Understanding the effects of network characteristics on focal firm performance.

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Declaration

I hereby certify that this thesis, presented for examination for the PhD degree of the Bayes Business School, City University of London, is entirely my own research work, carried out jointly by my PhD supervisors, Dr Canan Kocabasoglu-Hillmer and Dr Joerg Ries. The copyright of this thesis rests with the author. Quotation from it is permitted, provided that full acknowledgment is made. This thesis may not be reproduced without the prior consent of the author. The material used from other resources is acknowledged. I also certify that the work in this thesis has not been previously submitted for a degree or other qualifications.

Abstract

The overall purpose of this dissertation is to understand how networks interact with each other in a supply chain context. In particular, this thesis investigates the embeddedness of firms in networks, the characteristics of networks, and their impact on the focal firm performance. Firms are embedded in two separate networks: the internal network consisting of the parent company and its subsidiaries, and the external network consisting of customers, suppliers, and their subsidiaries. Incorporating three theoretical perspectives: embeddedness, social network theory and complexity theory, this dissertation examines three research questions:

(1) What is the relationship between physical proximity of the firm with its supply network, geographic dispersion of its internal network and its financial performance?

(2) What are the impacts of the dimensions of buyer network complexity on supplier operational and sales performance?

(3) What is the relationship between the degree of sharedness of suppliers, shared suppliers' centrality, and buyer innovation performance?

The first study[1] argues that the relationship between the firm's physical proximity with its supply network and firm performance is moderated by the degree of geographic dispersion of its internal network. Using a large-scale study based on secondary data, the first paper is one of the first studies that offer an understanding of the possible interaction of internal and supply networks of a buying firm and the effect on performance. The dataset consists of 100 buying firms from the electronics industry where their supply network data is collected from FactSet and internal network data from Orbis. The results reveal that the performance effects of physical proximity of the firm with its supply network is negatively moderated by the geographic dispersion of the firm's internal network.

In the second study[2], the focus is on the complexity defined at the *buyer* network-level. Therefore, the impacts of structural dimensions of buyer complexity (i.e., horizontal,

[1] This study got shortlisted into the Harry Boer award for the best paper authored by a PhD student in EurOMA2020, and soon later, the paper was invited to a special issue in the International Journal of Operations & Production Management. The paper went through a major and then, a minor revision process before being accepted in May 2021. Please find paper here: Chedid, F., Kocabasoglu-Hillmer, C. and Ries, J., 2021. The interaction between supply networks and internal networks: performance implications. International Journal of Operations & Production Management, 41(6), pp.860-881.

[2] This paper was presented at EurOMA 2021 online Conference and was published in the conference proceedings.

vertical, and spatial) on supplier sales performance as well as its operational performance are examined, and these dimensions are formulated by including the additional layer of the buyer's internal network complexity. These impacts are examined using 96 supplying firms and their 4163 buyers from the electronics industry, collected from FactSet. The internal network data of these buyers is collected from Orbis in order to operationalize the network constructs. The results confirm that the consideration of complexity at the downstream side is important and support the argument that examining internal complexity of buyers' networks uncovers differential effects when looking at the structure of these networks.

The third study examines two important factors resulting in a buyer higher innovation performance: the extent of shared suppliers that the buyer has in its supply network with its peers and the centrality of these shared suppliers. This study also suggests that there is an interplay between these two factors and that, together, they will strengthen the impact on buying firm innovation. This study builds on a dataset containing 96 public buying firms (focal firms) with their supply networks resulting in a total of 4713 suppliers. Overall, the results reveal the importance of considering the centrality of the shared suppliers and shed lights on supplier centrality when buying firms search for critical input on innovative technologies and processes.

Abbreviations:

Supply Network	SN
Supply Chain	SC
Internal Network	IN
Multinational Companies	MNCs
Buyer Network	BN
Customer Network	CN
Complex Adaptive Systems	CAS
Business-to-Business	B2B
Geographic Dispersion	GD
Social Network Theory	SNT
Social Network Analysis	SNA
Horizontal Complexity	HC
Vertical Complexity	VC
Spatial Complexity	SC
Return on Assets	ROA
Profit Margin Percentage	PMP
Gross Margin	GM
Sales Volume	SV
Cash Conversion Cycle	CCC
Operating Cycle	OC

Chapter 1: Introduction

1.1. Network Perspective of the Supply Chain

A supply chain can be defined as a connected network of companies that consist of suppliers, manufacturers, sub-suppliers, customers, and third-party service providers that interact to perform the supply chain activities of the firm and provide the end-product or service (Mentzer *et al*., 2001).

In extended supply chains, firms depend heavily on their supply networks since these networks are a vital source of products, materials, and data for the focal firm (Choi and Hong, 2002; Bellamy *et al*., 2014). A supply network is defined as all the interlinked companies that exist upstream to any focal firm in the value system (Porter, 1985). These companies are generally referred to as supply network partners of a given focal firm.

In addition, customer networks are becoming increasingly important in today's dynamic business environment, where supplying firms are being challenged to respond to buyers' sophisticated requirements (Ryals, 2006; Lee *et al*., 2015). A lot of these challenges occur because buying firms' needs are continuously changing in terms of what they purchase and what their expectations are (Tuli *et al.,* 2007; Patatoukas, 2012). Customer networks emerge as a promising approach to study customer-supplier relationships where both parties intertwine activities, resources, and processes to create new value (Ryals, 2006; Senn *et al*., 2013).

In a B2B context, the buyer or customer network is defined as formal connections between a focal firm and firms that purchase its goods and services (Nohria, 1998). Buyers' networks are a supplier's main source of information about the buyers' needs and their respective levels of satisfaction (Zimmerman and Blythe, 2013; Tuli *et al.,* 2007).

In both cases, the need to look at supply chains as a network of firms (whether upstream or downstream) that can collectively achieve operational effectiveness, better performance, and sustainable competitive advantage has been recently emphasised in the operations and supply chain management literature (Choi and Hong, 2002; Kim, 2014; Bellamy *et al*., 2014; Kim, 2017). Generally, the relationships between network entities, from upstream suppliers to downstream customers, are not just dyadic, they entail paths through a network of firms. Indeed, previously, the focus has been on paths between just two nodes: supplier to focal firm, and focal firm to customer. Yet, the concept of network has always been there, and recently, the notion of a network is starting to replace that of a simple path.

Moreover, SCs are not just a combination of buyers and suppliers' relationships; in reality, each entity in the SC is, in a lot of cases, an MNC that operates international networks of subsidiaries that are dispersed around the world. Therefore, networks do not only consist of the direct ties of the focal firm to each of its supply or customer network partners, but also of the ties to the subsidiaries that form the internal network of these entities (Demeter *et al*., 2016). In other words, network partners intersect and coordinate not only with the headquarter firms as one entity, but with their several subsidiaries as well as their headquarters. In line with this, Demeter et al (2016) have suggested two distinct networks (see Figure 1): an internal network composed of several subsidiaries belonging to the same company, and an external network identified through information and material flows between different companies that cooperate with each other in a supply chain.

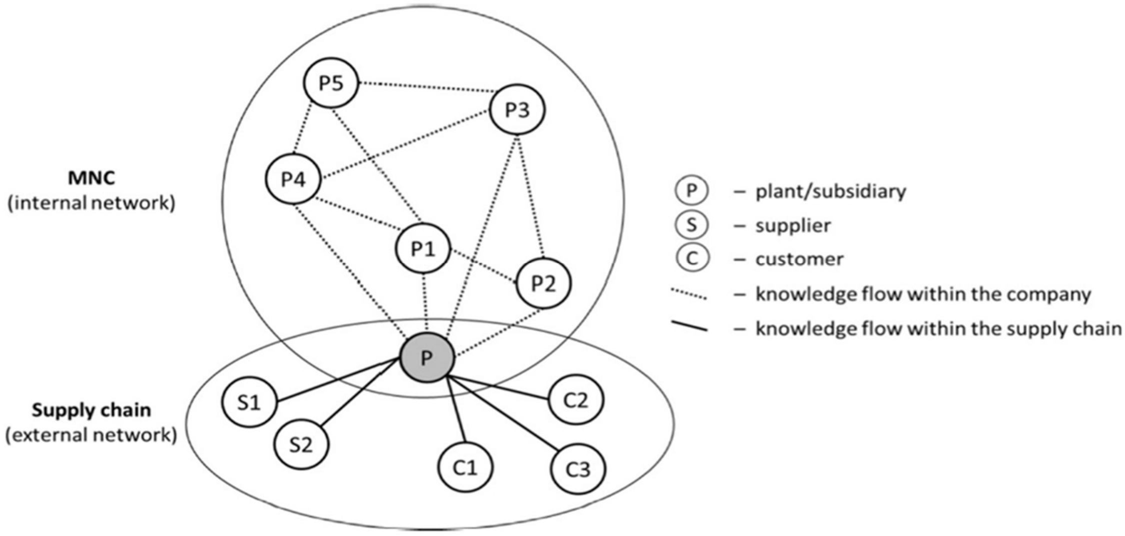

Figure 1: Integration of a plant in the internal and external network adopted from Demeter et al (2016)

1.2. Supply Networks

As mentioned above, a supply network refers to all the interconnected firms that exist upstream to any firm in the supply chain (Porter, 1985). Thus, the focal firm is considered as embedded in the large network of interconnected supply partners (Choi *et al*., 2001).

Supply networks are important elements of competitive and globalized markets. Firms improve their competitive advantage by being parts of a supply network because they can benefit from lower production costs, higher product quality (Bray *et al*, 2019), and increased responsiveness with respect to the customers' rapidly changing needs and expectations (Chopra and Sodhi, 2004).

In today's business environment, that is characterized by an increased dependence on supply networks, the embeddedness of a focal firm in its network is rising as a very important aspect to be considered in research on focal firm performance.

Embeddedness refers to the extent to which a firm depends on its suppliers and buyers in a specific network structure (Granovetter, 1985; Uzzi, 1997). Thus, the focal firm is considered as embedded in the large network of interlinked supply partners (Choi *et al*., 2001). Both anecdotal evidence and research on supply networks highlight the operational benefits of effectively managing a supply network. Effective management of their supply networks allows firms to improve their operational (Kim, 2014) and financial performance (Lu and Shang, 2017). The supply network of a firm has also been viewed as a source of innovation (Bellamy *et al*., 2014). While this has become an important field in the operations and SCM research, the need for more research on supply networks has been recently emphasised in the literature (Kim, 2014; Bellamy *et al*., 2014; Chedid *et al*., 2021).

Nowadays, the more global modern supply chains are becoming, the higher their exposure to risks because when supply networks are globally spread, they are exposed to higher complexity in the business environments. Being in different countries of the world, different parts of the network come under the rules and regulations of different political governments (Meixell and Gargeya, 2005). Thus, what occurs in one part of the supply network can affect what occurs in its other parts. Different supply network topologies lead to different levels of supply network outcomes. In other words, different structures have different levels of effectiveness, but they would also provide greater levels of complexity at the network-level. Prior research has conjectured that the way a firm's supply network is structured, formally termed as structural characteristics, will bear influence on its performance. In addition, scholars in operations management have encouraged future research to study the structural dimension of social networks, specifically, accounting for the embedded nature of buyer-supplier dyads (Autry and

Griffis, 2008; Villena *et al*., 2011; Bode and Wagner, 2015). The supply network structure and embeddedness, as well as their impact on factors such as relationship performance or innovation performance are important subject areas of interest.

In addition, in the supply chain management studies, it has been argued that the degree of complexity results from the structural properties of the supply chain that are formed by the number and variability of elements defining the supply chain and their interactions such as the number of entities, plants, facilities, products, and transportation routes (Bode and Wagner, 2015; Lu and Shang, 2017; Campos *et al*., 2019). In addition to that, uncertainty, technological complexity, the number of suppliers, the products' structure, and the manufacturing processes flow are also considered sources of complexity (Vachon and Klassen, 2002; Choi and Krause, 2006; Brandon-Jones *et al*., 2014).

Supply chain management scholars underline the need to further investigate the impact of supply chain complexity, Fawcett et al. (2011) believe that it is crucial to find the point at which good complexity becomes bad. Complexity is an important characteristic of supply networks. Research on complexity have highlighted its multidimensional nature and focused on its various features (Choi and Krause, 2006; Jacobs and Swink, 2011; Manuj and Sahin, 2011). Complexity has been suggested to relate with three main aspects of a system: the multiplicity, the diversity, and interrelatedness. Multiplicity and diversity, often denoted as structural complexity, concern the complexity associated with number and variability of elements defining the system. Interrelatedness, referred to as operational complexity, focuses on the interactions between the elements of the system (Jacobs and Swink, 2011).

In the supply network literature, the structural complexity dimensions are commonly used to describe the complexity characteristics of networks (Choi and Hong, 2002; Bode and Wagner, 2015; Lu and Shang, 2017; Sharma *et al*., 2019; Adhikary *et al*., 2020). These dimensions include *vertical complexity* which is the number of tiers or the depth of the supply network (Choi and Hong, 2002; Lu and Shang, 2017), *horizontal complexity* which refers to the number of suppliers in each tier (Choi and Hong, 2002; Bode and Wagner, 2015; Lu and Shang, 2017), and *spatial complexity* which is the geographical spreading of the supply network (Choi and Hong, 2002; Bode and Wagner, 2015; Lu and Shang, 2017). These supply network dimensions of complexity increase the level of supplier interactions or interrelationships (Bozarth *et al*., 2009; Choi and Krause, 2006;

Vachon and Klassen 2002). For instance, increasing the number of suppliers will add complexity to the vertical component of supply network complexity by expanding the number of information flows, material flows and relationships to handle (Bozarth *et al.*, 2009). In a nutshell, the structural dimension is believed to increase supply network complexity because of the greater number and spread of members, information, data, and heterogeneity that should be taken into consideration to manage efficiently the supply network (Choi and Hong, 2002).

Although definitions and measurements of supply chain complexity may differ due to contextual differences, there is a general agreement that supply chain complexity refers to the number and variety of elements and the degree to which they interrelate (Vachon and Klassen, 2002; Choi and Krause, 2006; Brandon-Jones *et al.*, 2014; Bode and Wagner, 2015; Giannoccaro *et al.*, 2017; Lu and Shang, 2017).

1.3. Customer Networks

The consideration of customer networks has also been growing. On one hand, supplying firms see the importance and benefits of attracting and maintaining large buyer networks to grow and maximize their revenues (Zimmerman and Blythe, 2013). Besides, suppliers are increasingly realizing the importance of not only knowing their buyers, but also maintaining a large buyer network to ensure greater access to sources of information about emerging trends and new preferences (Ellis, 2010; Chowdhury, 2011). Lee *et al* (2011) show that buyer network size in the retail industry positively influences supplier financial performance through marketing program implementation. On the other hand, the time, effort, and resources associated with achieving a satisfactory level of buyer control, communication and coordination are intensified when dealing with high numbers and high heterogeneity of buyers (Bozarth *et al.*, 2009). This structural complexity increases the level of operational load on supplier's internal resources and contributes to a perceived uncertainty (Chowdhury, 2011), which weakens the supplier's efficiency and ability to capture profits. Although suppliers with large buyer bases generate more sales and profits (Lee *et al.*, 2011), they also spend more on selling, general, and administrative expenses and hold more of their assets in inventory (Patatoukas, 2012). These mixed views suggest a need to consider these various forces simultaneously in order to understand their cumulative impact. The buyer network has been predominantly investigated in the marketing literature where the impact on supply chain complexity is not considered and a more revenue focused perspective is taken while the operational challenges of managing a complex network received less attention.

Existing B2B literature has suggested that complexity in buyer demands results from greater diversity among buyers, higher expectations for customized products and services, and an increasing number and diversity of buying personnel involved in the buying process (Ingram 2004; Schmitz and Ganesan, 2014). In line with this, extant studies in the marketing literature consider buyer complexity as the degree to which supplying firms must respond to a diverse array of buyers' needs (Zimmerman and Blythe, 2013; Wiersema, 2013). However, previous studies show that supplying firms that are managing higher levels of complex buyer networks are more likely to intensely manage their downstream side of the supply chain (Romo and Schwartz, 1995). Such firms are more likely to invest into supply chain contracts and buyer-supplier relationships to manage complexity or even reduce it.

