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How Innovative is a Firm in a Structural Hole Position?

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Abstract

Purpose: Marketing networks are essential for firms to gain new information and resources, yet their effect on innovation performance under uncertainty remains unclear. This study aims to elucidate the effects of technological and demand variability on the innovation performance of first-tier suppliers, considering different levels of structural holes. It particularly explores how structural holes moderate the relationship between uncertain factors and innovation performance. **Research design, data and methodology:** To assess the hypotheses, a survey was conducted with the first-tier suppliers. The survey targeted internal networks and the relationships between manufacturers, suppliers, and subsuppliers. Structural equation modeling was employed to validate the hypotheses using measures from previous research. **Results:** The findings indicate that the impact of technological uncertainty and demand variability on innovation performance varies based on the extent of structural holes in the network. **Conclusions:** This study provides both theoretical and practical insights for distribution channels, highlighting the competitive advantage of interfirm networks in uncertain conditions. However, the focus on the engineering industry may limit the generalizability of the findings. Future research should explore a broader range of industries to improve result applicability.

Keywords : Structural Hole, Technological Uncertainty, Demand Variability, Innovation Performance, Interfirm Networks

JEL Classification Code : C42, D3, D81, D83

1. Introduction[1)]

Innovation and high-quality product development are essential for firms in various industries to maintain their market positions and competitive edge (Tidd & Bessant, 2018; Crossan & Apaydin, 2010). This necessity is especially pronounced in technology-centric sectors where innovation performance plays a pivotal role (Zhatkanbaev et al., 2015). Effective innovation is recognized as a crucial capability, often reliant on the exchange of resources and information with external channel partners (Song & Montoya-Weiss, 1998). In this context, channel relationships are defined as the interactions within the internal network entities that include the manufacturer, supplier, and sub-supplier relationships.

Environmental uncertainty, characterized by rapid and unpredictable changes in the market environment, poses significant challenges to firms (Milliken, 1987; Abdi et al., 2017). Scholars such as Duncan (1972) have highlighted two critical dimensions of environmental uncertainty: technological uncertainty and demand variability. Technological uncertainty refers to the unpredictability caused by rapid technological advancements, the increasing complexity of parts, and the introduction of novel functionalities in components (Garud & Nayyar, 1994; Rosenkopf & Nerkar, 2001). Demand variability, on the other hand, pertains to the fluctuating demand for major products in the market (Lee et al., 1997), which complicates effective risk management across the supply chain.

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In an effort to secure resources under such uncertain conditions, firms are compelled to harness both their internal knowledge and develop external resources (Caloghirou et al., 2004). However, the increasing complexity and uncertainty of the business environment make it challenging for firms to manage all necessary resources internally (Gilsing et al., 2008; Achrol & Stern, 1988). Therefore, establishing robust network relationships with exchange partners has become critically important (Lechner & Dowling, 2003). For example, engineering firms that offer consulting and technical services to clients, and whose finished products are supplied by first-tier subcontractors, require extensive communication and information exchange with these partners.

The dynamics between buyers and first-tier suppliers during the innovation process have been extensively explored (Petersen et al., 2005). Recently, the focus has expanded from straightforward dyadic buyer-supplier interactions to more comprehensive network studies, highlighting the strategic advantages of marketing networks (Gulati et al., 2000). These networks connect firms through various interactions among members, such as shared suppliers and industry associations, facilitating the exchange of critical information on competitor strategies, technological advancements, and market trends (Powell et al., 1996). The efficient flow of resources within these interfirm networks bolsters firms' capabilities, thus providing a significant competitive advantage (Nahapiet & Ghoshal, 1998).

Interorganizational networks offer substantial informational advantages, enabling firms to swiftly respond to uncertain environments (Uzzi, 1997). These networks facilitate the exchange of knowledge and resources, which are crucial for innovation and adaptability (Baum, & Ingram, 2002). Although exchange partners might find it challenging to predict firm performance under such conditions, there is increasing evidence that structural holes play a vital role in these scenarios (Reagans & Zuckerman, 2001; Burt, 1992, 2004, 2005). Structural holes serve as connectors between distinct clusters of unique information, providing network benefits that are cumulative rather than duplicative (Burt, 1992). These gaps in the network enable firms to bridge otherwise disconnected groups, thereby accessing diverse and non-redundant information that can spur innovation (Ahuja, 2000). Structural holes facilitate access to novel information and opportunities for partners, enhancing their adaptability and competitive edge (Burt, 2004). For instance, firms that occupy these structural holes can leverage their position to introduce new ideas and innovations by synthesizing disparate pieces of information from different clusters (Obstfeld, 2005). This ability to broker information across structural holes not only fosters creativity and problem-solving but also enhances the firm's capacity to respond to market changes and uncertainties (Fleming et al., 2007).

Despite the acknowledged significance of structural holes, empirical research investigating the impact of technological and demand variability on innovation performance, especially with structural holes as a moderating factor, remains limited. Scholars frequently suggest that structural holes improve buyer performance (Ahuja, 2000; Zaheer & Bell, 2005). Within vertical channel relationships, first-tier suppliers can assume the role of structural holes, effectively linking separate clusters of suppliers and buyers, thereby facilitating enhanced communication and resource flow between these groups.

