent, R. J., & Monczka, R. M. (1998). Purchasing and supply management: trends and changes throughout the 1990s. *International Journal of Purchasing and Materials Management*, 34(3), 2-11.
- Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: The network effect. *American sociological review*, 674-698.
- Vickery, S. K., Jayaram, J., Droge, C., & Calantone, R. (2003). The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships. *Journal of operations management*, 21(5), 523-539.
- Villena, V. H., & Craighead, C. W. (2017). On the same page? How asymmetric buyer–supplier relationships affect opportunism and performance. *Production and Operations Management*, 26(3), 491-508.

- Villena, V. H., Revilla, E., & Choi, T. Y. (2011). The dark side of buyer–supplier relationships: A social capital perspective. *Journal of Operations management*, 29(6), 561-576.
- Williamson, O. E. (1973). Markets and hierarchies: some elementary considerations. *The American economic review*, 63(2), 316-325.
- Wyman, O. (2015). *Car Innovation—A comprehensive study on innovation in the automotive industry, Detroit, MI*. [http:// www.emic-bg.org/files/CarInnovation2015_engl.pdf](http://www.emic-bg.org/files/CarInnovation2015_engl.pdf). Accessed August 19, 2020.
- Yan, T., Yang, S., & Dooley, K. (2017). A theory of supplier network-based innovation value. *Journal of Purchasing and Supply Management*, 23(3), 153-162.
- Zhao, X., Huo, B., Flynn, B. B., & Yeung, J. H. Y. (2008). The impact of power and relationship commitment on the integration between manufacturers and customers in a supply chain. *Journal of operations management*, 26(3), 368-388.