Moreover, extant research in the supply network literature has primarily focused on two dimensions of a focal firm's network: the structure of a network and the complexity of a network. However, these studies considered the structural complexity dimensions of a supply network only (e.g., Lu and Shang, 2017, Sharma *et al.*, 2019) and their impacts on performance. The consideration of buyers' networks is still scarce. Furthermore, the literature implicitly assumes linear relationships (e.g., Bode and Wagner, 2015), yet the effects of structural dimensions on financial performance are more complicated. For example, as the number of buyers (captured by horizontal complexity) increases, profits and revenues are likely to increase (Zimmerman and Blythe, 2013). However, a greater number of buyers may also indicate more delivery coordination (Hammoudan *et al.*, 2016) which might outweigh the profits. The lack of empirical research in this area motivates me to investigate in more depth customer networks.

1.4. Internal Networks

As Ghoshal and Bartlett (1990) argue, many top global companies are increasingly tapping into differentiated advantages among different subsidiaries, suppliers, and customers networks. MNCs refer to "a coordinated system or network of cross-border value-creating activities, some of which are carried out within the hierarchy of the firm, and some of which are carried out through informal social ties or contractual relationships" (Cantwell *et al.*, 2009, pp. 569). These activities generally take place within subsidiaries which are embedded in local networks and interact with a variety of actors such as suppliers, customers, and their subsidiaries (Ciabuschi *et al*., 2014). Previous literature has shown how such local embeddedness of subsidiaries positively influences the stock of knowledge (Meyer *et al*., 2011) and performance (Andersson *et al*., 2002) helping them to contribute and improve the competitive advantage of the MNC (Dyer and Nobeoka, 2000). Being embedded with local business units and learning from them is strategically important for subsidiaries because they can access valuable resources and knowledge to build a competitive advantage for themselves and for their parent company (Rosenkopf and Almeida, 2003; Cantwell *et al*., 2009).

Gaining external skills and expertise is an important strategy for the company's growth, since it may improve innovation performance and support the achievement of a sustainable competitive advantage (Tsai, 2001). The attainment of these external competences is mainly done by the internal network of the MNC that consists of foreign subsidiaries that accumulate valuable resources and capabilities through their network of relationships in the local market (Zeng *et al*., 2013). This technological knowledge mainly resides in various geographic regions (Dunning and Lundan, 2008) and this pushes the firms to scout, access, and source external technologies. This geographic dispersion creates possibilities to experience multicultural regions which expose the employees to heterogeneous and valuable resources, problem-solving techniques and information sources that allow them to build competitive advantages for the MNC (Andersson *et al*., 2002; Nell and Andersson, 2012).

When subsidiaries develop close links with other network units such as consistent and frequent interactions with other subsidiaries, intra-network knowledge and intra-organizational learning are facilitated and enabled more quickly (Schmid and Schurig, 2003). Thus, subsidiaries need to be deeply integrated into their local network, i.e., more participation in knowledge and information sharing activities between network members is required. In line with this, several types of knowledge can be found, the first distinction was made by Polanyi (1958) according to whom knowledge can be split into two different but sometimes complementary types: tacit knowledge and codified knowledge.

Codified or explicit knowledge includes all written, codified, and digitized sources that are easily documented and conveyed through manuals or books, communicated over long distances (Zack, 1999; Spencer, 2008), and can therefore be replicated or shared by people who did not take part in the process of creating it.

The other type of knowledge, tacit or implicit knowledge, includes insights and intuitions that resides in the human mind through their daily behaviour and experience (Zack, 1999). This type of knowledge can only be imitated through observation, practice, and learning; therefore, it is easier to be communicated through face-to-face interaction (Hoang and Rothaermel, 2005; Spencer, 2008; Frankort *et al*., 2012). Thus, internal networks play an important role when it comes to tacit or implicit knowledge that includes insights and intuitions residing in the human mind through their daily behaviour and experience (Demeter *et al*., 2016).

The advantages of the physical proximity of business activities between internal and external network of firms are obvious here. Thus, members of spatially close communities can certainly share and transfer this tacit knowledge (Alcacer and Chung, 2007; Spencer, 2008). This is why encouraging local activities and promoting geographical proximity or development of clusters, appear essential (Narasimhan and Nair, 2005). Thus, it is necessary for companies to locate in permanent geographical proximity to one another or collocate in order to benefit from the effects of the flow and transfer of this tacit knowledge.

Therefore, internal networks are extremely important conduits that enable tacit knowledge transfer, facilitate performance improvement, and improve the competitive advantage of the MNC. For these reasons, the consideration of internal networks is crucial.

1.5. Shared Suppliers

The literature has demonstrated the importance of network consideration in modern SC studies (Choi and Hong, 2002; Bellamy *et al*., 2014, Lu and Shang, 2017). These studies have shown that focal firms are increasingly relying on their suppliers to develop their next generation of products and services (Azadegan and Dooley, 2010; Choi and Krause, 2006; Dyer and Nobeoka, 2000). Therefore, supply networks have gained considerable attention where researchers linked node and network-level measures to performance metrics related to firm innovation (Bellamy *et al*., 2014; Sharma *et al*., 2019). Globalization of SCs is a key aspect driving the need for more supply network research, particularly innovation research in industries such as electronics (Ernst, 2003), and semiconductors (Macher *et al*., 2002) where the impact of globalization and the consequent innovative capacity within these industries is growing and the reliance on external partners in delivering firms needs is increasing. In other words, the trends for disintegration and globalization observed in these industries suggest that the focus of innovation is moving towards supply networks. Given this shift, characteristics of supply networks such as their structure or their coordination and control mechanisms will have a bearing on the way innovation activities are executed, as well as on their outcomes (Yan *et al*., 2017; Kumar *et al*., 2020).

Recently, researchers explored the link between a focal firm's network of suppliers and its innovation output (Bellamy *et al*., 2014; Narasimhan and Narayanan, 2013; Sharma *et al*., 2019). Several studies in social network analysis, for example, have demonstrated that belonging to an interconnected network of firms in the supply chain, fosters innovation capabilities and facilitates both internal and external communication of the focal firm (Bellamy *et al*., 2014; Yan *et al*., 2017). Furthermore, previous studies focused on the importance of understanding the role of upstream/supplier network structure on the innovation output (Bellamy *et al*., 2014; Sharma *et al*., 2019). Bellamy et al (2014) investigated the relationship between a firm's supply network accessibility and interconnectedness and its innovation output while Sharma et al (2019) studied the effects of horizontal, vertical, and spatial complexity of a supply network on focal firm innovation performance. These studies have substantially extended empirically the innovation literature on supply networks and demonstrated how crucial is the in-depth investigation of these networks.

Moreover, buying firms increasingly form networks around the supply, production and delivery of goods and services, and in a lot of cases, these firms source from the same suppliers as their peers, for several reasons. These suppliers become shared suppliers.

A stream of literature has noted that there are many strategic benefits from outsourcing to a shared supplier, one is reducing the supplier's vested interest in a competing buying firm and thereby limiting the supplier's incentive to deliver the product to the competitor on more preferential terms (Arya *et al*., 2008). Besides, other studies suggest that technology spillovers can be associated with investing in a shared supplier and, in turn, become an advantage for competitors under outsourcing from common supplier which would improve the firms' profits (Qi *et al*., 2015). Other authors studied the firms' investing in a shared supplier to improve the reliability (Wang *et al*., 2014) and improving quality performance of sourced goods (Agrawal *et al*., 2016). Another stream of research considered the capacity reservation and allocation in a supply chain with shared suppliers (Qi *et al*., 2019). Another highly mentioned reason is cost saving. A firm may outsource to take advantage of the cost efficiency and/or scale economies of the supplier that sources to a high number of players/competitors in the industry (Loertscher and Riordan, 2019; Shy and Stenbacka, 2003). Nevertheless, some studies argue that even if it is more costly, a firm may source from a shared supplier if the strategic interaction among competitors is considered.

Shared suppliers may act indirectly as hubs for knowledge transfers and with more shared suppliers (i.e., more hubs) in a buyer's supply network; the effect becomes intensified and might improve the buyer's innovation performance. However, with a bigger network of shared suppliers, unintended knowledge leakages are intensified too (Martinez-Noya and Canal, 2018). This trade-off becomes a challenge when outsourcing to a shared supplier (Muthulingam and Agrawal, 2016). In line with this, much debate revolves around whether sourcing from a shared supplier has negative effects on the buyer in terms of spillovers, or positive effects in terms of innovation benefits. Enhancements in one area may require trade-offs in another and one buyer's positive impact might be negative for another buyer (Wen *et al*., 2021). Sourcing from a shared supplier provides a buyer with increased access to the supplier's capacity and innovation, but such investment is costly and may benefit the competing firm if it also has access to the capacity: a spillover effect (Muthulingam and Agrawal, 2016).

Looking at the majority of these previous studies examining shared suppliers, the focus was on analytical models. Most of these studies explore different incentives to outsource to common suppliers and different challenges associated with it, using analytical modelling. None of them appear to empirically examine the benefits or the disadvantages of the extent/degree of shared suppliers in a buyer's supply network and its potential effect on innovation output.

While sharing suppliers with direct competitors has been shown to benefit innovation spillovers, there is also a wider network effect to consider. Recent work has shown that centrality in a supply network can be a key determinant of innovation (Idiagbon-Oke and

Oke, 2020; Kim and Fortado, 2021). High centrality offers an opportunity to tap into important resources and discover novel or alternative aspects and practices (Lau *et al*., 2020; Kim and Fortado, 2021). Supplier centrality is defined as the extent to which a supplier maintains links with well-connected firms in a network structure (Borgatti and Li, 2009). Supplier centrality indicates the level of a supplier's direct and indirect connections to other influential firms. For example, Intel and Advanced Micro Devices hold a very central position in the computer industry. Practical evidence suggests that informational flows both within a firm and externally through a firm's supply chain need to be identified and leveraged to foster more innovations (Bellamy *et al*., 2020).

In line with this, the more the central position the supplier holds with respect to direct competitors, the more accidental knowledge leakages are likely to happen. In other words, the more central a shared supplier is, the more innovative outcomes are likely to happen. A few studies have explored the link between centrality and innovation (Potter and Wilhelm, 2020; Kim and Fortado, 2021; Chae *et al*., 2019). For example, Kim and Fortado (2021) found a positive effect of supplier centrality on supplier innovation value, while Potter and Wilhelm (2020) revealed a positive influence of supplier degree centrality on the generation of supplier–supplier innovations and investigated the extent to which this relationship is moderated by the structural embeddedness of firms in the supply network.

However, none of these studies considered the innovation outcome of the buyer as a result of its supply network that is simultaneously shared and central. It is important to note that the difference between a supplier that is shared and a supplier that is central: the former is considered "shared", if it is being shared by at least two buyers, whereas the latter means that the supplier holds a central position in the network. In other words, in the third study's context, a buyer considers a supplier as "shared", if the supplier supplies to at least one other buyer in the same industry while a central supplier is related to the extent of sharedness that would make the position of this supplier central in comparison with other suppliers. Nonetheless, little is known about the effects of these notions as well as the interaction of both on buying firm's innovation.

Chapter 2: Research Questions

2.1. Research Question 1

The importance of the supply network to firm performance is well documented in extant literature. Until now, the firm and its suppliers have been conceptualized as single entities. Yet, multinational corporations (MNC) are composed of a complex, geographically dispersed internal network of subsidiaries. The supply and internal networks are inherently linked. Given the above (sections 1.1, 1.2 and 1.4), the goal of the first study is to understand the interaction between a focal firm's suppliers and the parent company as well as its subsidiaries at the network-level.

In other words, the first research question that this dissertation examines is whether the interaction between the firm's supply network (including suppliers and their subsidiaries) and the firm's internal network (including headquarter and subsidiaries) affects its performance. To pursue these objectives, the first study adopts a dual view of embeddedness from the international business literature and transfers it into a supply chain management context. In addition, the first paper builds upon the social network theory of the firm to explain the interaction of both networks by considering them simultaneously. By doing so, this paper extends supply network literature by considering the internal network of the focal firm and its suppliers by bridging supply network (cf. Choi and Hong, 2002; Bellamy *et al.,* 2014), internal network (cf. Nell and Andersson, 2012; Demeter *et al.,* 2016) and dual embeddedness (cf. Figueiredo, 2011; Meyer *et al.,* 2011) research. This paper is one of the first studies that offer an understanding of the interaction between supply and internal networks of a focal firm and the effect on financial performance.

2.2. Research Question 2

As mentioned in sections 1.3 and 1.4, the literature has not recognized the distinctive effects of internal structural complexity dimensions in the consideration of network complexity of buyers and suppliers. In the case of multinational buyers, their internal network includes several subsidiaries that are dispersed around the world. The buyer's internal network complexity is an important dimension to consider for two main reasons: (1) it is an additional structure that participates heavily in activities within the buyer network and forms more complexities due to the supplier links to the different parts of that buyer network, (Stendahl, 2018), and (2) it can be designed to respond and absorb the external complexity (Celo *et al*., 2018). Neglecting these indirect structural links between the supplier and its buyers masks critical information to supply chain management decisions.

Therefore, this research aims to fill these gaps using a large-scale empirical study. In this second study, the interest is in the complexity defined at the buyer network-level, which is called external complexity to the supplier. This second study examines the impact of dimensions of buyer complexity (i.e., horizontal, vertical, and spatial) on supplier performance and these dimensions are formulated by including the additional layer of the buyer's internal network complexity. With the consideration of the complexity of buyer networks that includes the internal network of each buyer, this study is able to contribute to the literature on supply chain complexity by drawing a more complete picture of these networks (see Figure 2). These impacts driven by the complexity dimensions of buyers' networks are not essentially always bad, therefore two types of performance measures are considered, separately: sales and operations.

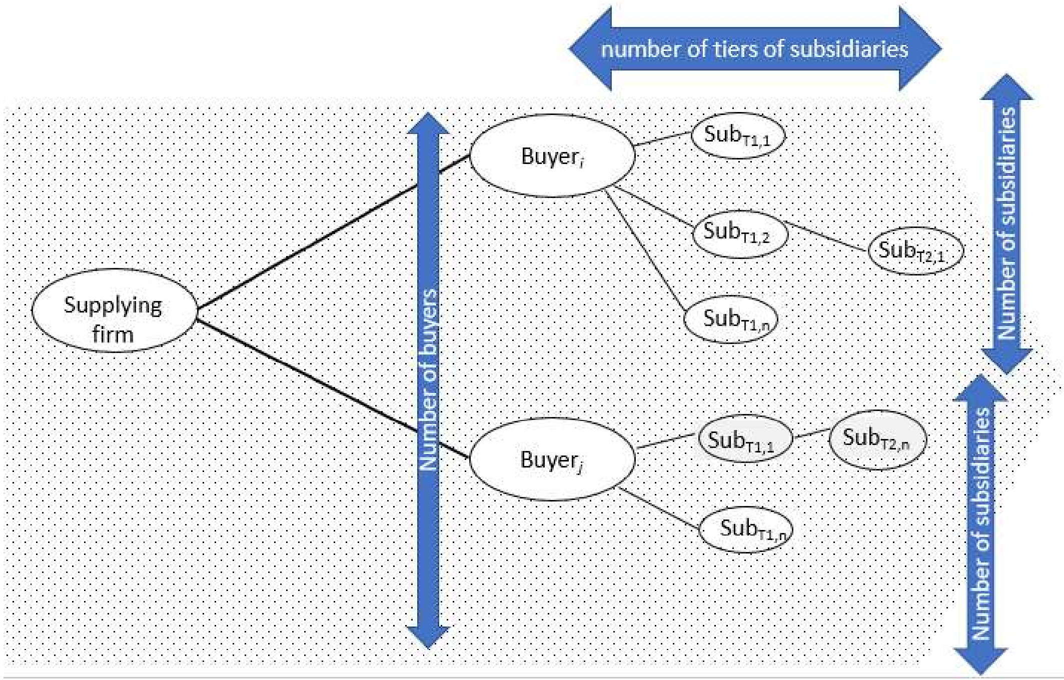

Figure 2: Illustration of the supplier's buyers' networks including internal networks

2.3. Research Question 3

As mentioned in Section 1.2, there has been extensive empirical research on supply networks and several contributions have been made to this domain. Yet, as shown in section 1.5, none of these studies have given attention to a shared network of suppliers that buying firms source from and share with other buyers regarded as their competitors. Furthermore, none of the existing studies has considered the potential impact resulting from the consideration of the shared supplier characteristics- in particular, the shared supplier centrality.