The primary aim of this research is to offer an in-depth understanding of the effects of technological and demand variability on the perceived innovation performance of first-tier suppliers, particularly under conditions characterized by varying levels of structural holes. By exploring these dynamics, the study seeks to illuminate how changes in technology and demand influence suppliers' perceptions of their own innovative capabilities when operating within different network structucohenmres. Specifically, it aims to investigate how varying levels of structural holes impact the way environmental uncertainty affects the innovation outcomes of firms. Through this analysis, the study intends to provide deeper insights into the interplay between network structures and external uncertainties in shaping innovation performance. This study contributes to the existing literature in two significant ways. First, it empirically examines the effects of technological and demand variability on innovation performance under structural hole conditions, an underexplored area. Second, it provides empirical evidence on how structural holes influence these relationships differently based on contextual environments. The study posits that technological uncertainty can positively impact innovation performance if suppliers possess the capability to manage such uncertainty. Conversely, in situations of demand variability, it is more beneficial to collaborate closely with partners rather than solely relying on new information through structural holes.

The rest of this research is organized as follows: In Section 2, the study offers an in-depth review of the theoretical foundations pertinent to its focus. This section also details the process by which the research hypotheses were developed, providing a comprehensive framework for understanding the subsequent analysis and findings.

Section 3 describes the research design and methodology employed in this study, including data collection and analytical procedures. Section 4 provides a comprehensive overview of the study's findings, encompassing thorough analysis and detailed presentation of results. Finally, Section 5 offers a discussion of the findings, practical implications, limitations of the study, and recommendations for future research.

2. Literature Review

The chapter covers three major theories of satisfaction, motivation, and need. it also discusses the dimension of organizational commitment and job satisfaction and their significance on the employee and their work.

2.1. Structural Holes

Structural holes serve as connectors between different networks, allowing firms to gain advantages from both internal and external network interactions (Burt, 1992). These gaps occur in the information flow where firms do not have direct links with each other (Ahuja, 2000). By acting as intermediaries, structural holes enable the connection of two otherwise unconnected entities, as depicted in Figure 1. This connection helps firms discover new business opportunities through unique, non-overlapping contacts (Burt, 2005).

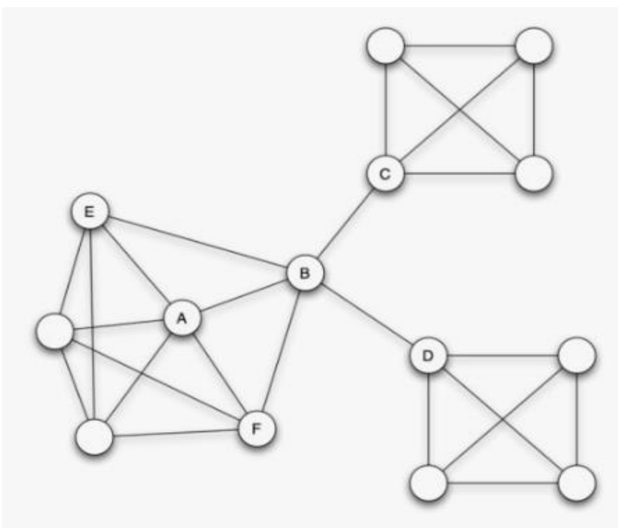

Figure 1: Structural Hole, Burt (1992,1997)

When firms position themselves within these structural holes, they act as channels for information exchange between different networks, enabling them to leverage this information for strategic gain. As the number of unique, non-overlapping contacts grows, the advantages of structural holes are amplified. According to the theory of structural holes, firms embedded in networks with many structural holes gain multiple benefits, including access to novel information, increased control through brokerage roles, and improved efficiency (Burt, 1992).

Access to non-redundant information is a significant advantage for firms, as it enables them to tap into unique opportunities, referrals, and resources that are not available within homogeneous firm networks (Grant, 1996). Firms that bridge structural holes are often more innovative, leveraging these connections to implement new ideas and strategies (Burt, 2005).

Moreover, firms positioned in structural holes can swiftly access resources from distinct parts of their network, staying abreast of emerging threats and opportunities. They can also evaluate the quality of potential exchange partners, thereby enhancing their strategic decisions (Hansen, 1999; Hargadon & Sutton, 1997). Interaction within these networks facilitates the development of new knowledge, particularly regarding market dynamics and competitive threats, while also adding value by acting as brokers to efficiently monitor and disseminate information (Hargadon & Sutton, 1997).

Structural holes enable firms to exert control over their exchange partners (Burt, 1992). Firms that act as intermediaries occupy superior positions within their networks, allowing them to influence and manage their exchange partners' information flow and resource allocation (Aldrich, 1999; Burt, 1992). This strategic positioning grants these firms the ability to mediate and resolve conflicts between partners, thereby maintaining network stability (Zaheer & Bell, 2005). The control afforded by these positions translates into a competitive advantage during negotiations, as firms in brokerage roles possess multiple alternatives and consequently stronger bargaining power compared to others (Prell, 2012). This enhanced bargaining power allows them to effectively regulate information dissemination among network members, ensuring that the flow of information is optimized for their strategic benefit. (Balakrishnan & Koza, 1993).

The concept of social capital, defined as the resources derived from enduring network relationships, is crucial for understanding network dynamics. Structural hole theory highlights how gaps in networks can generate significant social capital, positioning firms advantageously to leverage network benefits (Burt, 1992; Nahapiet & Ghoshal, 1998). Studies indicate that firms occupying advantageous network positions can directly enhance their performance through increased social capital (Zaheer & Bell, 2005).

Social capital, defined by Coleman (1988) as the resources derived from network relationships, is significantly impacted by structural holes. Burt (2005) argues that bridging structural holes creates social capital by linking disparate network segments, thus facilitating the flow of valuable information and enhancing collective action. This integration of structural holes with social capital theory is further explored by Granovetter (1973), who underscores the strength of weak ties in building trust and reducing opportunism.

Several empirical studies validate the theoretical claims about structural holes and social capital. For instance, Burt (2004) demonstrates that individuals or organizations bridging structural holes are more likely to generate good ideas and achieve innovation. Similarly, Podolny and Baron (1997) explore how networks rich in structural holes can enhance managerial performance by providing access to diverse resources and opportunities.

In another study, Gulati and Gargiulo (1999) examine the formation of interorganizational networks and highlight how structural holes facilitate learning and capability development in alliance formations. These findings are corroborated by Goerzen and Beamish (2005), who analyze how network diversity, including structural holes, impacts multinational enterprise performance.

Typically, the interplay between structural holes and social capital has been a pivotal subject in network theory and organizational studies. Structural holes act as conduits for novel information and resources, enabling firms to access diverse knowledge that is not available within tightly-knit networks.

Burt (1992) posits that firms positioned in structural holes benefit from enhanced access to non-redundant information, fostering innovation and strategic decision-making. This perspective is supported by Hansen (1999), who highlights the role of weak ties in facilitating knowledge transfer across organizational subunits, thereby addressing the search-transfer problem in network theory.

This brokerage role enhances their negotiation power and conflict resolution capabilities (Zaheer & Bell, 2005). Aldrich (1999) emphasizes that such firms can mediate relationships, thereby regulating the dynamics within the network to their advantage. This control translates into stronger bargaining positions, as firms with multiple alternatives can leverage their intermediary status to influence outcomes (Prell, 2012).

2.2. Technological Uncertainty

Resource dependence theory suggests that firms must assess and adapt to their technological environment to manage resources effectively. This theory emphasizes that technological uncertainty, characterized by unpredictable technological advancements, significantly impacts firms' innovation processes. Firms facing technological uncertainty must invest heavily in R&D to mitigate associated risks and enhance their innovation capabilities (Caldeira & Ward, 2003; Song & Montoya-Weiss, 2001).

Technological uncertainty often leads to increased R&D costs and higher failure rates in innovation projects. Firms that cannot manage these technological challenges face rising coordination costs and frequent project delays. The absence of standardized technology further exacerbates this uncertainty, necessitating continuous efforts to stay competitive (Auster, 1992; Stump & Heide, 1996). Empirical studies indicate that technological uncertainty negatively impacts firm performance due to the inherent risks associated with innovation (Jalonen, 2012; Furr, 2021).

Research has shown that firms in high-tech industries face higher levels of technological uncertainty, requiring significant investment in R&D to remain competitive. Managing this uncertainty involves not only adapting to new technologies but also integrating them effectively into existing systems (Hansen, 1999). Zhang and Aumeboonsuke (2022) found that technological innovation, while crucial for competitiveness, can lead to reduced firm performance if not managed properly, highlighting the importance of risk-taking capacity in this context.

Bolli et al. (2020) examined the impact of technological diversity on innovation performance, finding that diversity can mitigate some negative effects of technological uncertainty by providing a broader base of knowledge and resources. This diversity allows firms to better navigate the uncertainties associated with rapid technological changes.

The integration of diverse technological capabilities can enhance a firm's ability to innovate under uncertain conditions (Chen et al.,2023).discussed how early supplier involvement and knowledge orchestration capabilities can improve innovative performance despite high technological uncertainty. This integration helps firms manage the complexity and unpredictability of technological advancements more effectively.

2.3. Demand Variability

R Demand variability, previously referred to as obectiveti uncertainty, relates to the extent to which estimates for product volumes are perceived as unpredictable (Walker & Weber, 1984). Factors such as extended supply chains, global economic fluctuations, and macroeconomic events have intensified demand variability (Gupta & Maranas, 2003). It is a primary source of variability in supply chains; failing to manage demand fluctuations can lead to unmet customer demand, loss of market share, or increased costs (Gupta & Maranas, 2003).

Demand variability is evaluated based on fluctuations in component demand and confidence in demand forecasts (Siddiqui & Erum, 2016). High demand variability can cause unexpected production costs or excess capacity for suppliers and stock-outs or excess inventory for buyers, thus increasing transaction costs due to the need for contract renegotiations. Effective coordination of production variations is essential to mitigate these issues.

Incorporating demand variability into supply chain strategies can enhance risk management practices across the supply chain (Gupta & Maranas, 2003). It presents significant challenges for businesses striving to minimize stock-outs while avoiding high inventory costs. Suppliers often struggle with accurately predicting demand, risking either surplus inventory or stock shortages. This unpredictability necessitates robust forecasting and inventory management systems to buffer against variability (Lee et al., 1997).