The focus is on centrality of the shared supplier in this study's context for two main reasons:

- Centrality influences both incoming and outgoing spillovers and facilitates incremental innovations. It has been shown to a have strong association with innovation output (Kim and Fortado, 2021; Chae *et al*., 2019; Kim *et al*., 2020; Gao *et al*., 2015; Narasimhan and Narayanan, 2013), especially in this context as it measures the degree to which the shared supplier is shared with more other competitors.
- It reflects the unique contributions of a large number of ties within the network of a shared supplier and the unique influence of network brokers that have a large degree of power and control within this network (Potter and Wilhelm, 2020).

Therefore, given that there is an empirical gap in understanding the phenomenon of suppliers centrality in conjunction to shared suppliers, this study aims to understand the effects of each and whether the extent of shared suppliers that a buyer has in its supply network interacts with centrality of these shared suppliers to influence buyer innovation. Additionally, this study uses a multilevel analysis as a robustness approach to confirm the results.

Chapter 3: Literature Review and Theoretical Standpoints

3.1. Social Network Theory

Supply chain management research is increasingly examining SC relationships beyond the buyer-supplier dyad, looking instead on the supply network (Wagner and Neshat, 2010; Giannoccaro *et al*., 2017). Given that a SC is, in reality, a network of companies and thus comprises several interrelated parties, SNT highlights the advantages of viewing a company as embedded within a larger network of relationships. It views a firm's economic activities as embedded in structures of social interactions (Granovetter, 1985; Brass, 1998), which create a network that is defined as "a set of nodes and the set of ties representing some relationship, or lack of relationship, between the nodes" (Brass *et al*., 2004, pp. 795). The main argument of SNT is that actors are embedded in networks of interconnected social relationships that offer opportunities and constraints on behaviour (Brass, 1998; Brass *et al*., 2004).

Choi et al (2001) argued that social network perspective could be an appropriate approach to study supply networks. Likewise, many studies in the supply chain management literature have shown the salience of social network perspective to study supply chains (Borgatti and Li, 2009; Kim *et al*., 2011; Kim, 2014).

This stream examines SCs as complex social networks and uses methods from SNA to understand relational ties and their effect on social capital, knowledge transfer, resource access, convergence, and contagion in supply chains (Krause *et al*., 2006).

SNA, which has theoretical roots in sociology, is a theory and an analytical method that permits for an in-depth study of the structural characteristics and the relationships of networks that are not completely understood if studied using link between two nodes (Choi *et al*., 2001; Kim *et al*., 2011). In other words, networks serve as both an external expression and a theoretical method of embedded theory (Lin and Kede, 2011). The assumption that organizational entities are embedded within a network of relationships is fundamental to the social network analysis approach (Wasserman and Faust, 1994). The network researcher seeks to model these relationships to portray the structure of a group. The effect of this structure on the functioning of the group could be studied, as well as, on the actors within the group (Wasserman and Faust, 1994; Brass, 1998).

The SNT makes important assumptions about actors, relationships, and the resulting structures (Wasserman and Faust, 1994). Social network models consider actors such as firms or individuals as being interdependent instead of independent, conceive relational links between actors as means for transfer of resources and perceive the network structures as offering opportunities or constraints for the actors, their decisions, and their actions (Burt, 1992).

For example, SNT supports the idea that firms occupying a central network position are likely to achieve better performance due to their access to more information and resources. The more the in-degree and out-degree links a firm has with other units in the network, the higher its node centrality, which in turn leads to higher access to heterogeneous knowledge (Tsai, 2001). This concept indicates that the more ties a node has the more it is considered as central, thus, when a node is linked to a high number of other nodes, this node has high degree centrality.

Researchers have called for further research that uses the key concepts in SNA and that could be helpful to the SCM field. Jackson (2008) believed that the SCM context has specific characteristics that require building network theory. A large number of SC papers have implemented concepts and tools proposed by Borgatti and Li (2009) that were founded in SNT (Autry and Griffis, 2008; Kim *et al*., 2011). In fact, SNA provides a practical model that identifies how network actions and processes are linked to network outcomes, and how network characteristics under the control of management influence network outcomes. This view allows understanding the benefits gained from reach of resources, knowledge and information sharing within a network of interdependent entities (Granovetter, 1985; Jackson, 2008). These relationships allow explaining actions in organizations by showing the constraints and opportunities for individuals, issues, and organizations that are combined with their characteristics.

Based on a literature review of the use of SNA in the SCM research done by Wichmann and Kaufmann (2016), scholars mainly focussed on the relationship between partners in the network, such as buyer-supplier relationships, relational links, and relationship performance. For instance, Zhou et al. (2014) studied the relational ties among buyers and their key suppliers. More precisely, they examined how strong the ties are and their impact on the acquirement of particular knowledge from the suppliers. Gao *et al*. (2015) also investigated the structure of supplier networks such as buyer-supplier relational strength and density of supplier network and their impact on product innovation. The outcomes of a supply chain may be related to the connections the supply chain entities have developed with each other. In fact, the value of a company's relationships extends beyond its firm-level to include everyone the firm is working with and connected to. As Burt (1992) has extensively argued, the connectedness of networks affects the performance of the firms in them. When it comes to the context of supply chains, well-connected entities of supply chain are more likely to be able to help to remove barriers or jointly resolve issues that might prevent supply chain operations and progress (Uzzi, 1997; Bellamy *et al*., 2014). In addition to that, the practical challenges associated with social network analysis was highlighted and is mainly related to collecting the social network data (e.g., Kim *et al*., 2011).

Another important aspect of SNT is that it highlights the effect of a lack of connections on node performance (Burt, 1992). For example, a buyer or supplier that connects disconnected units, i.e., that holds the position of a structural hole (see Figure 3), enjoys brokerage opportunities. A hole implies that firms on each side have access to discrete knowledge and information (Burt, 1992). Hence, a structural hole maximizes resource-sharing and knowledge transfer advantages for the buyer or supplier. In addition, such benefits to the buyer or supplier vary with its connections whether these other nodes are suppliers, customers, or subsidiaries.

In other words, in the first study of this dissertation, when the buyer holds a structural hole position, its subsidiary will be connected to the buyer's suppliers and customers, and they, consequently, will allow the connection to their subsidiaries. Therefore, subsidiaries will have the potential to embed themselves within heterogeneous and different types of knowledge networks, in order to accumulate their capabilities required to strengthen their performance and competitive position (Cantwell and Mudambi, 2005; Zeng *et al.*, 2013). Studies on the supply networks in SCM and SNT, however, have not considered the internal network of firms that consists of globally dispersed subsidiaries and whether these internal firms interact with the SN, i.e., the supplier, the customer, and their subsidiaries, to have a different impact on SC outcomes. Previous studies on SNs have considered each supplier and the focal firm as single entities neglecting the internal network of the focal firm and its suppliers that interact on the business activities as suggested by previous literature (Nell and Andersson, 2012; Demeter *et al.*, 2016).

The research area on the interaction of such network of subsidiaries, suppliers and suppliers' subsidiaries is still nascent. Taking a social network view enables this study to better represent SCs and their structure and allow to study characteristics of the two networks to fill this gap.

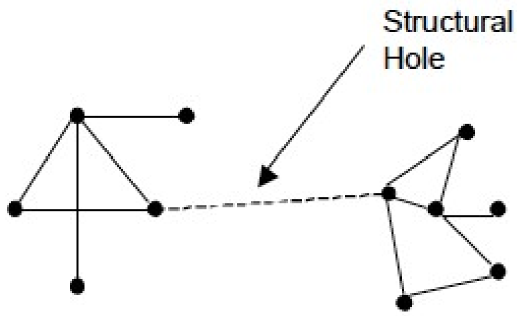

Figure 3: Structural hole

<u>Key metrics</u>

The network literature has recognized various metrics for networks that can help understand supply chains (Wasserman and Faust, 1994; Borgatti and Li, 2009; Kim *et al.*, 2011).

Network metrics can be considered at two levels: the node-level and network-level.

a- Node-level metrics measure how an individual node is embedded in a network from that individual node's perspective. The most prominent three types of node-level metric: degree, closeness, and betweenness centrality.

b- Network-level metrics compute how the overall network ties are organized. The network-level metrics are network density, centralization, and complexity.

3.1.1. Node-level metrics (Firm-level)

There are different types of centrality metrics and nodes could be identified to be important, in different aspects.

1- <u>Degree centrality</u>

This concept indicates that the more ties a node has the more it is considered as central, thus, when a node is linked to a high number of other nodes, this node has high degree centrality. A node having high degree centrality would definitely be more visible in a network because of its larger connectedness with other nodes (Freeman, 1978; Marsden, 2002).

2- Closeness centrality (ease of reaching other nodes)

Closeness centrality focuses on how close a node is to all the other nodes in the network beyond the ones that it is directly linked to them. A node is central if it can easily reach all the others, and that is why closeness centrality take indirect ties into account. This type of centrality is usually related with the freedom of a node in social networks (Freeman, 1978; Marsden, 2002). Thus, a node with a high closeness centrality measure has more independence from the influence of other nodes and has greater ability for independent actions.

3- Betweenness centrality (role as an intermediary, connector)

Betweenness centrality measures how frequently a node is positioned on the shortest path between all arrangements of pairs of other nodes. When a given node links with nodes that would otherwise be disconnected, other nodes become reliant on this node to reach the rest of the network. This node would be then considered to fill a structural hole. This measure focuses on the role of a node as an in-between intermediary and suggests that this reliance of others makes the node central in the network. Hence, the betweenness centrality typically represents a node's potential influence or control in the network (Marsden, 2002). Hence, a node with large betweenness centrality has an important capacity to facilitate or limit interactions between other nodes (Freeman, 1978).

3.1.2. Network-level metrics (group level)

Furthermore, social network analysis offers metrics about the structure of the overall network, such as network density, network centralization, and network complexity.

1- Network density

Network density measures the actual number of total ties in a network relatively to the number of potential or maximum possible ties that connect all nodes (Kim *et al.*, 2011). In other words, it is a measure of the overall density of a network, a network where all nodes are linked to all other nodes would give a network density of one.

2- Network centralization

Network centralization refers to the extent to which the overall density is structured around specific nodes in a network (Freeman, 1978). Theoretically, it can be regarded as an extension of the node-level centrality, i.e., if a network has high network centralization, this means that all links go through few central nodes. The network with highest possible centralization is the one with a star structure, in which a single node at the centre is tied to all other nodes and these other nodes are not tied to each other. Similarly, the lowest centralization is when all nodes have the same number of links to others. Network centralization and network density are complementary (Kim *et al*., 2011). While centralization is related to the distribution of influence or control across the network, density concerns network cohesiveness. A network that has every node linked to all the other nodes would have a highest possible density. This network would be a highly cohesive network but would not have a dispersed control structure.

3- Network complexity

Network complexity is defined as "the number of dependency relations within a network" (Frenken, 2000, pp. 260) and thus would be determined by the number of nodes in the network and the degree to which they are connected (Kaufman, 1993; Frenken, 2000). Network complexity is related to network density and network centralization. First, network density is conceptually associated with network complexity because a denser network needs more effort to be developed and maintained. Second, network centralization is linked with network complexity because of the high coordination costs required when every node is connected to all other nodes which is the network with the least centralization. According to SNT, network complexity can be determined by the number of nodes and degree of interdependency between nodes in a known network. Network complexity is also a network-level measure and is related to network size and density. Therefore, two types of social network analysis output metrics: size and density could be used to denote the number of supply network members and the level of complexity between them (Kim *et al*., 2011).

In the first study, given that the focus is on the link between the focal firm and its suppliers at the network-level, the first study follows a social network approach of the firm to explain the interaction of both networks by considering them simultaneously.
In the other two studies, many of these dimensions capture the measures used, for instance, in the second one, the complexity is captured at the network-level and in the third study, the supplier centrality is captured at the node-level. Therefore, both the second and the third study build on social network perspective which influences complexity, centrality, sharedness and their roles in networks.

3.2. Embeddedness

To understand the behaviour of any single supplier in a supply network, it is necessary to explore the concept of embeddedness. Embeddedness is an important subject in sociology and economics that improves our understanding on the effect of social structure on economic life. In fact, many economic, political, and social interactions are formed by the structure of relationships. Embeddedness is defined as the extent to which a firm depends on its suppliers and buyers in a specific network structure (Granovetter, 1985; Uzzi, 1997). The concept of embeddedness indicates the contextualisation of an economic action in ongoing arrangements of relationships and seizes the contingent nature of the activities of an economic actor taking advantage of being embedded in a bigger social structure. Granovetter (1985) split embeddedness into two main aspects: structural and relational. Structural embeddedness focuses on the configuration of an entity's network of relationships, while relational embeddedness emphasises the role of quality of those relationships (Rowley *et al.*, 2000).
There are two different streams in the literature on structural embeddedness: the first one looks at the influence of a structure of relationships, considering the aspect of a configuration or architecture of a network in which a focal firm and its partners build patterns of connections (Granovetter,1985). The other stream is more position oriented and highlights the positional aspect that a company has in a network (Gulati, 1998). Considering the two research streams, Kim (2014, pp. 221) defined structural embeddedness as "the value of a firm's structural position in a triadic or more complex network that involves informational and reputational benefits and is influenced by a monitoring and controlling mechanism."

Past research proposed several levels of structural embeddedness, containing company-level, dyad-level, and network-level. Kim (2014)'s study showed that the understanding of structural embeddedness and relational embeddedness must be taken into consideration in the efforts to improve firms' performance. In fact, the study found that the greater understanding of the supplier positional advantage is critical in the development of the operational performance and the structural position helps to improve the dyadic relationship and exchange between a buying firm and its supplier.

The concept of structural embeddedness asserts that companies are affected not only by the nodes they are directly connected to but also by distant nodes they are indirectly connected to (Uzzi, 1997). In other words, being embedded implies being embedded in both direct relationships, such as suppliers and indirect relationships such as suppliers 'subsidiaries. In line with this, embeddedness forms the social network, in which specific resources and regulations that bring benefits constitute the social capital (Krause *et al*., 2006; Lin and Kede, 2011). Embeddedness is the prerequisite of networks that rely on being embedded in relationships to get formed and identified, hence, network is a concentrated illustration of embeddedness.

Most studies focus on the likely positive effects of embedded relationships (Bellamy *et al*, 2014); however, some researchers have also highlighted many negative effects on firm performance such as complexity, opportunism, redundant information, and relationship inertia that all lead to higher relationship and maintenance cost, and therefore, reduce the positive impact of relational and structural embeddedness (Uzzi, 1997; Villena *et al*., 2011; Rowley *et al*., 2000). By looking at both, supply networks and internal networks, a broader view could explain these divergent results of previous studies.

In the first study of this dissertation, the focus is on the structural embeddedness and mainly on the ties of the external and internal networks of the focal company. In other words, the focus is on the structural embeddedness of the focal firm and the interest is in the configuration of the network ties by integrating the supply and internal network together (dual embeddedness) by looking at structural characteristics of both. Similarly, in the second study, the focus is on the structural embeddedness of a buyer's network that includes the internal network while taking a complexity perspective.

3.2.1. Dual Embeddedness

In the international business literature, the term dual embeddedness (see Figure 1) refers to the simultaneous integration of a company into its internal and external network (Figueiredo, 2011; Meyer *et al*., 2011). Dual embeddedness studies examine mainly how local market knowledge can be obtained from external networks and dispersed within the MNC through the internal network of subsidiaries (Andersson *et al*., 2002; Meyer *et al*., 2011). Dual embeddedness is also defined as the dual linkages used by the firm to create capabilities to achieve better performance (Ciabuschi *et al*., 2014). It indicates that subsidiaries simultaneously sustain a positive relationship and efficient communication with both headquarters and local companies in host locations. In this way, the subsidiaries are able to tap into this network of local companies, in order to learn about expertise and customers and thus, seize local knowledge (Figueiredo, 2011). Then, they use their connectivity within the MNC's network to convey this knowledge. Subsidiaries have to be sufficiently close to the supply network within the local environment to generate knowledge access and inflows, and simultaneously be sufficiently close to the MNC's internal network for the knowledge to be successfully transferred and exploited through the MNC (Meyer *et al*., 2011). This may require physical proximity between the supply and internal networks.

Meyer et al (2011) have noted that there has been rarely any empirical research studying the simultaneous impact of internal and external network. Most studies have either examined the effect of external or internal network and it is, hence, unclear whether physical proximity and geographic dispersion simultaneously relate to firm performance. Despite the recognised importance of knowledge sharing in networks, the level of embeddedness of subsidiaries and its outcomes have not received much attention in the operations management literature. In contrast, the international business literature discusses internal integration and notes that greater internal integration creates opportunities for subsidiaries to learn from each other (Ghoshal and Bartlett, 1990; Gupta and Govindarajan, 2000) and thus creates potential further development.