Effective management of demand variability involves strategic planning and the use of advanced forecasting techniques to anticipate and respond to market changes. Firms must develop flexible supply chain practices that can adapt to varying demand levels, thereby reducing the risks associated with demand variability (Mentzer et al., 2000). By doing so, firms can improve their innovation performance by ensuring that their supply chain operations support their innovation efforts.

2.4. Innovation Performance

A firm's innovation performance is a critical determinant of competitive advantage and long-term success. It involves the ability of a company to develop new products, processes, or services that provide value to customers and drive business growth. Innovation performance can be defined as the outcome of a firm's innovation activities, which include the development of new products, processes, or services that lead to improved market position and financial performance (Crossan & Apaydin, 2010). It is often measured by metrics such as the number of new products introduced, the percentage of sales from new products, patent counts, and R&D expenditure (Gimenez-Fernandez et al., 2020; Benitez et al., 2022).

Benitez et al. (2022) explored the role of digital leadership in enhancing innovation performance. They found that firms with strong digital leadership capabilities are better able to digitize their platforms, streamline processes, and foster innovation. This results in higher innovation performance through the effective use of digital tools and technologies. Research by Gorodnichenko and Schnitzer (2013) and Hottenrott and Peters (2012) examined how financial constraints impact innovation performance. They found that small and young firms often face significant financial barriers, limiting their ability to invest in R&D and innovation activities. Overcoming these constraints requires strategic financial planning and access to external funding to sustain innovation efforts. Sun et al. (2020) investigated the impact of open innovation on firm performance. Their study highlighted that open innovation practices, such as collaborating with external partners and integrating external knowledge, enhance a firm's ability to balance exploration and exploitation activities, leading to improved innovation performance. Bolli et al. (2020) examined the impact of technological diversity on innovation performance. They found that diversity can mitigate some negative effects of technological uncertainty by providing a broader base of knowledge and resources, allowing firms to better navigate the uncertainties associated with rapid technological changes.

3. Hypotheses Development

3.1. Technological Uncertainty and Innovation Performance

Technological uncertainty, characterized by rapid advancements, complexity in product components, and novel functionalities, has been a critical factor influencing firm innovation performance.

Resource dependence theory posits that organizational actors can evaluate and interpret their technological environment, influencing their strategic decisions (Caldeira & Ward, 2003). Firms perceive technological uncertainty through the lens of technology application in projects and anticipated technological changes (Song & Montoya-Weiss, 2001).

Technological uncertainty encompasses the perceived unpredictability arising from rapid technological advancements, the increasing complexity of product components, and the novelty of product functions in the innovation process (Hoetker, 2005; Chen & Paulraj, 2004; Petersen et al., 2005; Wasti & Liker, 1999). For instance, suppliers may encounter uncertainty due to evolving standards or specifications of materials (Heide & John, 1990).

Elevated technological uncertainty can result in unforeseen challenges such as increased R&D costs and higher innovation failure rates (Auster, 1992). The inability of network members to manage technological challenges exacerbates coordination costs and leads to project delays. Furthermore, the lack of standardized technology intensifies technological uncertainty (Stump & Heide, 1996), necessitating ongoing efforts from firms to maintain competitiveness. The perception of technological uncertainty thus plays a crucial role in shaping firms' decisions and actions related to innovation projects. This relationship is supported by empirical evidence showing that technological uncertainty negatively impacts firm performance due to the unpredictable nature of technological progress and the associated risks (Jalonen, 2012; Furr, 2021).

Technological uncertainty is not only about the unpredictability of technological advances but also about the complexities involved in integrating new technologies

into existing systems. The dynamics of technological uncertainty are influenced by factors such as the pace of innovation, the degree of disruption caused by new technologies, and the firm's ability to adapt to these changes (Hargadon & Sutton, 1997). Firms operating in high-tech industries often face higher levels of technological uncertainty, requiring them to invest significantly in R&D and continuously innovate to stay ahead of competitors (Hansen, 1999).

Therefore, understanding and managing technological uncertainty is critical for firms aiming to enhance their innovation performance. The following hypothesis is proposed:

H1: There is a negative impact on innovation performance as technological uncertainty increases.

3.2. Demand Variability and Innovation Performance

Demand variability can have significant implications for a firm's innovation performance. Variability in demand creates uncertainty in production planning and inventory management, which can disrupt the innovation process. High demand variability necessitates frequent adjustments in production schedules, leading to increased costs and resource allocation challenges.

Ivanov and Dolgui (2021) emphasize that firms need to develop robust forecasting and flexible supply chain strategies to mitigate the negative effects of demand variability on innovation.

Demand variability influences both exploratory and exploitative innovation. Exploratory innovation involves developing new technologies and products, while exploitative innovation focuses on improving existing products and processes (March, 1991). Firms facing high demand variability need to balance these two types of innovation to remain competitive. Jansen et al. (2006) suggest that firms with high absorptive capacity can better manage this balance by effectively leveraging external information and integrating it with internal knowledge.

Studies provide insights into how firms manage demand variability to enhance innovation performance. For instance, a study by Flynn et al. (2010) highlights the importance of internal integration in managing demand fluctuations and improving innovation outcomes. Firms that integrate their internal processes can quickly adapt to changes in demand, thereby supporting continuous innovation. Another study by Schoenherr and Swink (2012) shows that firms with strong supplier and customer integration can better coordinate their innovation activities, leading to improved innovation performance. Based on the argument, the following hypothesis is proposed:

H2: There is a negative impact on innovation performance as demand variability increases.

3.3. Structural Holes as Moderator

In the context of inter-firm networks, when a new supplier that bridges structural holes enters a business relationship, this supplier brings new information about the external environment to the buyer. This influx of information helps the buyer manage uncertain environmental conditions. Structural holes serve as a governance mechanism through their network position, which inherently reduces the likelihood of opportunistic behavior (Wu et al., 2000). This is because the new information and resources provided by structural holes can diminish information asymmetry between exchange parties (Wathne & Heide, 2000).

Additionally, firms that bridge structural holes can access resources from unique parts of their network, gain early insights into potential threats and opportunities, and assess the quality of possible exchange partners and potential members (Powell & Smith-Dorr, 1996; Uzzi, 1996). Knowledge is partially developped through firm interaction (Nahapiet & Ghoshal, 1998), allowing actors bridging structural holes to develop new understandings.

As a result, structural holes enable network members to obtain new information and resources (Wu et al., 2000), which can solve the problem of information asymmetry between exchange parties. Therefore, the presence of structural holes can moderate the effects of environmental uncertainty on innovation performance.

Previous studies have shown that knowledge from external ties is critical to innovation performance (Mansfield, 1988; Saxenian, 1990). Innovation performance is significantly influenced by a firm's ability to acquire new information from external ties (Deeds et al., 2000). This inflow of new information typically forms the basis for developing capabilities (Teece, 1996), which evolve as the ability to apply new knowledge increases (Deeds et al., 2000). Particularly, absorptive capacity, the firm's ability to evaluate and assimilate external knowledge, allows the firm to recognize and acquire valuable new information and apply it to the enhancement of dynamic capabilities (Deeds et al., 2000). Thus, interaction with external organizations is crucial for firms' dynamic capabilities, enabling them to enhance innovation performance with accumulated resources such as know-how and knowledge through organizational learning.

Regarding the structural holes theory, firms can increase their access to new information from external ties by occupying these holes. This information is transformed into knowledge or know-how, which is essential for innovation performance, especially in technology-intensive industries. Therefore, a supplier's structural holes that facilitate new information inflow from external ties can moderate the negative relationship between technological uncertainty and innovation performance. Hence, the study proposes the following hypothesis:

H3: When there is a higher level of structural holes, the negative correlation between technological uncertainty and innovation performance is diminished.

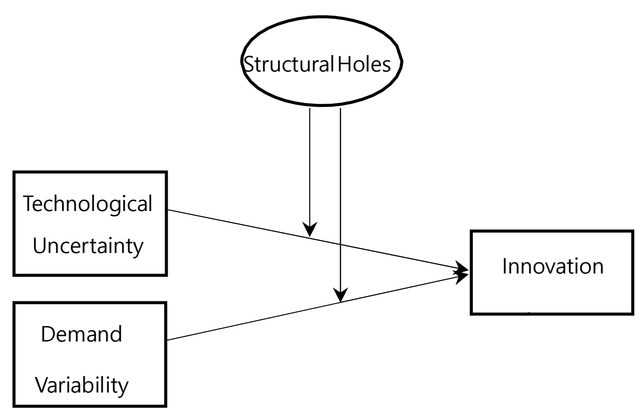

Figure 2: Research Model

Demand variability, characterized by unpredictable fluctuations in product demand, can hinder a firm's adaptability. Such uncertainty often prompts buyers to establish relationships with multiple channel partners to mitigate risks (Ganesan, 1994). Consequently, buyers increase the level of structural holes in their network to access new information. As structural holes become more prevalent, the flow of information improves, making it easier for buyers to verify the inventory status of their suppliers. This enhanced information flow enables buyers to better predict situations and address issues related to the demand for major products.

From the buyer's perspective, being able to forecast inventory situations helps in managing problems related to demand variability. When demand variability is anticipated or stable, firms are less likely to encounter problems in their innovation performance because the external environment does not significantly impair their management capabilities. Therefore, structural holes can positively moderate the negative impact of demand variability on innovation performance. Based on this understanding, current study proposes the following hypothesis:

H4: When there is a higher level of structural holes, the negative correlation between demand variability and innovation performance is diminished.

4. Methodology

The study examined the relationships between a manufacturer, its key first-tier suppliers, and those suppliers' business partners to test the hypotheses regarding the impact of technological and demand variability on first-tier suppliers' perceptions of the buyer's innovation performance. Given that manufacturers heavily rely on their suppliers' performance, there is significant interaction aimed at enhancing cooperation and information exchange. The researcher selected this research set based on the theory that major suppliers exhibit the most intensive interaction and the highest level of dependence on the manufacturer.

This study employed systematic random sampling to select major first-tier suppliers from a mailing list of a prominent engineering firm. This firm specializes in providing consulting and technical services to clients, while the final products are supplied by these first-tier suppliers. Through comprehensive interviews with industry experts and managers, it was confirmed that procurement activities of first-tier suppliers play a crucial role in the supply chain. To ensure accurate data collection, procurement managers of these first-tier suppliers were surveyed.