The first study in this thesis, therefore, answers to the call for research on subsidiary dual embeddedness (Demeter *et al*., 2016) and does so by investigating the relationship between physical proximity with supply network and performance and the moderating effect of geographic dispersion of internal networks of a set of firms and their subsidiaries from the electronics industry.

From the dual embeddedness perspective, it has been shown that the parent company can shape the knowledge flows by carefully considering the subsidiaries in relation to both the external and internal networks (Achcaoucaou *et al.,* 2014). Thus, the role of the parent company in creating relational embeddedness of the subsidiary has been investigated in the past. In other words, the interplay between supply and internal networks has been recognized at the subsidiary-level. Previous studies have shown the performance benefits to the subsidiary of being simultaneously embedded in both networks (cf. Figueiredo, 2011; Achcaoucaou et al., 2014; Ciabuschi et al., 2014; Cenamor et al., 2019). These studies have focused on the relational embeddedness of each subsidiary in both the external and internal network. Demeter et al (2016) and Golini et al (2016) are the few studies that have applied an operations and supply chain management lens to dual embeddedness. Yet, the internal network of subsidiaries significantly complicates the operations of the MNC. Subsidiaries are located in countries with economic and social differences (Prahalad and Doz, 1987). They are also interdependent (Prahalad and Doz, 1987), which creates the need of integrating and coordinating the subsidiary network (Ghoshal and Bartlett, 1990). Thus, the impact of structural embeddedness of this overall subsidiary network has not been explored so far.

3.3. Complexity in SCs

Complexity theory has its roots in the natural sciences (Kauffman, 1995). It began as a tool for understanding non-linear dynamics in the natural sciences that were not well understood. Complexity theory contains new views about a type of system, referred to as Complex Adaptive Systems (CAS). Therefore, CAS may be considered a sub discipline of complexity theory. The ideas of CAS have been developed in the systems science literature (cf. Holland, 1995) and have roots in many disciplines such as biology and artificial intelligence. Models of CAS focus on the interplay between a system, the actors within that system, its environment, and the co-evolution of both the system and the environment. A complex system is characterized in terms of the nonlinear dynamic interactions of the entities of that system which stems from their extensive interconnectedness. These interactions may change over time in an unpredictable way. In line with this, CAS examines how changes in an individual actor's schema lead to different aggregated outcomes. In addition, CAS can be composed of actors that can themselves be characterized as smaller complex systems or a nested system of smaller-scale complexity (Pathak *et al*., 2007). From this perspective, CAS is a way of thinking and interpreting a network (i.e., a system) and its behaviour.

Choi et al (2001) have extended the concept of complexity to the supply chain management literature, where the ideas to model supply chains as CAS have been introduced, mainly because most suppliers are connected to numerous supply chains that ultimately generate diverse products serving heterogeneous, and often hard-to-predict, sets of consumers. Moreover, they examined a CAS, where three emphases became evident: an internal mechanism, an environment, and the co-evolution of both. In the SN, individual firms are actors and constitute the nodes in the network. In terms of environment and coevolution, any changes to a specific industry drive the suppliers to respond quickly and evolve. In addition, Pathak et al. (2007) discuss a CAS view of supply networks where suppliers are the entities that are interrelated in networks within a national or international context. In supply networks, schemas are the rules that the firms, or the decision makers within these firms, use to make the decisions for the firm, and guide its action. Moreover, calls for considering CAS principles in examining supply networks have increased as this perspective incorporates realism and empirical data into research models that can be understood in a practical business setting (Anderson, 1999; Pathak *et al*., 2007).

The concept of complexity has also attracted attention in a wide variety of academic fields. It is generally related to a system's characteristics and connections among members within that system. In social sciences, Simon (1962, pp. 468) defined a complex system as a system that is "made up of a large number of parts that interact in a non-simple way." In the organization theory literature, complexity has been treated as a structural variable that characterises both organizations and their environments. With regard to organizations, Daft (1989) associated complexity with the number of activities or subunits within the system, noting that structural complexity is typically measured in three different dimensions: horizontal, vertical, and spatial complexity (Daft, 1989; Anderson, 1999; Daft, 2006; Walsh and Dewar, 1987). Horizontal complexity corresponds to the number of entities in the same level, vertical complexity refers to the number of levels in the system, and spatial complexity refers to the number of operating locations or sometimes, the degree of dispersion among entities within the system. With regard to environments, complexity is associated with the number of different systems or elements that should be dealt with simultaneously by the organization (Walsh and Dewar, 1987). Organization design aims to coordinate the complexity of an organization's structure with the complexity of its environment (Galbraith, 1973). In line with this, many authors (Daft, 1989; Andersson, 1999) suggested that these internal and external systems behave in a nonlinear way and potentially achieve strategic fit through their co-alignment (Lin *et al*., 2016). Similar to these definitions, Bozarth et al (2009) identified two dimensions of complexity: detail and dynamic. They defined the former (also called structural or static complexity) as the distinct number and variety of elements defining the system (Bozarth *et al*., 2009; Campos *et al*., 2019). The latter is dynamic or operational complexity and is defined as the uncertainty or unpredictability of a system triggered by the interactions between the elements of that system (Bozarth *et al*., 2009; Campos *et al*., 2019). In practice, these aspects are often closely interrelated, because the larger the number of varied elements, the greater is the possible number of interactions and thus the variety of behaviours and states the system may exhibit. This is particularly true in supply chain networks.

Choi and Hong (2002) transferred the notion of structural complexity from the organization theory literature and applied it to the supply chain context, where it has been frequently discussed and studied (Bode and Wagner, 2015; Bozarth *et al*., 2009; Brandon-Jones *et al*., 2015), they proposed that horizontal complexity refers to the number of suppliers, vertical complexity refers to the number of tiers, and spatial complexity corresponds to the extent of the dispersion among entities within the network (i.e., geographic distance between a focal firm and its suppliers).

Supply network complexity has been shown to adversely influence performance through cost, quality, delivery time, and frequency of disruptions (Bode and Wagner 2015; Bozarth *et al*., 2009; Brandon-Jones *et al*., 2015; Craighead *et al*., 2007; Larsen *et al*., 2013; Mizgier *et al*., 2015). The findings of these aforementioned studies show that as complexity increases, buyers and suppliers find it more difficult to coordinate their supply network and hence, the supply network performance, characterized by the ability of the network to satisfy customer requirements, suffers.

Complexity is a critical characteristic of buyers' networks too. Downstream complexity arises from the supplier's connections with downstream partners. An example would be a supply chain with multiple downstream demand points that independently place orders from a supply point without regard to supply constraints or the needs of other demand points. Structural dimensions are considered to increase buyer network complexity because of the greater number of information, data, and variability (products, requirements, culture, language, etc.) that should be considered to manage the downstream buyer network both effectively and efficiently (Bozarth *et al*., 2009; Patatoukas, 2012; Kim, 2017). Different types of buyers are also more likely to vary with regard to competition on orders and order winners, creating the potential for conflicting manufacturing tasks, lower levels of manufacturing performance (Bozarth and Edwards, 1997; Bozarth and McCreery, 2001), and potential misalignment between manufacturing capabilities and customer needs (Bozarth and Berry, 1997; Da Silveira, 2005).

Drawing on organization theory and supply network research, the following complexity measures can be derived for the downstream network in this dissertation's second study: the number of buyers as horizontal complexity of the focal firm, the tiers of subsidiaries of each buyer as vertical complexity and the geographic dispersion of buyers as spatial complexity. Furthermore, an additional layer of horizontal complexity is considered in a way that it includes the number of subsidiaries of each buyer, representing the overall horizontal complexity of the buyers' networks. In a similar manner, the additional layer of spatial complexity accounts for the geographic dispersion of subsidiary units of each buyer. In line with this, the International Business literature (Nell and Andersson, 2012; Achcaoucaou *et al*., 2014) has tended to emphasise on the importance of this additional structure of subsidiaries as it participates heavily in activities within the parent company network (which is in this paper, the buyer network) and builds strong and interdependent relationships with the business partners i.e., customers and suppliers. This could form much more complexities at the supplier level that are ignored in the past literature.

Besides, while there is an established literature on supply chain complexity (Choi and Krause, 2006; Bozarth *et al*., 2009; Bode and Wagner, 2015; Adhikary, 2020) and the relevance and importance of buyer networks is known (Kim, 2017; Patatoukas, 2012; Jhang *et al*., 2021), all these previous studies examined only the effects of *supply* networks' structural complexity (See Table 18 in Appendix A) on manufacturing performance (Bozarth *et al*., 2009), financial performance (Lu and Shang, 2017), innovation performance (Sharma *et al*., 2019), environmental performance (Adhikary, 2020) of buyers, and frequency of supply chain disruptions (Bode and Wagner, 2015).

Bode and Wagner (2015) found that all three complexity dimensions (horizontal, vertical, and spatial) positively impact the frequency of disruptions. Lu and Shang (2017) found that an individual complexity dimension can have both positive and negative effect on financial performance and the overall effect depends on the magnitude of the complexity dimension itself. Sharma et al (2019) studied the impact of these dimensions on focal firm innovation and, in line with Lu and Shang (2017), they found strong support for the nonlinear effects with the declining returns of an increased supply network complexity and innovation performance. Although Bozarth et al (2009) included downstream complexity in their study and showed that upstream complexity, internal manufacturing complexity, and downstream complexity all have a negative impact on manufacturing plant performance (operational and market-based), their consideration of downstream entities did not encompass the internal dimension which relates to the internal network of subsidiaries of these buyers.

Nonetheless, other stream of researchers suggested some benefits of complexity; for instance, Gimenez et al (2012) argued that high supply chain complexity leads to an improvement in performance through different dimensions of supply chain integration, supply chain practices, patterns, and attitudes. Furthermore, the results of Wiedmer et al (2021) show that supply complexity is both detrimental and beneficial, such that it can intensify the disruption impact, but it can also enhance a recovery from a disruption. Some of the structural dimensions in the network such as structure and complexity may enhance flexibility and redundancy (Sheffi and Rice, 2005). A higher structural network complexity essentially involves a higher number of nodes, arcs, or flows in the network (Choi and Hong. 2002), thus, an increase in buyer network size provides the supplying firm with an enhanced understanding of its buyers. Moreover, in the sales literature, studies showed that buyer complexity increases the motivation of salespeople as they believe that they are personally responsible for work outcomes and encourages them to think and behave in specific ways (Coelho *et al.*, 2011), this, in turn, leads to an increase in the sales performance (Schmitz and Ganesan, 2014).

The second study investigates the different effects of buyer network complexity dimensions on supplier performance. The reasoning is that supplier performance is influenced by the adaptive behaviour set in motion due to complexity-related factors in its buyer network as well as its buyer's *internal* network. The extant literature lacks clarity regarding the magnitude of these factors buyer network complexity does that. By means of this study, the aim is to address this gap. Therefore, supply chain complexity is empirically examined at the downstream level.

Similarly, these dimensions are transferred from the organization theory into the buyer network which would entail the number of buyers as horizontal complexity of the focal firm, the number of tiers of subsidiaries of each buyer as vertical complexity and the geographic dispersion of buyers as spatial complexity. An additional layer of horizontal complexity is considered in a way that it includes the number of subsidiaries of each buyer, representing the overall horizontal complexity of the buyers' networks. In a similar manner, the additional layer of spatial complexity that accounts for the geographic dispersion of subsidiary units of each buyer.

To sum up, although structural complexity has been highly investigated in the supply chain management literature, the important insights derived from prior research has overlooked the downstream side. Thus, there is a need for an understanding of network complexity at the demand side (Wiedmer *et al.*, 2021).

3.4. SN Characteristics and Performance

This section discusses a few empirical studies examining the influence of network characteristics on operational, financial, and innovation performance, which are the main performance measures[3] examined in this dissertation.

The relationship between network characteristics and firm performance has been the subject of extensive discussions in the supply chain management literature. In a complex and dynamic environment such as supply chains, even simply buyer-supplier dyad with fundamentally basic information and material flow, tend to reveal operational complexity and eventually impact both firms' operational and financial performance (Manuj and Sahin, 2011; Kim, 2014; Lu and Shang, 2017). Understanding the architecture and characteristics of the supply network is important as it influences the operational efficiency and financial advantage of a buying firm in several ways. Likewise, understanding the customer network and its characteristics is as important as it influences the sales benefits, the operational performance, and the profitability of the supplying firm (Kim, 2017).

[3] Please see Table 19 for a review on the main performance measures used in the SC literature.

Voss et al (1997, pp. 1048) define operational performance as "the measurable aspects of the outcomes of an organization's processes, such as reliability, production cycle time, and inventory turns. Operational performance in turn affects business performance measures such as market share and customer satisfaction."

Financial performance measures the firm's ability to use its assets and resources to generate revenues (Lu and beamish, 2001; Lanier *et al*., 2010).

Basole et al (2018) suggest that supply networks that are appropriately managed and designed can be associated with significant improvements in firm operational performance. They show that structural prominence, which depicts the firm's centrality in the supply network, and density which characterizes the interconnectedness among firms in a supply network, positively influence operational efficiency. Other studies show evidence that higher geographic dispersion of the upstream and downstream supply chain results in decreased operational performance, which is translated by increased costs of logistics, as well as a dip in service performance (Bozarth *et al*., 2009; Lorentz *et al*., 2012). Kim (2014) shows evidence that understanding supplier positional advantage improves the buying firm's operations and operational performance. In other words, they show that operational benefits are subject to the buyer's capability to recognize and understand with whom its suppliers are doing business and how well these suppliers are located in the network to obtain novel information and access innovative ideas.

Building on prior findings in the literature regarding the buyer's operational advantages of embedded relationships, Kim and Henderson (2015) demonstrated financial benefits of the customer's dependency as well as the supplier's dependency that accrue to the focal firm. Lu and Shang (2017) assert that supply base structure significantly influences buyers' financial performance, and they found that complexity in supply networks does not always hurt firm performance. Lanier et al (2010) show that firms in concentrated supply chains jointly achieve superior financial performance, but the excess is captured largely by the buyers located at the downstream side such as retailers.

These studies provide some examples of research done on network characteristics and their impacts on operational performance as well as on financial performance. Nevertheless, firms are embedded within networks of customers and suppliers with which they do not only exchange products and services, but also data, and information (Yan *et al*., 2019; Kumar *et al*., 2020). All these exchanges are potential sources of innovation.

Innovation in the products and services offered by a firm does not originate exclusively from activities within the boundaries of the firm. Rao (2018) state that up to 65% of innovation is driven by suppliers. Supply network actors do not just supplement internal innovation efforts. In fact, the stock of knowledge that is available through the firm's supply network should be aligned with internal research and development strategies in order to gain superior innovation performance (Narasimhan and Narayanan, 2013). In line with this, SC scholars have proved that firms rely on their supply networks to improve their innovation performance (Sharma *et al*., 2019). Azadegan and Dooley (2010) suggest that firms can gain from the innovativeness of their supplier to enhance their cost, quality, product development, delivery, and flexibility performance. The structure of a supply network has been linked to the innovations (in terms of patents) produced by a focal firm (Bellamy *et al*., 2014). Besides the structural characteristics of the network, other factors such as partner technological diversity also impact the innovative efforts of firms (Gao *et al*., 2015). Carnovale and Yeniyurt (2015) examined the impact of network structure, focusing on the various dimensions of betweenness, density, brokerage, and weakness on the innovation performance of the supply network. They found support for the argument that innovation in a supply chain is highly dependent upon the network structure of the interfirm relationships. Furthermore, recent studies have started to uncover how, and which structural characteristics of supply networks can influence the generation of innovation output (Potter and Wilhelm, 2020). Most studies in this field focused on suppliers degree centrality in the supply network and innovations generated by firms (Gao *et al*., 2015; Chae *et al*., 2019). Potter and Wilhelm (2020) found that supplier degree centrality has a positive effect on the co-development of supplier–supplier innovations within a supply network setting. In another stream of literature, researchers investigate supplier involvement with the focal firm as the route to innovations. Roy et al (2004) show that the interactions between buyers and suppliers are a key driver of innovation. The geographical locations of supplier plants also matter as a catalyst for these interactions. Chu et al (2019) found a positive association between buyer-supplier geographic proximity and supplier innovation, while Sharma et al (2019) found that geographic dispersion between buyers and suppliers negatively affect innovation performance. The primary focus of this line of research on innovation has been on understanding the value of managing a supply network for firm innovation performance and implications.

While a network perspective is increasingly permeating to explore performance related subjects due to networks and their characteristics, there is still a lot to be done on supply chain networks (Kim, 2017; Chae *et al*., 2019; Son *et al*., 2021).

Chapter 4: Hypothesis Development and Methodology

Study 1

4.1. Interrelation of SNs and INs

Supply chains are comprised of networks that consist of not only the direct ties of the focal firm to each of its supply network partners such as suppliers and customers, but also of the ties to the subsidiaries that form the internal network of the focal firm (Demeter *et al.*, 2016). Although the firms in the supply chain are now starting to look towards their suppliers as additional sources of flexibility and improvement, their performance could be improved by their internal capabilities (Yan *et al.*, 2019).

Supply networks have, therefore, gained considerable attention but, to date, no empirical studies have considered the interaction of the supply network of the firm and its internal network of geographically dispersed subsidiaries.

Demeter et al (2016) pointed at an unresolved issue concerning the unknown complementarities through which the internal network interrelates and interacts with the overall supply network. They also stated that no prior research study has recognized the case where both internal and external networks are considered as an integrative system rather than as separate parts.

These arguments suggest that the interaction between the supply network of the firm and its internal network should be investigated. Given that focal firms are embedded in these two distinct networks, it is important to consider both networks when studying the performance of a buying firm.

On one hand, extending a company's supply network to dispersed geographic locations is commonly perceived as a managerial decision to improve sourcing performance (Demeter, 2013). When focal firms rely on geographically dispersed suppliers, the relationship with them needs extensive coordination efforts and reaching them as fast as possible has become an essential and valuable strategy (Droge *et al.*, 2004). Previous research has discussed how supply chain proximity or collocation enhance the firm's ability to provide better customer service, control the flow of material and better coordinate plans to be responsive to demand fluctuations (Narasimhan and Nair, 2005).

While global supply chains enable the integration of a global portfolio of suppliers, they also allow to integrate geographically dispersed internal processes to gain advantages of diverse location benefits.

On the other hand, extending a company's subsidiary network to dispersed geographic locations is commonly viewed as a way to strengthen the competences of the company and reach high performances (Tsai, 2001). As a consequence, multinational companies (MNCs) operate international networks of subsidiaries that are dispersed around the world (Ghoshal and Bartlett, 1990). The reason for their existence is their ability to transfer, recombine, and exploit resources through several contexts and between countries (Meyer *et al*., 2011).

Other scholars suggested that globalization increases the complexity in networks they are being exposed to several risks when being globally spread (Bozarth *et al*, 2009; Bode and Wagner, 2015).

Although it is intuitive that supply networks and internal networks are likely to have impacts on firm performance, most of the evidence that we have seen in the literature do not include the complexity of internal networks. The question of how the supply and internal network cumulatively and in relation to each other affect firm performance has been overlooked so far. Therefore, it is essential to improve our understanding of the interaction of the supply network and the internal network of geographically dispersed subsidiaries and establish whether proximity to suppliers and geographic dispersion of internal operations have an influence on the overall performance of the focal firm in the network. Please see Model in Figure 4: the internal network is captured through its geographical dispersion (Stock *et al.,* 2000; Lorentz *et al*., 2012) and the focal firm-supplier links are captured through the physical proximity (Narasimhan and Nair, 2005; Bray *et al.*, 2019) of the suppliers with the focal firm, including their subsidiaries.

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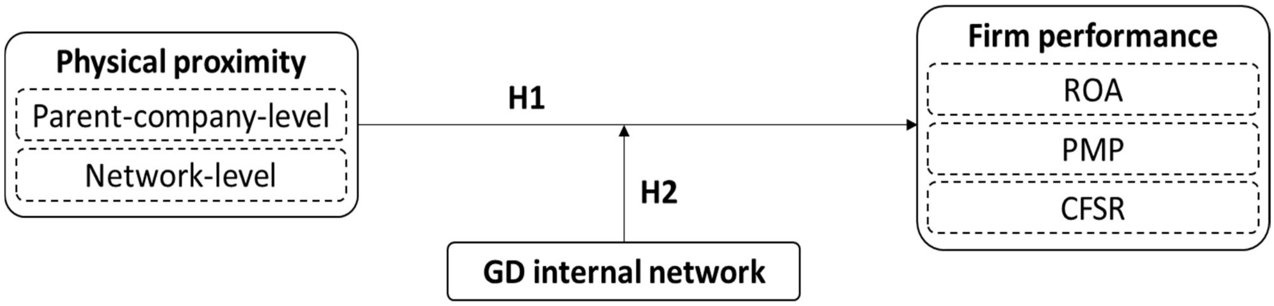


Figure 4: Research Model 1

4.2. Hypothesis

Physical Proximity

Physical proximity to suppliers has been widely regarded as an effective way to improve buyer performance (Narasimhan and Nair, 2005; Dou *et al*., 2018). Buyers prefer nearby suppliers and consider proximity to be the third most important rationale behind facility location after market entry and personnel cost (Berking *et al*., 2016). Narasimhan and Nair (2005, pp. 304) defined supply chain proximity as “the physical closeness of the buying and supplying firm” and proved that it is positively associated with the formation of a strategic alliance program and firm performance. The distance between the buyer’s and supplier’s facilities is particularly detrimental when they are located in different countries (Bray *et al.*, 2019).

Physical proximity to suppliers enhances the ability of the focal firm to provide superior customer service, allows for better control the flow of materials and improves the coordination of production schedules to be more responsive to changes in demands (Narasimhan and Nair, 2005; Dou *et al*., 2018). The physical closeness of buyers and suppliers allows to monitor suppliers more easily and to lower monitoring costs (Cousins *et al.*, 2008; Bray *et al.*, 2019). It also facilitates the development of local norms and makes it easier for companies to acquire information about the supplier’s plants (Dou *et al*., 2018). It provides a chance to develop or improve the relationship with the supplier leading to an adaptation of the product design to co-create solutions to problems, or even co-design when developing new components for the local environments as well as reduce product defect rates (Bray *et al*., 2019). Geographic proximity to suppliers reduces the need to use internal firm assets when production materials and/or facilities are at the same location as is the case for automobile and phone makers, for instance. These advantages operate as incentives as well as financial rewards to the firms.

Physical proximity of buyers and their subsidiaries to their suppliers and the suppliers' subsidiaries, in a given country, facilitates a deeper understanding of that country. For example, this mechanism allows these companies and their subsidiaries to search deeply and understand the relevance of new technologies for problem-solving (Alcácer and Zhao, 2012). This proximity increases the opportunities for identifying technologies that are not always apparent to the firms and helps them improve their knowledge. Since firms with strong ties can better assimilate external knowledge with internal technologies (Alcacer and Zhao, 2012), proximity enables a subsidiary to achieve the focus required to integrate external knowledge into the parent company's routines and technologies, to accelerate organizational learning and to leverage the benefits of proximity to improve the firm's financial performance. In addition, a local partner is likely to have more in-depth information about several features of the host country environment, in comparison with other partner options. Local partners are familiar with the requirements and concerns of the local customers, have the appropriate information about local competitors and have the local links to contacts that can offer timely information.

Altogether, being close to a supplier, whether at the parent company or the subsidiary-level, can reduce local knowledge deficiencies, help to identify suitable solutions, and increase the essential astuteness to propose solutions and strategies that can be effectively and rapidly developed and implemented. This, in turn, can improve the financial performance of the firm. All of the aforementioned studies seem to agree on the positive effects on firm performance. Therefore, this study hypothesizes the following:

Hypothesis 1: There is a positive relationship between physical proximity of internal and supply networks and financial firm performance.

Geographic dispersion

While the previous hypothesis focuses on the relationship between the supplier and buyer, including their networks, this section focuses on another issue. It is not only the structure of supplier network that matters, a point that has received significant attention in supply chain literature (Choi and Hong, 2002; Bode and Wagner, 2015; Lu and Shang, 2017) but also the internal network of the focal firm itself. Firms that manage a large number of suppliers, with whom they have physical proximity are likely to experience lower financial benefits when their internal network of subsidiaries is geographically dispersed. In other words, leveraging the benefits of close physical proximity to the supply network may be less effective in terms of financial performance when it requires a widely dispersed geographical network of subsidiaries.

Geographic dispersion is strongly associated with the spatial complexity of the network which has been defined by Bode and Wagner (2015) as the extent of the dispersion among members within the network. O'Leary and Cummings (2007) suggest that geographic dispersion has generally been defined in spatial terms, drawing on measures that take into consideration physical distances, number of countries, sites, or locations. Network complexity may cause lower network performance because it increases the interdependence among firms, which, in turn, leads to a higher need for coordination, conflicting goals, and trade-offs that are not easily resolved (Giannocaro *et al*., 2017). A high degree of complexity in the internal network may cause high levels of risks and/or costs for firms when they consider maintaining or further increasing the relation to specific investments, i.e., embeddedness (Manuj and Mentzer, 2008). Given that these studies consider the focal firm as a single entity, the complexity of the internal network is not considered yet.

In this study, the geographically dispersed internal network of the focal firm captures this internal complexity that is unrecognised when studying network complexity. The dispersed internal network of subsidiaries significantly complicates the operations of the MNC as well as the overall coordination of material and information flows with suppliers. Bausch and Krist (2007) indicated that the ability to manage complexity is a key success feature. Higher levels of physical proximity therefore contribute positively to firm performance only if there is no high internal complexity. This implies that companies should appropriately manage internal systems while being able to deal with external networks to enable performance benefits. In line with this, the study hypothesizes the following:

Hypothesis 2: The geographic dispersion of the internal network negatively moderates the relationship between physical proximity and financial firm performance.

4.3. Methodology

4.3.1. Data

The main purpose of this study is to understand how the supply and internal networks collectively affect firm performance. For this reason, the sample for this study was drawn from the electronics industry, which is composed of large MNCs that make use of global internal networks of subsidiaries as well as global supply networks (Bellamy *et al.*, 2014). In addition, the electronics industry faces short product lifespans and high market unpredictability (Sodhi and Lee, 2007), which increases the pressure to work closely with suppliers and to deploy their technology to continually offer new product and process innovations that add value (Bellamy *et al.*, 2014). Thus, the internal and supply networks in the form of subsidiary structures and supply chain structures in the electronics industry are found to be a suitable research context to investigate the network-level implications for firm performance. The network-level factors are captured through the analysis of physical proximity and geographic dispersion of those two networks in the context of dual embeddedness.

This study builds on a supply chain dataset of 100 public buying firms (focal firms) from the electronics industry, 5,028 suppliers, 23,228 buyers' subsidiaries and 243,216 suppliers' subsidiaries spanning across 139 countries. Large and public manufacturing firms were identified in Orbis, based on a market capitalization above $6bn and based on their primary business Standard Industry Classification (SIC) code of either SIC 35 (Industrial and Commercial Machinery and Computer Equipment), or SIC 36 (Electronic and other Electrical Equipment and Components (except Computer Equipment)). In total, 104 companies that matched the outlined criteria were obtained. The supply networks of these 104 focal firms were identified using FactSet, which is a global database that collects interfirm relationship data from primary public sources such as investor reports, SEC 10-K annual filings and press releases. Both the relationships disclosed by the company as well as reverse relationships which are reported by their suppliers are included in the database. For all companies, focal firms and suppliers, the subsidiary information was collated from Orbis. Data on the geographic location of the focal buying firms, its subsidiaries, its identified suppliers, and their subsidiaries were retrieved and collected from Orbis as well as the data for the dependent and control variables for each focal firm. In the data collection process, four focal firms were dropped from the sample due to missing data which resulted in a final sample of 100 firms with their internal and external networks.

4.3.2. Dependent Variables

The dependent variables for this study are chosen from among firm-level financial performance measures. Financial performance is frequently used as a proxy in supply chain research (cf. Stock *et al*., 2000; Hendricks and Singhal, 2005; Lanier *et al*., 2010; Kim and Henderson, 2015; Lu and Shang., 2017) as it allows to assess a firm based on factors outside of the firm's boundaries (Stock *et al*., 2000) that are externally observable and have been validated in the course of the annual audit processes. Moreover, it represents the ultimate bottom line of firm performance in terms of value captured from creating and delivering products and services less cost incurred to do so. While previous papers have addressed the implications of embedded relationships with supply chain partners based on innovation and product development measures (cf. Bellamy *et al*., 2014; Kim, 2014), operations-related measures (cf. Stock *et al*., 2000; Bray *et al*., 2019), market-based measures (cf. Narasimhan and Kim 2002, Kim, 2014), or financial measures (cf. Kim and Henderson, 2015; Lu and Shang, 2017), no study has investigated the firm's financial implications of dual embeddedness into supply and internal networks so far.

More specifically, in this study, three ratios were used to assess the financial performance implications for the focal buying firm: Return on Assets (ROA), Profit Margin Percentage (PMP) and Cash Flow to Sales Ratio (CFSR). ROA, measured by net income as a percentage of total assets, is one of the most frequently used performance measures in studies on firm internationalization (Bausch and Krist, 2007, Please see Table 17 in Appendix A). It considers fixed as well as current assets to support business activities and highlights the profit generated from these assets. Therefore, ROA is an indicator of how profitable an operation is relative to its total assets. PMP, measured by net income as percentage of operating revenue, is a frequently studied efficiency measure in the supply chain context (see, for example, Choi and Hong, 2002). It allows to assess a firm's ability to control its costs at a given level of sales (Lanier *et al.,* 2010). Lower costs due to more efficient internal operations or improved supply chain efficiency allows for higher profit margins and thus increased PMP. Lastly, CFSR, measured by cash flow as a percentage of operating revenue, has been adopted in studies assessing the financial state of a firm and its valuation (Rujoub *et al.,* 1995; Dickinson, 2011). It refers to a firm's ability to turn sales into cash, after paying for operating expenses and capital expenditures, which can be used to expand operations, reduce debt and/or to pay dividends. Lower CFSR can indicate high capital expenditures, increasing receivable volumes, or increasing overhead cost.

4.3.3. Independent Variables

One of the central independent variables for this study is the physical proximity between a focal firm and its suppliers. The physical proximity was measured in two ways. In the first case, similar to past network-level supply chain research (Bray *et al.,* 2019), the internal networks of subsidiaries for the focal firm and its suppliers were ignored. Thus, the measure in this case was computed as follows: it is the fraction of suppliers being located in the same country as the focal firm at the parent company level only. In the second case, the measure was computed differently: it is the fraction of suppliers being located in the same country as the focal firm including the internal networks of subsidiaries for the focal firm and its suppliers in addition to their parent companies. This resulted in the two following proximity measures P_j (note that superscript 1 denotes the parent company level while superscript *N* denotes the network-level):

$$P_j^1 = \frac{\sum_i s_{ij} x_{ij}}{\sum_i s_{ij}}$$

where s_{ij} denotes supplier i of the focal buying firm j and x_{ij} is a binary variable that is 1 if parent company of supplier i is located in the same country as the parent company of the focal buying firm j, and 0 otherwise.

$$P_j^N = \frac{\sum_i \sum_k s_{ijk} x_{ijk}}{\sum_i \sum_k s_{ijk}}$$

where s_{ijk} denotes entity k (including parent company and subsidiaries) of supplier i of the focal buying firm j and x_{ijk} is a binary variable that is 1 if entity k of supplier i is located in the same country as an entity (parent company or subsidiaries) of the focal buying firm j, and 0 otherwise.

4.3.4. Moderating Variables

Next, the geographic dispersion of the focal firm's internal network incorporating both, the breadth and depth was derived following Stock et al. (2000) and Lorentz et al. (2012). The breadth of the buyer's internal network is measured by the number of foreign countries in which the buyer has at least one subsidiary, whereas the depth of the buyer is captured by the total number of subsidiaries per foreign country. These two measures allow to calculate the percentage of subsidiaries in each country. The geographic dispersion was afterwards obtained as:

$$D_j = 1 - \frac{\sum_n \left| c_{jn} - \frac{1}{N} \right|}{2\left(1 - \frac{1}{N}\right)}$$

where c_{jn} denotes the fraction of subsidiaries of focal firm j located in country n and $N = 139$ is the number of countries considered in this study. The geographic dispersion measure ranges from 0 to 1. A value of 0 or close to 0 implies that the internal network is entirely concentrated in a single country, whereas a value of 1 or close to 1 implies an evenly spread internal network across all 139 countries.