These managers were chosen due to their extensive relationships with second-tier suppliers and business partners, and their significant interaction with the engineering firm. Their unique position allows them to provide valuable insights into their firms' and transaction partners' operations. By focusing on first-tier suppliers with diverse relationships with their transaction partners (including buyers, second-tier suppliers, and other business partners), the study aimed to investigate the impact of technological uncertainty and demand variability on the buyer's innovation performance within the context of structural holes. This comprehensive approach enabled a detailed examination of how these uncertainties influence the performance and interaction dynamics in the supply chain. To tackle the possibility of non-response bias, the study employed a comparison between early and late respondents following the approach of Armstrong and Overton (1977). The mean values for various scales, including environmental uncertainty, structural holes, and unilateral and bilateral governance, were examined. The analysis revealed no significant differences between the two groups, indicating that non-response bias is likely not a major concern.

Table 1: Scale Items and Construct Evaluation

Constructs	Items	Standardized λ*	C.R	Construct Reliability	AVE
Technological Uncertainty (α=.88)	1. The technology employed in our primary products is undergoing significant and rapid change.	0.51	-	0.75	0.56
	2. There have been profound changes in the technology utilized in our primary products over the past few years.	0.88	7.64		
	3. Predicting the future evolution of technology in our main products is challenging.	0.92	8.12		
Demand Variability (α=.72)	1. Forecasting demand for our company's primary products is exceedingly challenging.	0.78	-	0.76	0.88
	2. There is significant uncertainty regarding the demand for our primary products.	0.91	14.92		
	3. The demand for our company's main products experiences unpredictable fluctuations.	0.84	11.67		
Structural Holes (α=.91)	Company A, which has a relationship with our company, has important technology, resources and information required for our company.				
	1. Our company's buyers and suppliers have developed a relationship with us, accessing information from A company that would otherwise be inaccessible.	0.88	-	0.90	0.89
	2. Our company's purchasing entities and suppliers have formed a relationship with us and are gaining access to essential technology from A company that would otherwise be unavailable.	0.97	15.49		

	3. Our company's purchasing partners and suppliers have developed a connection with us, acquiring resources from A company that would otherwise be inaccessible.	0.94	19.21		
Innovation Performance (α=.93)	1. The new product from this buyer has shown greater success compared to the previous product.	0.92	-	0.92	0.59
	2. This new product from the buyer has demonstrated success in terms of profitability compared to previous products.	0.97	19.05		
	3. The new products from this buyer have contributed significantly to achieving our profitability objectives compared to our previous offerings.	0.72	17.61		

Note: χ^2 (80) = 112.128 (p = .010), goodness-of-fit index = .914; adjusted goodness-of-fit index = .871; comparative factor index = .982; rootmean square error of approximation = .050. SFL = standardized factor loading, AVE=average variance extracted.

4.2. Measurement Development

The study utilized existing measures of the focal variables from prior research. Additionally, this study conducted in-depth interviews with three purchasing managers to evaluate the relevance of these measures. Based on feedback from these interviews, adjusted the wording of certain items. All items were measured using a 7-point Likert-type scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Given that the items were in English, this research developed a Korean version of the questionnaire for our research setting. To ensure the Korean questionnaire was equivalent to the English version, a bilingual individual back-translated it from Korean to English. Any discrepancies were resolved through discussion between the two translators. The study measured technological uncertainty to capture first-tier suppliers' perceptions of unpredictable technology (Chen & Paulraj, 2004; Hoetker, 2005; Petersen et al., 2005). As technological uncertainty increases, the difficulty in accurately forecasting technical requirements for products also rises. The current study adapted items for technological uncertainty from Heide and John (1990) and modified them for our study. Demand variability was used to gauge the difficulty in accurately predicting the demand for specific components. This measure was based on the scale developed by Walker and Weber (1984). Structural holes were measured to assess the benefits derived from social capital, particularly the brokerage opportunities available to first-tier suppliers due to dispersed ties (Burt, 1997). An increase in structural holes leads to a higher inflow of information from the external network. The study developed items for structural holes based on the works of Burt (1997) and Ahuja (2000) tailored to our research context. Innovation performance was used to evaluate first-tier suppliers' perceptions of the buyer's innovation performance, which contributes to the economic profits of channel members (Song & Parry, 1997). This research obtained and modified the items for innovation performance from their study for our research context.

4.3. Measurement

The study assesses the validity of the constructs (i.e., structural holes, technological uncertainty, demand variability, and innovation performance). The study conducts an item-total correlation test to eliminate ill-fitting items. The study employs exploratory factor analysis (EFA) for the variable screening. The remaining items are then subjected to confirmatory factor analysis (CFA) to assess construct validity (e.g., Kline, 1998) using AMOS. Finally, the study measures Cronbach's alpha for each construct to measure reliability. Based on this procedure, the study finds that the measurement model has acceptable fit indices: $\chi 2(80) = 112.128$ (p = .010), GFI = .914 AGFI = .871, CFI = .982, RMSEA = .050.

All factor loadings are significant, indicating the unidimensionality of the measures and sufficient convergent validity (Anderson & Gerbing, 1988). These values indicate that the measurement is well-fitted. All factor loadings are above 0.5 ($p < .01$), showing the convergent validity of each construct. The AVE is also calculated for convergent validity. The AVE values of each construct range from .563 to .892, thus exceeding the minimum threshold of .50. The study evaluates the discriminant validity of all latent variables through their AVE values (Fornell & Larker, 1981). The study calculates all the AVE values to identify whether they are greater than the squared values of the coefficients of the correlations between variables. The results range between .00 and .24. The highest square root (.24) is smaller than the lost AVE (AVE Technological Uncertainty = .561).