4.3.5. Control Variables

Finally, firm size, firm age, and number of suppliers were included as the control variables for the focal buying firm. Firm size is measured as the natural logarithm of the number of employees (Chae *et al.*, 2018) and was included for three reasons: First, past literature provides evidence of a positive association between firm size and financial performance (Lanier *et al.*, 2010). Second, it is more likely that larger firms tend to have a higher physical proximity intensity with their suppliers and a wider geographic dispersion of their internal networks than smaller firms. Third, firm size is likely to influence the buyer's tendency to engage in visits and socialisation with suppliers that suggest capitalizing on supply chain proximity (Cousins *et al.*, 2008). Firm age was measured as the difference between the year of foundation and the year of the data collection, it was included to account for knowledge and experience gained over time. Long-established firms may have a better understanding of how to utilize their supply network as well as their internal network of subsidiaries and how to derive valuable information from them over the years. Therefore, their experience is an important way for them to learn how to operate in foreign markets (Rosenkopf and Almeida, 2003). Lastly, the firm's number of suppliers was considered. A firm with more suppliers is more likely to be flexible with regard to supplier switching and to make use of redundancy in case of disruptions which may result in better financial performance (Lu and Shang, 2017). Also, a firm with more suppliers is likely to have a higher degree of proximity of its internal and supply networks allowing for improved access to information and resources which is more likely increase the financial performance in the long run (Demeter, 2013).

4.3.6. Analysis

Multilevel hierarchical regression was employed to test the hypotheses using version 25.0 of SPSS (IBM Corporation, 2015). The first assumption is normality, that assumes that scores on the dependent variable are distributed normally. Visual examination of data plots and histograms are usually used to check for normality. The second assumption is linearity, which assumes that the dependent variable is a linear function of the independent variable. Linearity can be assessed by scatterplots and regression analysis. The third assumption of multiple regression is independence, which assumes that one variable's error is independent of another variable's error. Independence can be assessed through examination of residual plots. The fourth assumption is homoscedasticity, which assumes that the variance is constant across all levels of the predicted variable. This can be tested by a scatterplot of residuals versus predicted values. See Appendix A to view the histograms for each variable. As shown, the visual inspection of the histograms appeared to meet the normality assumption; however, in some case, the histograms show that the normality assumption could be violated due to the skewness, therefore, a logarithmic transformation was used (Wooldridge, 2010). Also, there was an inspection to see whether any outliers exist in the data, however, after removing some extreme values that were suspected to act as outliers, the results remain unchanged.

Moreover, a visual inspection of the scatterplot of residuals versus predicted values were analysed in order to check for homoscedasticity. While some of the data points appeared to have more variability than others, there did not appear to be an overall pattern. Therefore, these results suggest that homoscedasticity is not violated, as the variability of the residuals must be robust to violate this assumption. See Appendix A to view the residuals histograms and scatterplots for all variables of the three studies.

Table 1 presents the descriptive statistics for the variables: description, mean and standard deviation; Table 2 includes the models' specifications that explain the different models of Figure 4 and Table 3 shows the correlation values for all the study variables. A multicollinearity diagnosis for the sample is conducted. Multicollinearity is another assumption of multiple regression, if it is present, this means that there are correlations between two or more of the independent variables, which could lead to problems interpreting which independent variable is contributing to the variance explained in the dependent variable. Multicollinearity can be assessed by Tolerance or Variance Inflation Factor (VIF) values for all variables of the three studies presented in Table 20 of Appendix A. To reduce the concern of multicollinearity, in line with established procedures, especially in the presence of interaction terms, related variables were mean centered before calculating the proposed interaction term that is used to test the hypotheses (Aiken and West, 1991). Then, the VIFs for each independent variable were assessed to determine the significance of multicollinearity among them; VIF values are well below the commonly agreed threshold of 10. Therefore, multicollinearity should not be a major issue for further analysis.

A multilevel hierarchical regression analysis was used to test the hypotheses, three models were constructed as follows: first, Model 1 is constructed, which is the baseline model, by only including the control variables. Second, the main effect variables were added to Model 1 to construct Model 2. Finally, the proposed interaction term was added to Model 2 to construct Model 3.

To test for the interaction effect between physical proximity and geographic dispersion, the product terms were computed by multiplying the centred geographic dispersion scores by the centred physical proximity scores. Therefore, non-essential collinearity is reduced by centring the scores around the mean before computing the product terms.

Table 1: Description, mean and SD of all variables of Study 1

Variable	Description	Mean	SD
Firm size	Number of employees	73156.32	103057.884
Firm age	2019 - Founding year	52.1	42.6547
Nbr of suppliers	Number of suppliers	50.28	63.180
P_j^1	Physical proximity at the parent company level	0.38242	0.2485
P_j^N	Physical proximity at the network-level	0.8001	0.2072
D_j	Geographic dispersion of subsidiaries	0.1912	0.1111
ROA	Return on asset	10.618	8.953
PMP	Profit Margin percentage	15.467	12.985
CFSR	Cash flow as percentage of sales	18.1724	14.014

Table 2: Models Specification of Study 1

	Variables	Level
Model 1	P_j^1, D_j, P_j^1 x D_j, ROA	Parent-company-level
Model 2	P_j^N, D_j, P_j^N x D_j, ROA	Network-level
Model 3	P_j^1, D_j, P_j^1 x D_j, PMP	Parent-company-level
Model 4	P_j^N, D_j, P_j^N x D_j, PMP	Network-level
Model 5	P_j^1, D_j, P_j^1 x D_j, CFSR	Parent-company-level
Model 6	P_j^N, D_j, P_j^N x D_j, CFSR	Network-level

Table 3: The correlations for all the study 1 variables.

No	Variable	1	2	3	4	5	6	7	8	9
1	Firm size	1								
2	Firm age	.343**	1							
3	Nbr of suppliers	.582**	.264**	1						
4	P_j^1	-.424**	-0.143	-.215*	1					
5	P_j^N	0.194	.310**	.214*	0.085	1				
6	D_j	.309**	.382**	.281**	-0.179	.502**	1			
7	ROA	-.295**	-.200*	-0.106	.197*	-0.020	-.202*	1		
8	PMP	-.357**	-.294**	-0.112	.240*	-0.008	-.283**	.851**	1	
9	CFSR	-.371**	-.275**	-0.133	0.167	-0.062	-.267**	.563**	.736**	1

** Pearson correlation coefficients significant at p =0.05 level*
*** Pearson correlation coefficients significant at p =0.01 level*

4.3.7. Results

The results are presented in Table 4. As explained earlier, physical proximity was measured using two different variables and a multiple linear regression was ran for each of them separately for the three considered financial performance measures (as illustrated in Table 2).

The results do not support a significant positive relationship between the physical proximity of supplier and internal networks and firm performance for either one of the two physical proximity measures. Therefore, hypothesis 1 is not supported.

As for the moderating effect of geographic dispersion on the relationship between physical proximity and financial performance, the results varied across the proximity measures and performance variables. Geographic dispersion of the buyer's internal network negatively moderates the relationship between physical proximity at the parent company level and the firm's profitability relative to its assets, i.e., the relationship between variables P_j^1 and ROA ($\beta = -61.888$, $p < .05$). Geographic dispersion of the buyer's internal network also negatively moderates the relationship between physical proximity at the network-level and the firm's ability to generate cash from sales, i.e., the relationship between variables P_j^N and CFSR ($\beta = -107.399$, $p < .05$). The results did not support this moderation effect of geographic dispersion for the relationship between physical proximity, either at the parent company level or the network-level, and operating efficiency of the focal firm as measured by its profit margins. Thus, the results only show partial support for hypothesis 2.

Table 4: Hierarchical regression for the interaction effect between physical proximity and geographic dispersion on performance

	ROA		PMP		CFSR	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Control Variables						
Firm size	-4.73 (2.35)	-5.56** (2.22)	-9.30** (2.59)	-9.71** (2.38)	-10.495** (3.59)	-10.81** (3.29)
Firm age	-0.024 (0.023)	-0.023 (0.023)	-0.03 (0.025)	-0.037 (0.026)	-0.047 (0.034)	-0.053 (0.034)
Nbr of suppliers	0.017 (0.017)	0.017 (0.017)	0.022 (0.018)	0.022 (0.018)	0.036 (0.026)	0.036 (0.025)
Intercept	32.49** (10.26)	36.95** (9.70)	54.78** (11.28)	57.65** (10.37)	66.89** (15.67)	69.99** (14.36)
Predictor Variables						
D_j	-11.65 (8.70)	-10.64 (9.91)	-2.99 (9.58)	-4.83 (10.61)	-20.39 (13.29)	-17.92 (14.67)
P_j^1	0.67 (3.94)		1.75 (4.34)		-1.46 (6.02)	
$P_j^1 \times D_j$	-61.89** (30.86)		-35.69 (43.25)		-38.74 (47.12)	
P_j^N		3.14 (5.46)		2.623 (5.83)		1.95 (8.07)
$P_j^N \times D_j$		-40.99 (41.06)		-60.24 (43.89)		-107.40** (60.75)
R^2	15.70%	13.80%	22.50%	25.0%	19.80%	22.90%
Adjusted R^2	10.30%	8.20%	17.50%	20.10%	14.60%	18%
F statistic	2.895**	2.471**	4.457**	5.110**	3.832**	4.614**
Change in R2 related to moderator	3.60%	0.90%	0.10%	1.50%	0.60%	2.60%
F statistic for change	4.021**	0.997	0.681	1.858	0.676	3.126*
N	100	100	100	100	100	100

** *p<0.05*
* *p<0.10*

Figures 5 and 6 provide a closer look at the two significant results. In Figure 5, the supply network is captured in the way it has traditionally been captured by past research, in that, it considers the relationship between the focal firm and the supply network at the parent company level (Bray *et al*., 2019). In this case, when the geographic dispersion of the internal network of the buying firm is high, ROA is much lower when the firm has a high level of physical proximity to its supply network as compared to the case of a low level of physical proximity (ΔROA = 8.97). On the contrary, for firms that have a low level of geographic dispersion, the drop in ROA is much lower as their physical proximity to suppliers increases, with ΔROA = 2.13.

Figure 6 shows the results when the focal firm's internal network of subsidiaries as well as the suppliers' subsidiaries are considered. In this case, when the geographic dispersion of the internal network of the focal firm is high, the drop in CFSR is much higher when there is high physical proximity to its supply network as opposed to when there is low physical proximity (ΔCFSR = 12.05), as compared to the case of low geographic dispersion (ΔCFSR = 2.76). These results are in line with the second hypothesis.

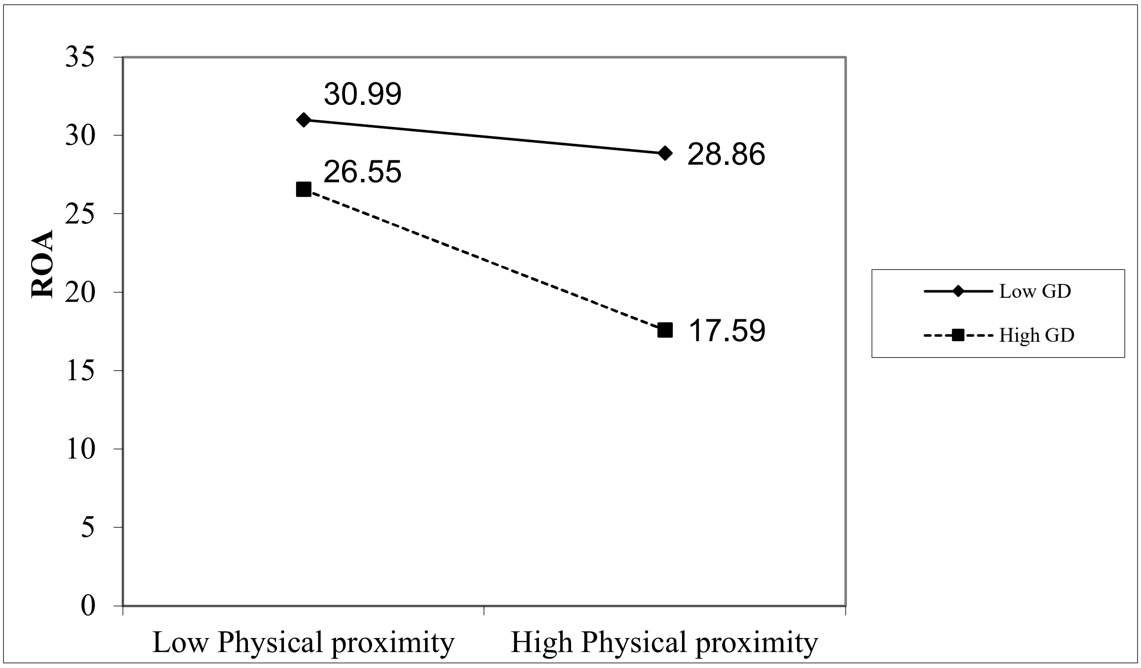


Figure 5: The moderation effects on ROA

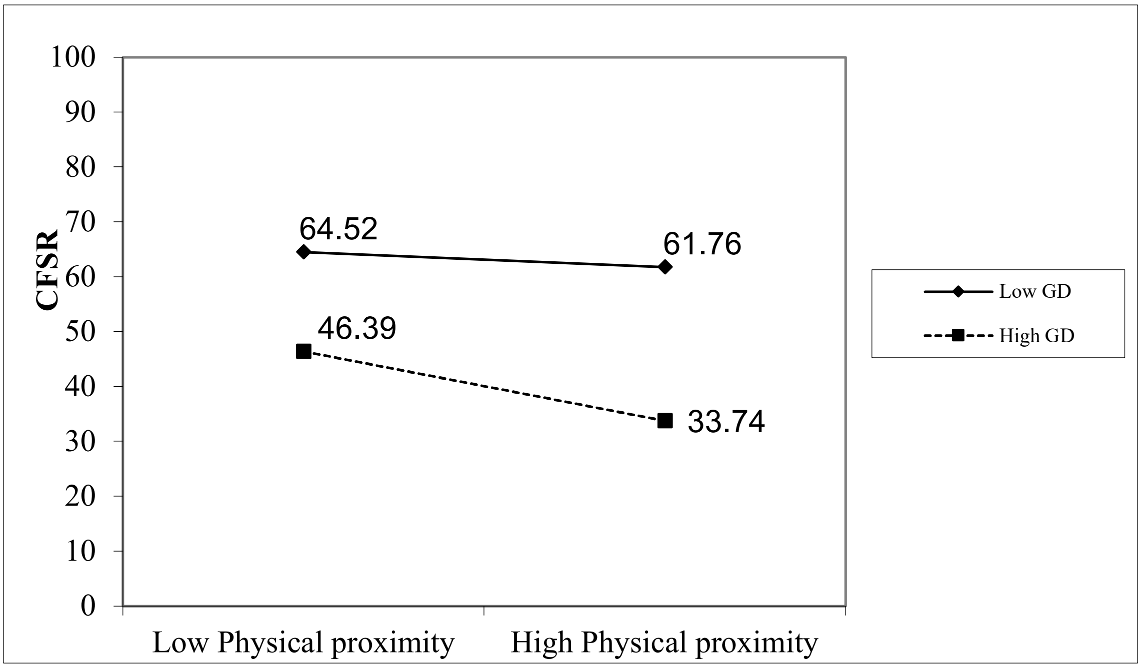


Figure 6: The moderation effects on CFSR

Study 2

4.4. Customer Networks Complexity

From a supplier perspective, buyers are considered a key intangible asset of the firm (Zhang *et al*., 2016) since the buying firm brings profits as well as innovation and market access to the supplying firm (Zimmerman and Blythe, 2013). In line with this, a large buyer network can be an invaluable resource for both firm strategy and success; hence, supplying firms continue to invest in expanding buyer bases and cultivating relationships with them (Bayus *et al*., 2003). In addition, marketing researchers often investigate ways to attract more buyers in the belief that doing so will enhance supplier financial profitability (Zimmerman and Blythe, 2013). Gould (2012) defined business performance as the ability to win and keep customers. It has been widely acknowledged in the marketing literature that winning is the result of all the effort to generate revenues and profits from the customers. Also, Jackson (1985) argues that suppliers may be able to use their buyers' brands and reputations and promote themselves to attract more buyers. Relationships with buyers are not only a source of legitimacy and reputation for supplying firms (Chowdhurry, 2011), but also enhancing activities such as opportunity recognition (Rowley *et al*., 2000).

Another stream of research examines customer portfolios which represent one of the main contexts for business marketing and thus an important focus for B2B. A focal firm's customer portfolio comprises all its customer relationships in the entire customer base (Reinartz *et al*., 2004) and is considered as a central setting for a variety of strategic business marketing decisions, especially customer relationship management (Reinartz *et al*., 2004). Terho and Halinen (2012) suggest that complex relationships generally reside in a networked context, they argue that in order to build a full picture of the nature of firms' total customer portfolios, scholars should consider the quality of the relationships in the portfolio together with the broader context impinging on the structure of the portfolio.

Consequently, they suggest three the dimensions to embrace the relational characteristics – strength, dynamism, and interconnectedness of relationships in the portfolio, that in turn address the relational complexity in the customer portfolio. They also suggest four other dimensions – broadness, concentration, heterogeneity of the customer base, and customer turnover – that capture the level of the structural complexity of the portfolio. These structural attributes include dimensions of complexity, heterogeneity, and concentration, and all reflect the number and diversity of external factors facing an organization. They typically determine the degree of a portfolio's structural complexity; the wide, dispersed, and heterogeneous customer base combined with high customer complexity indicating high downstream structural complexity to the supplying firm. These properties make these dimensions comparable to the structural complexity dimensions relating to horizontal, vertical, and spatial complexity that have been studied extensively in the supply network literature (discussed in more details in the next section).

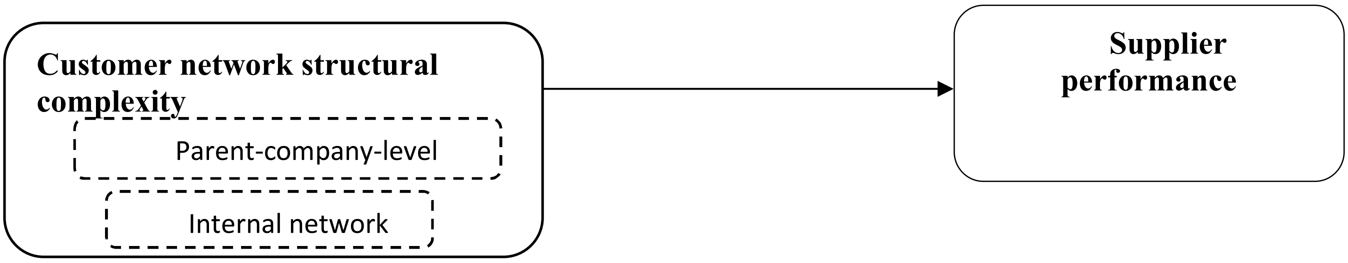
Suppliers can choose to create relationships with a few major buyers, or they can seek a broader buyer network (Kim, 2017). A good example is the Nypro's lean customer selection strategy where it fired 60% of its customers to move its customer base to fewer but larger customers that provide a large volume of business. Prahalad and Ramaswamy (2000) argue that buyers play an important and active role in business markets to the extent that they can fundamentally change the dynamics of the marketplace. The broadness of the portfolio carries information about the complexity arising from the number of buyer relationships (Holweg *et al*., 2018).

In addition, downstream entities form networks that often exhibit shifts in strategies and objectives within a dynamic environment, which complicates the operations for the supplying firm (Zimmerman and Blythe, 2013). A survey of top executives at McKinsey & Company revealed that one of the most dominant features of B2B context is the increasing diversity of buyer's demands from off-shelfs products to more complex and customized solutions with different levels of expectations. Bozarth et al (2009) have discussed the downstream complexity of a supply chain with various downstream demand entities that independently place orders on a supply entity. They argue that the downstream complexity increases as the number of buyers a plant serves and their heterogeneity increase. When the number of buyers increases, the magnitude of the tasks related to buyer-supplier relationship management, demand management and order management all amplify (Eckstein *et al*., (2015); Holweg *et al*., 2018). All downstream activities occur as a direct outcome of a buyer's order, hence, variability in orders and demands is a substantial source of complexity on the supplier. These variabilities create more complexities when the orders are being generated from different parts of the world and serving distinct buyers' markets and industries. Holweg et al (2018) argue that operations managers should reflect on volume and operations separately, meaning that, with scale come complexity concerns that can rise, levels of management that can escalate and control that can become much more complicated.

Therefore, there is a trade-off between the increase in sales and the increase in manufacturing costs and complexity (Kekre and Srinivasan, 1990). For instance, Eckstein et al (2015) suggest a trade-off between sales growth as a result of product complexity and improved operational efficiency via product rationalization.

Moreover, most of the studies in the marketing literature consider the buying process to be much more complex and customized in a B2B context (Wiersema *et al.,* 2013). Buyers, with a responsibility to their company and specialist product knowledge, are more demanding than the average consumer. The products themselves may be highly complex, often requiring a sophisticated buyer to understand them. In line with this, supplying companies generally use direct marketing efforts such as email, phone, and in-person communication to cultivate profitable relationships with their B2B buyers and minimize their churn (Kim and Kumar, 2018). B2B firms acknowledge that direct communications have significant influence on buying decisions (Senn *et al.,* 2013). Not all buyers require the same level or the same kind of marketing communications due to their experience and underlying perceptions. These buying entities whose managers are young professionals, are becoming more and more influenced by their experiences as consumers and are now seeking the same experiences in their business interactions. Thus, to build strong and profitable B2B relationships, firms need to consistently engage in such marketing approaches leading for more expenses and more communication (Kim and Kumar, 2018).

While it is important to capture the impact of the buyer's network structure on supplier performance, it is equally important to understand the complexity of this buyer network structure. Buyer network structure can have a positive impact on supplier performance such as facilitating market reach and boosting the revenues, however, the complexity in the buyer network can also increase the costs of managing the buying companies which may harm the performance of supplying firms. Please see model in Figure 7.



More specifically

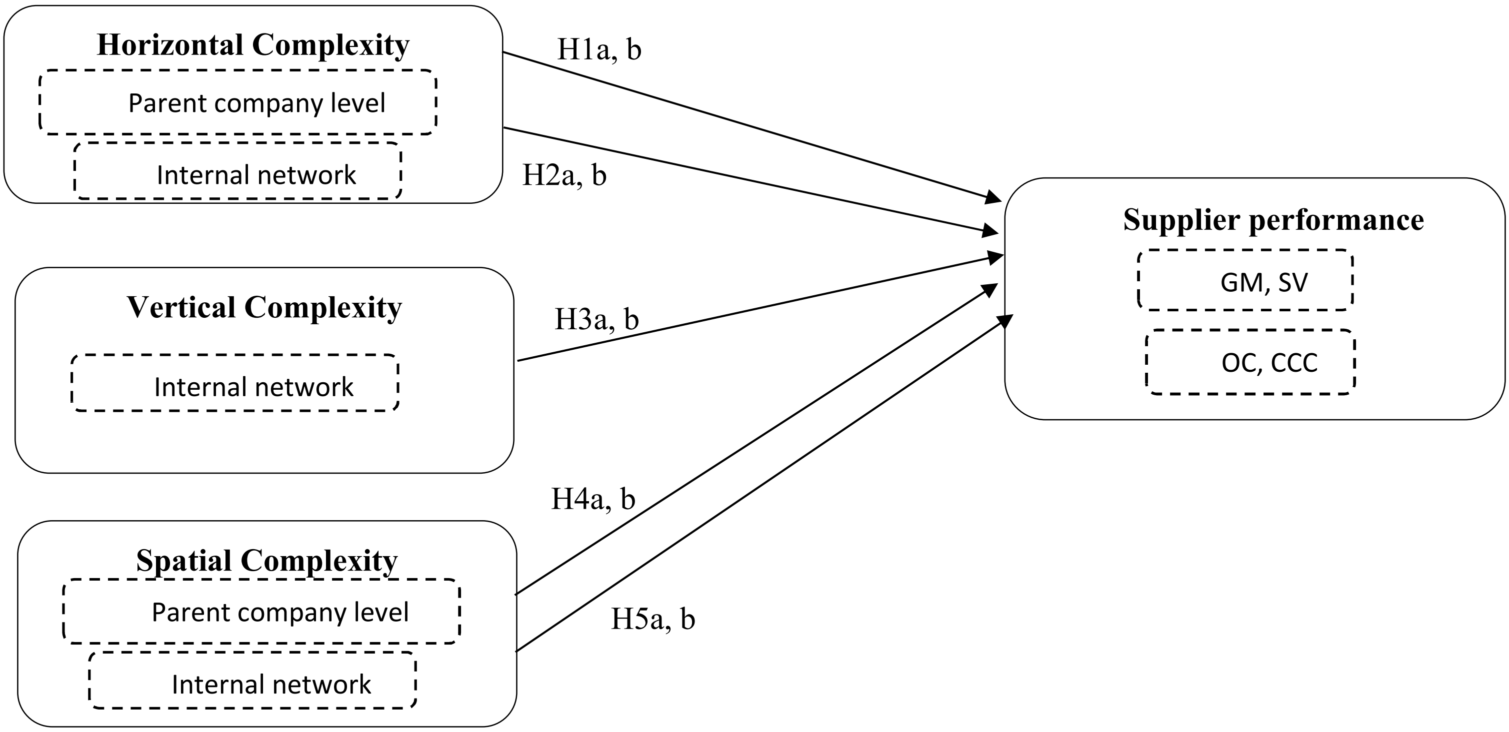


Figure 7: Research Model 2

4.5. Hypothesis

Horizontal Complexity

In general, relationships with buyers offer suppliers a secure loyal buyer network and opportunities to reach a high level of profitability. Network size is proven to be one of the most important network characteristics as it determines the amount of information embedded in a network (Hutt and Walker, 2006; Ellis, 2010). All things being equal, "bigger is better" (Burt 1992). Bigger networks, measured as the number of nodes, provide more access to information on emerging trends and varying preferences. For instance, a manager who actively examines and visits a large number of buyers is likely to learn more than a manager who monitors a limited number of buyers. This facilitates the increase of the manager's sales portfolio (Schmitz and Ganesan, 2014). Also, a bigger network gives the supplier more opportunity to validate market information (Katz and Shapiro, 1986) and to identify crucial buyer requirements (Romo and Schwartz, 1995). Although a more various set of market preferences and requirements may exist in a bigger network, it helps the supplying firm to better estimate the needs of diverse buyer segments and to be prepared to respond to their modifications more accurately. This, in turn, allows the supplier to maintain a certain level of sales and sales support (Ingram, 2004). In addition, previous research shows that suppliers having a large buyer base are more likely to enlarge their overall profit pie by increasing sales to their buyers (Zimmerman and Blythe, 2013; Kim, 2017). Furthermore, according to the network externality theory (Katz and Shapiro, 1986), as the size of a firm's buyer network increases, buyers consider that more benefits can be derived from their association with a certain supplying firm. This results in a positive feeling toward the supplying firm and its brands. In a similar vein, buyers' network size can bolster the supplying firm's reputation (Galunic *et al*., 2012; Zhang *et al*., 2016), which in turn, increases the benefit of attracting more buyers and more sales. Buyer network size is a key determinant for more sales as a bigger network in itself means more sales, largely due to the bigger volume of orders that the supplier must satisfy. Hence, this study hypothesizes a positive relationship between horizontal complexity and sales performance.

H1a: Horizontal complexity at the downstream side has a positive relationship with supplying firm sales performance.

However, one of the most obvious and significant characteristic of network relationships is the complexity that results from the number of participants (Choi and Krause, 2006). In a B2B environment, more personalization requirements are expected from suppliers and/or service providers (Dotzel and Shankar, 2019). Buying firms tend to frequently require customization of services, products, and price structure, even if they belong to the same sector (Rauyruen and Miller, 2007) and their needs are continuously changing in terms of what they purchase and what their expectations are (Patatoukas, 2012). Moreover, many buying firms use the service and products in a different manner. Complexity is driven by the number of elements within the system and the degree to which these elements are differentiated (Choi and Krause, 2006). Suppliers tend to focus too narrowly on individual buyers and miss the collective picture of all buyers in their networks (Epp and Price, 2011). In line with this, Bozarth and Edwards (1997) found that manufacturing plant operational performance decreases as the number of major buyers and product lines increase. Similarly, variability in buyers' needs in terms of design requirements and delivery reliability had a significant negative impact on plant performance. Supplying firms with fewer buyers encounter less potential variability and component requirements and would have more focused orders to support (Bozarth and Edwards, 1997; Bozarth and McCreery, 2001). According to the CAS, complex systems interacting with each other considerably generate behaviours that are impossible to forecast (Anderson, 1999). Therefore, an additional complexity creates more uncertainties and consequently higher operational concerns (Bozarth and McCreery, 2001). Specifically, a less horizontally complex buyer network would lead to lower transaction and operational costs due to reduced negotiation with suppliers, less communication channels and better tracing of problems.

In line with this, no two buyers are alike, neither are their requirements; for example, two buyers may buy similar products which would increase the sales, but each will do so in order to address their own unique problems. The two buyers may require different levels of service and advice. They may ask their supplier to adapt the product or the way that the product is delivered to their particular requirements. Some of the customers are likely to be more important than the others to some suppliers and those suppliers are likely to expect more business from some of their customers but may want to develop new products together with others. Each of these buyers will have a unique relationship with the suppliers which will need to be managed differently by the supplier.

Therefore, as discussed above, the horizontal complexity dimension, which is linked to the number of direct buyers in a supplier's downstream network, may exert an important effect on supplier sales performance. There can be too much of a good thing as horizontal complexity could be a structural characteristic that hurts its operational performance, both magnitudes are possible depending on the performance measure. Thus, this study hypothesizes a negative relationship between horizontal complexity of the buyers' network and supplier operational performance.

H1b: Horizontal complexity at the downstream side has a negative effect on supplying firm operational performance.

Horizontal Complexity – network-level

Repeatedly, research has shown the importance of understanding buyer networks and their characteristics, however, no research has considered the internal network of each buyer. In fact, buyers are a combination of networks of the parent company and subsidiaries that can be local or international. A stream of research supports the effect of social influence, i.e., buyers impact the behaviour of others in their social network (e.g., Giudicati *et al*. 2013). Indeed, subsidiaries can be considered as major entities in the social network of their parent company (Chedid *et al*., 2021). As the central organisational unit in the MNC, headquarters have the potential to influence their subsidiaries especially when subsidiaries are wholly owned (Stendahl, 2018) and vice versa. Hence, buyers can influence their wide network of subsidiaries to share the same parent companies' supplier or buyers could be ordering on the behalf of their subsidiaries in different countries. The subsidiaries can also benefit from cheaper deals and better quality through their network embeddedness (Golini *et al*., 2016). In addition, a lot of buyers establish subsidiaries which would enhance close business relationships with respect to sales and purchase of products and services (Ciabuschi *et al*., 2014; Demeter *et al*., 2016).

Therefore, a buyer with a wider internal network of subsidiaries should represent a pool of companies and markets through which suppliers can gain bigger reach and higher volumes of sales (Zimmerman and Blythe, 2013). The impact on the supplier would be higher volume of sales that result from a bigger internal network of their buyers. Thus, this study hypothesizes a positive relationship between horizontal complexity of the buyers' network and supplier sales performance.

H2a: Network-level horizontal complexity at the downstream side has a positive effect on supplying firm sales performance.

However, considering the effects on the supplier's operational side, buyers with larger internal networks exhibit greater complexities than buyers with fewer. In this paper's context, this level of complexity corresponds to the number of subsidiaries in each buyer network which is introduced and defined as horizontal complexity at the buyer network-level. This is noteworthy because subsidiaries in these buyers' networks might play a key role in supplier's sales pool, however, the more subsidiaries, the higher the information load, uncertainty, and management costs that will complicate the communication and coordination of orders and, consequently, hurt the cash performance (Chedid *et al*., 2021). This is exacerbated when these orders are not governed by the buyer parent company (Golini *et al*., 2016). In other words, the greater the complexity in the buyer network itself, the more the burden on the supplier in terms of managing complexities when dealing with large buyer networks. This complexity is associated with the breadth of the buyer network, and an excessively wide network of subsidiaries could have negative impacts on operational performance that are not necessarily always apparent to the supplier when trying to reap the benefits associated with additional sales through the buyer's subsidiaries. This greater complexity carries with it the challenge of coordination and control as well as information asymmetry (Lu and Shang, 2017) that are more likely to be caused from dealing with bigger networks of subsidiaries in comparison to smaller ones. Consequently, this will increase the inventories held, delay the payment time from buyers and extend the time needed to convert purchases to cash. Therefore, this study hypothesizes a negative relationship between horizontal complexity of the buyers' network and supplier operational performance.

H2b: Network-level horizontal complexity at the downstream side has a negative effect on supplying firm operational performance.