Table 2: Results of the Research Findings

	1	2	3	4
1. Technological Uncertainty (TU)	1.00			
2. Demand Variability (DV)	.256	1.00		
3. Structural Holes (SH)	.034	.060	1.00	
4. Innovation Performance (IP)	.086	-.049	-.070	1.00
M	3.95	4.07	4.45	2.03
SD	1.25	1.39	1.56	.96

Finally, the study measures construct reliability, finding that each factor shows a satisfactory level. Overall, these results indicate appropriate measure reliability and validity. Table 1 describes each construct's CR, and presents the factor loadings, reliability measures, goodness-of-fit indices, and AVE values for each construct. Table 2 shows the inter-construct correlations.

5. Analysis and Results

5.1. Hypotheses Test

The study employed structural models to test the hypotheses. Suppliers' technological uncertainty and demand variability were used as exogenous variables, while suppliers' performance and structural holes were considered endogenous variables. The results showed that technological uncertainty positively influenced innovation performance ($\gamma 11 = .32$, $t = 4.98$), which did not support H1. On the other hand, demand variability negatively impacted the supplier's performance ($\gamma 11 = -.25$, $t = -2.52$), which supported H2. (see Table 3).

To evaluate the moderating effect of structural holes (i.e., H3 and H4), the study performed a specialized multisample analysis using AMOS, following the method outlined by Jaccard et al., (1996). The study split the sample firms into two groups, High structural holes, and Low structural holes, based on the median value of structural holes. These two groups were then analyzed using a nested structural model, where technological uncertainty and demand variability were the exogenous variables, and supplier's performance and structural holes were the endogenous variables.

Table 3: AMOS Results for H1 and H2

Description	Hypothesis		Coefficient	t value
	Hypotheses	Sign		
TU → P	H1	+	.31	4.98***
DV →P	H2	-	-.23	-2.53*

$X^2(24)= 40.536$, p=.018. Goodness-of-fit index=.96; adjusted goodness-of-fit index=.91; comparative factor index=.99; root mean square error of approximation=.068. *Significance at α=.05, **Significance at α=.01, *** Significance at α= .001

Table 4: AMOS Results for H3 and H4

Description	Hypotheses	High Hole		Low Hole	
		Coefficient	t value	Coefficient	t value
TU → P	H3	.32	4.54***	.27	2.14*
DV → P	H4	-.40	-2.80***	-.00	-.01

$X^2(48)=53.608$, p=.26.Goodness-of-fit index=.93; adjusted goodness-of-fit index=.89; comparative factor index=.98; root mean square error of approximation=.028. *Significance at α=.05, **Significance at α=.01, *** Significance at α=.001

To evaluate the moderating effect, the research used a two-step approach based on Jaccard et al. (1996). First, this study constructed a structural model using pooled data from the two groups (High structural holes and Low structural holes) and assessed its fit, termed the pooled-sample model. This model demonstrated a good fit to the data ($\chi 2=53.61$, df=48), supporting the suitability of the multisample model for hypothesis testing.

Next, the study estimated the multisample model by constraining the path coefficients for both groups to the same conditions, aiming to detect limited interaction effects. This research anticipated that if structural holes had a moderating effect, the multisample model (with constrained coefficients) would show a poorer fit compared to the pooled-sample model (with unconstrained coefficients) (Jaccard et al., 1996).

The comparison of the $\chi 2$ difference between the pooled-sample model ($\chi 2=53.61$, df=48) and the multisample model ($\chi 2=53.77$, df=49) revealed no significant moderating effect of high structural holes ($\chi 2=0.152$, df=1, $p>.05$) on the relationship between technological uncertainty and supplier performance. However, for the relationship between demand variability and supplier performance, the $\chi 2$ difference between the pooled-sample model ($\chi 2=53.61$, df=48) and the multisample model ($\chi 2=57.44$, df=49) indicated a significant moderating effect of structural holes ($\chi 2=3.818$, df=1, $p<.05$).

The study tested the multisample model to determine if there were significant correlations between uncertainty and the supplier's performance for the two groups (Jaccard et al., 1996; Mendenhall et al., 1996). Technological uncertainty had a significant positive effect on supplier performance for both high and low levels of structural holes, which did not support H3. Conversely, demand variability had a significant negative effect on supplier performance for the group with a high level of structural holes, but no significant effect for the group with a low level of structural holes, thus supporting H4.

6. Conclusion and Discussion

6.1. General Discussion and Implication

The study examined the impact of technological and demand variability on innovation performance in the presence of structural holes. It empirically illustrates how structural holes influence differently based on contextual environments. Contrary to previous network studies, findings reveal that technological uncertainty enhances innovation performance. When technological uncertainty involves the importance of technology and development speed, higher technical uncertainty implies higher added value in related parts, ultimately boosting innovation performance. Additionally, increased technological uncertainty leads firms to respond by creating parts in-house or vertically integrating with capable suppliers, rather than collaborating on innovation efforts (Oh & Rhee, 2008).

The moderating effect of structural holes was not confirmed in H3. The impact of structural holes may be diminished in collectivist cultures that emphasize 'ingroup' preferences (Xiao & Tsui, 2007). In such cultures, like Korea, individuals tend to make decisions with familiar parties, which reduces opportunism and builds B2B trust (Chung & Jin, 2011). Therefore, new external information might not be as vital to suppliers' performance because of in-group preferences. It is crucial to recognize that structural holes do not always have a positive influence on suppliers' behavior.

6.1.1. Theoretical Implications

The study has several important theoretical implications. First, this research extends network theory by highlighting the complex role of structural holes in moderating the relationship between technological uncertainty, demand variability, and innovation performance. For example, in the semiconductor industry, structural holes facilitate access to critical information and resources, thereby reducing opportunistic behavior and enhancing innovation (Burt, 1992). Structural holes enable firms to bridge gaps between otherwise disconnected entities, allowing for the flow of novel information and resources that are essential for innovative processes (Gilsing et al., 2008). This highlights the importance of strategic network positions in fostering innovative capabilities and addressing uncertainties.

Second, the findings challenge traditional network studies by demonstrating that technological uncertainty can enhance innovation performance. In the biotechnology sector, firms facing high technological uncertainty often experience improved innovation performance by investing heavily in R&D and vertically integrating with specialized suppliers (Fleming, 2001; Funk & Owen-Smith, 2017). This counters the traditional view that uncertainty hampers innovation, instead suggesting that higher uncertainty can drive firms to adopt more robust innovation strategies. By leveraging technological uncertainty, firms can develop cutting-edge products and technologies that offer significant competitive advantages (Teece, 2010).

Third, this study emphasizes the critical role of cultural factors in the effectiveness of structural holes. In collectivist cultures like South Korea, the preference for 'ingroup' decision-making can diminish the benefits of structural holes, affecting network dynamics and innovation strategies (Xiao & Tsui, 2007; Chung & Jin, 2011). In such cultures, the reliance on familiar, trusted relationships may override the advantages of new information from structural holes. This cultural context influences how firms manage their networks and highlights the necessity of considering cultural dimensions when analyzing network effects on innovation (Granovetter, 1985).

6.1.2. Managerial Implications

For managers, the study suggests that integrating capable suppliers through vertical integration or in-house development is crucial under high technological uncertainty. For instance, an automotive manufacturer might choose to develop advanced battery technology in-house or establish strategic partnerships with leading battery suppliers to enhance innovation performance. This approach allows firms to maintain greater control over their innovation processes and ensures a steady flow of critical components, thus reducing reliance on external partners and mitigating risks associated with technological uncertainty (Gilsing et al., 2008).

Managers should recognize that the benefits of structural holes vary across cultural settings. In collectivist cultures like China, fostering strong in-group relationships may be more beneficial than relying on structural holes. A Chinese electronics company might focus on building trust and strong ties within its existing network to improve innovation performance. This approach leverages the cultural preference for close-knit, trusted relationships, which can facilitate smoother collaboration and enhance the effectiveness of innovation efforts (Granovetter, 1985; Xiao & Tsui, 2007).

Firms need to adapt their innovation strategies based on technological uncertainty, demand variability, and the presence of structural holes. For example, a pharmaceutical company might employ unilateral governance in the absence of structural holes but shift to bilateral governance when structural holes are present to manage relationships more effectively. This flexibility allows the firm to better handle environmental uncertainties and enhance its innovation performance by leveraging different governance approaches to suit varying conditions (Guimera et al., 2005). By adopting adaptive strategies, firms can ensure that their innovation processes remain resilient and responsive to changing market demands and technological landscapes.

6.2. Limitations and Future Research

The theoretical scope of this study is constrained by its exclusive focus on the moderating effect of structural holes in the relationship between technological and demand variability and innovation performance. While this provides valuable insights, it overlooks other network dimensions that could also significantly impact supplier performance. For instance, network centrality and density have been shown to influence innovation outcomes by affecting the flow of information and resources within a network (Gilsing et al., 2008). Future research should expand the theoretical framework to include these dimensions to provide a more comprehensive understanding of network effects on innovation.

Another notable limitation of this study is the collectivistic culture of Korean firms from which the data was collected. Although the business environment in Korea has progressively aligned with global standards, Korean firms are still deeply influenced by high collectivism. This cultural context can impact the applicability of the findings to other settings. Previous research has indicated that collectivistic cultures prioritize in-group harmony and long-term relationships, which can influence network dynamics and innovation strategies differently compared to individualistic cultures (Xiao & Tsui, 2007; Chung & Jin, 2011). Therefore, future research should consider cultural factors when building research models to ensure broader applicability.

The data for this study was collected from subcontractors in the Korean plant engineering industry, characterized by long-term, turn-key projects that require extensive collaboration with suppliers. While this industry-specific focus provides detailed insights, it may limit the generalizability of the results. The unique characteristics of the plant engineering industry, such as its reliance on long-term projects and extensive supplier collaboration, may not be representative of other industries. For example, industries with shorter project cycles or less dependency on supplier collaboration might experience different network effects on innovation performance (Vanpoucke et al., 2014; Schoenherr & Swink, 2012). To address this limitation, future research should include a broader range of industries to validate and extend the findings.

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