Vertical complexity

Complex parent-subsidiary structures in large MNCs can involve several layers of subsidiaries, called first-tier subsidiary, second-tier subsidiary, third-tier subsidiary and so on. When the organizational hierarchy is composed of a multi-layered subsidiary structure, it will have the ability to create an internal capital market and raise capital through its subsidiaries (Hsu and Liu, 2018; Ayotte, 2020; Gul *et al*., 2018). This results in an increase in the firm's flexibility in its ownership and investment structure with successive layers of subsidiaries below (Hsu and Liu, 2018). This, in turn, increases the interdependence between the parent company and its subsidiaries which is considered as a benefit to the supplying firms in terms of increasing their sales network and volume. Golini et al (2016) studied the effect of the level of autonomy given by headquarters to the subsidiaries (i.e., parental control) in a network on performance. They point on the challenges of autonomy as it prevents subsidiaries from benefitting from the specialised resources existing within the network, typically the ones developed by the parent company over the years (Keupp *et al*., 2011). In this type of vertical network, the parent company has an integrator role and coordinates the network as being a hub (Achrol and Kotler, 1999) and would, in a lot of cases, influence the subsidiaries to share the same supplying firms. Indeed, a critical feature of a multi-layered subsidiary structure is its flexibility which allows the parent companies to be more responsive to fluctuating economic environments by allowing these multi-layered subsidiaries to persist, evolve, and take advantages from existing business relationships independently of other parts (Prechel, 1997; Golini *et al*., 2016). Overall, these arguments highlight the potential sales opportunities that the supplier receives which has not been recognised among researchers. Thus, these arguments suggest a positive relationship between vertical complexity of the buyers' network and supplier sales performance.

H3a: Network-level vertical complexity has a positive effect on supplying firm sales performance.

However, Hsu and Liu (2018) found that companies with multiple subsidiary layers are associated with a lower cash holding value. This goes in line with the agency theory of cash holdings that suggests that, even though pyramidal firms enjoy the benefits of internal capital markets, the value to shareholders of holding additional cash decreases. This negative effect is associated with higher levels of deviation between cash flow rights and voting rights for more pronounced multi-layered firms (Scharfstein and Stein, 2000). The complex nature of these multi-layered structures and the persistent disagreements about the valuation between the two sides create a lot of capital structure complexities and challenges to the parent company (Scharfstein and Stein, 2000; Ayotte, 2020). This is worth considering at the supplier level as it relates to payments and funds available at their buyer level as well as their cash flexibility.
Gul et al (2018) proposed a new measure to capture the complexity of parent-subsidiary structures which is the number of vertical layers within the parent-subsidiary and found that this number, measured from the parent company to the lowest-tiered subsidiary, is associated with higher audit risks to firms and higher audit fees. This dimension of complexity is related to information asymmetry and agency problems explaining the higher risk of financial misreporting associated with the presence of more layers. All these will weaken the bargaining power of suppliers (Lanier *et al*., 2010) and exacerbate the payment delays to suppliers which would worsen their operating and cash cycle performance.
Thus, when the vertical dimension of the internal network rather than the buyer as a single entity is considered, we start seeing the additional operational complexities and the increased concerns due to the presence of more layers. This complexity is associated with the depth or the hierarchical level of the buyer network, and an excessively deep or tiered of the buyer network could have a negative impact on operational performance. Therefore, these arguments suggest a negative relationship between vertical complexity of the buyers' network and supplier operational performance.

H3b: Network-level vertical complexity has a negative effect on supplying firm operational performance.

Spatial Complexity

Many companies supply other companies that are spread across different countries and markets, serving significantly dispersed buyers' networks. By maintaining a spatially diverse portfolio of buyers, suppliers can diversify their buyer networks in a way where they maintain their degree of sales and profits by utilizing alternatives if a country or a market breaks down. In this way, suppliers can also use diversification to maximize their sales performance and survival. Likewise, portfolio theory suggests a positive side to diversification which relates to diversified flexibility that allows firms to protect themselves from risk. It also suggests that an efficient portfolio exists that ensures an expected return while minimizing volatility, particularly in a highly dispersed network (Markowitz, 1991).

The most obvious benefits are related to scale and scope economies (Kogut, 1985) that are achieved from larger volumes of sales and production due to the revenue growth in the geographic extension of buyers and markets. Lu and Beamish (2001) investigated the impact of internationalization on a firm's growth and financial performance and found that learning from exporting is a key factor that facilitates building strong capabilities, achieving a larger volume of production, and growing. In addition, as there are many different market conditions across different countries, supplying firm can have unlimited possibilities to leverage their sales in different markets and become in a position to capitalize on market imperfections which allow them to achieve more sales and higher returns on their sales. In addition, the presence in many countries can relate to other benefits such as market power through an improved risk adjusted performance (Kim *et al*., 1993) and valuable experience in international markets (Tallman and Li, 1996) which permits supplying firms to regularly increase their commitment to spatial expansion of their buyer network. This capability to manage extensive networks of international buyers would attract more buyers as they perceive the supplier as a source of competence and reliability (Prahald and Ramaswamy, 2000).

Therefore, the above arguments suggest a positive effects of the buyer network spatial complexity on supplier sales performance.

H4a: Spatial complexity at the downstream side has a positive effect on supplying firm sales performance.

On the other hand, such dispersion is associated with spatial complexity that relates to the operational load on the supplier. The high level of geographic spread of buyers creates a less predictable behaviour as buyers are spread across multicultural regions which could expose the firms to uncertain markets (Bozarth *et al*., 2009). Previous studies have identified several operational challenges related to the relationship between the number of sites or locations and corresponding management difficulties (O'Leary and Cummings, 2007). Clearly, buyers that are dispersed over more locations and countries contribute to greater logistic challenges such as fragmented distribution with high transportation costs and varying government regulations. Second, global business engagements characterized by greater geographic dispersion are expected to require greater resource expenses to realize effective business-to-business coordination. As in the case of horizontal complexity, communication and coordination costs and difficulties rise with the number and distance of locations or sites, ceteris paribus (O'Leary and Cummings, 2007), in many cases, this results in time-consuming and costly international travel for the supplier (Lorentz *et al.,* 2016). Similarly, communication is more likely to be hindered when firms are dispersed across multiple geographic locations because employees share less contextual knowledge (Gibson and Gibbs, 2006) and because of the different languages, specifications, norms, and principles of working (Tachizawa and Wong, 2015). In addition, the variability of demand becomes more challenging to deal with when the buyers are more geographically dispersed (Bozarth *et al*., 2009), this intensifies the magnitude of the buyer relationship management activities, demand management efforts and order fulfilments. For example, dispersed buyers' demands for new products expose the supplier to many operational difficulties and delays due to longer average paths between supply chain nodes, lack of coordination and varying policies at different points that can lead to wide fluctuations in demand satisfaction.

In addition, Bode and Wagner (2015) show that the frequency of supply chain disruptions seems to increase with the spatial complexity at the supply network-level, this is also true for spatial complexity at the buyer network-level. A disruption at the downstream level has a very pronounced impact at the supplier level due to the bullwhip effect, demand uncertainty, order cancelations. Hence, a more spatially complex downstream network of buyers exposes the suppliers to more frequent operational risks.

Further, a greater geographic dispersion is associated with varying payment norms and procedures which complicate and elongate the average payment time to suppliers (Farris and Hutchinson, 2002). For instance, country and cultural differences may affect time periods to collect unpaid accounts receivables and require more local and in-transit inventories, which increase assets investments and costs (Lorentz *et al*., 2012).

Therefore, this study hypothesizes a negative relationship between spatial complexity and supplying firm operational performance.

H4b: Spatial complexity at the downstream side has a negative effect on supplying firm operational performance.

Spatial Complexity – network-level

Multinational buyers have also an extensive international footprint and operate units of geographically dispersed subsidiaries in several countries. This refers to their international breadth which is one of the main considerations in the analysis of MNCs (O'Leary and Cummings, 2007). In this paper's context, the dispersed market and country information from buyers and their networks of subsidiaries allows supplying firms to identify opportunities to pursue, appropriate product attributes, and updated product development processes (Fang, 2008). In this way, buyers and their internal networks act as information resources about tastes and preferences of local markets and codevelopers (Achrol and Kotler, 1999). This benefits the volume of sales for the supplying firms, which is bolstered by these additional subsidiary entities that are embedded in both their own and external networks.

In addition, the relationships of buyers with suppliers could refer the buyers as parent companies to order for their subsidiaries in different countries. In a lot of cases, these foreign subsidiaries can reduce their costs by sharing the same sourcing firms as their parent companies with the aim of benefiting from cheaper deals. An example could be when buying firms as networks consolidate their needs and their foreign subsidiaries' needs (Achlor and Kotler, 1999). Suppliers will find themselves facing aggregated demand from different markets and receiving large quantity orders and exclusivity arrangements. A common marketing task is to market the supplier's abilities, products, and exceptional benefits to these buying network companies in the aim of attracting more sales (Achlor and Kotler, 1999). Similar to horizontal and vertical complexity at the network-level, more sales are expected to be associated with more spatially complex internal networks of buyers.

H5a: Network-level spatial complexity at the downstream side has a positive effect on supplying firm sales performance.

However, these buyers' internal networks of subsidiary have their drawbacks, as more spatially dispersed networks can complicate the operations of the supplying firm. The extensive international footprint where subsidiary units operate could expose the supplying firms to higher levels of spatial complexity comparing to a less international network. The more diverse these networks are, the more challenging it would be to understand the requirements of the local markets and to respond appropriately to buyers demands (Goerzen and Beamish, 2003). Supplying firms with a large number of foreign buyers and buyers' subsidiaries have to comply with countless concerns such as foreign export regulations, multi-layered structure laws, varying technologies and dissimilarities in payment terms and conditions (Lu and Shang, 2017). The operational costs to adapt to these business guidelines can greatly affect the supplier' operations and hurt its cash performance.

Previous studies have identified several challenges related to sourcing to dispersed buyers' networks (Lu and Beamish, 2001). First, there is a lack of research on the operational challenges and impacts associated with the additional sales volume from more geographically diverse buyers' networks. This spatial complexity level may involve very high investments often with long return horizons. In addition, although suppliers can benefit from additional sales from more foreign markets, fulfilling demands and orders from geographically dispersed entities (buyers and their subsidiaries) become extremely sensitive to market downturns and disruptions (Dotzel and Shankar, 2019). This creates unforeseen sources of risks and uncertainties to the supplying firms, which adds an additional form of complexity, mainly due to the high operational requirements needed to overcome these challenges (Lorentz *et al*., 2012). Lastly, for the same reasons as spatial complexity at the parent company level, the differences related to payments, culture, agreements become more noticeable when the internal network of subsidiaries of these buyers is recognized.

Consequently, the effects of a spatially complex buyer base that includes the internal network of subsidiaries are expected to be negative when looking at the supplier's operational performance.

H5b: Network-level spatial complexity at the downstream side has a negative effect on supplying firm operational performance.

4.6. Methodology

4.6.1. Data

The second study is interested in the complexity defined at the buyer network-level, which is called external complexity to the supplier. It aims to examine the impact of dimensions of buyer structural complexity on supplier performance and these dimensions are formulated by including the additional layer of the buyer's internal network complexity. For this reason, the sample for this study was drawn from major supplying firms in the electronics industry. These industries are well known to have major MNCs and large buyer networks (Shao *et al*., 2018). Furthermore, the electronics industry is global in its nature with the majority of supplying firms headquartered in North America, Europe, and Asia. Therefore, this context will allow to account for potential geographic differences in these firms' buyer networks (Basole and Bellamy, 2014; Basole *et al.*, 2018). Thus, the internal and buyer networks in the form of subsidiary structures and downstream structures, respectively, in the electronics industry are found to be an appropriate setting to investigate the buyer network implications for supplying firm performance.

This study builds on a supply chain dataset of 96 public supplying firms (focal firms) from the electronics industry, 4,163 buyers, and 425,730 buyers' subsidiaries. Large and public manufacturing firms were identified in Orbis, based on a market capitalization above $6bn and based on their primary business Standard Industry Classification (SIC) code of either SIC 35 (Industrial and Commercial Machinery and Computer Equipment), or SIC 36 (Electronic and other Electrical Equipment and Components (except Computer Equipment)). In total, 100 suppliers were obtained that matched the outlined criteria. The buyer networks of these supplying firms were identified using FactSet, which is a global database that collects interfirm relationship data from primary public sources such as investor reports, SEC 10-K annual filings and press releases. Both the relationships disclosed by the company as well as reverse relationships which are reported by their buyers are included in the database. For all companies, the buyers, the suppliers, and the subsidiary data were collected from Orbis. In the data collection process, four focal firms were dropped from the sample due to missing data which resulted in a final sample of 96 supplying firms with their buyers networks.

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4.6.2. Dependent Variables

While previous studies on supply networks have examined the impacts of complexity dimensions on manufacturing performance (Bozarth *et al*., 2009), financial performance (Lu and Shang, 2017), innovation performance (Sharma *et al*., 2019), environmental performance (Adhikary, 2020) of buyers, and frequency of supply chain disruptions (Bode and Wagner, 2015), no studies have directly investigated the counteracting effects of buyer networks on sales vs operations. These impacts represent important and distinct aspects of performance. GM and SV are considered as measures of sales performance and OC and CCC to capture operational performance. GM is measured as the gross margin in absolute terms which is net sales less the cost of goods sold. It is commonly considered as a sales efficiency measure in the B2B marketing literature (Zallocco *et al*., 2009). SV is measured as net sales (Hendricks and Singhal, 2005; Zallocco, *et al*., 2009). OC is measured as inventory days of supply plus accounts receivable while CCC, also called Cash-to-cash cycle time is measured as inventory days of supply plus accounts receivable minus accounts payable (Farris and Hutchinson, 2002), both measures of operational performance are receiving increased attention in the literature (Lanier *et al*., 2010; Lorentz *et al*., 2012).

$$\text{CCC} = \text{DIO} + \text{DSO} - \text{DPO}$$

$$\text{OC} = \text{DIO} + \text{DSO}$$

Where:

$$\text{DIO} = \frac{Inventory}{Costs\ of\ Goods\ sold} \times 365$$

$$\text{DSO} = \frac{Accounts\ receivable}{Annual\ sales} \times 365$$

$$\text{DPO} = \frac{Accounts\ Payable}{Costs\ of\ Goods\ sold} \times 365$$

4.6.3 Independent Variables

The buyer network complexity construct was measured along three dimensions, i.e., horizontal, vertical, and spatial complexity. Horizontal complexity is measured by the number of buyers that each supplier has, vertical complexity as the average number of tiers of subsidiaries that the buyers have and spatial complexity by the geographic dispersion of buyers. As mentioned before, an additional layer of horizontal complexity is considered in a way that it includes the number of subsidiaries of each buyer, representing the network-level horizontal complexity of the buyers' networks. In a similar manner, the additional layer of spatial complexity accounts for the geographic dispersion of subsidiary units of each buyer. Please see details below.

Horizontal complexity**:** Based on the extant literature, horizontal complexity HC is operationalized as the total number of Tier-1 (direct) buyers (mean = 52.39; SD = 42.97) (Bode and Wagner, 2015; Sharma *et al.*, 2019; Adhikary *et al.*, 2020), whereas the network-level horizontal complexity HC-N is measured as the average number of subsidiaries per buyer in the buyer network of the supplier (mean = 4434.69; SD = 4348.09).

$$\text{HC} = n$$

$$HC - N = \frac{1}{n} \sum_{i}^{n} x_{i}$$

Where x indicates the number of subsidiaries per buyer and n indicates the number of buyers per supplier.

Vertical complexity: The average number of tiers of subsidiaries per Tier-1 buyer represents vertical complexity (mean = 2.79; SD = 0.795) (Lu and Shang, 2017; Sharma *et al*., 2019; Adhikary *et al*., 2020).

$$\text{VC} = \frac{1}{N} \sum_{i}^{N} t_i$$

Where *t* indicates the tier of subsidiaries of each buyer and *N* indicates the total number of buyers' subsidiaries per supplier.

Spatial complexity: Finally, spatial complexity SC is operationalized as the geographic dispersion of buyers which is captured by a modified spatial diversity index (Phelps, 2010), calculated based on the Herfindahl index of number of buyers headquarters 'countries (mean = 14.17; SD = 11.11) (Lu and Shang, 2017). Similarly, the network-level spatial complexity SC-N is captured by the Herfindahl index of number of buyers' subsidiary countries represented in the buyer network (mean = 90.14; SD = 37.76). The operationalization is as follows:

$$\text{SC} = [1- \sum(\frac{c_i}{c})^2] \times \frac{n}{n-1}$$

$$\text{SC-N} = [1- \sum(\frac{C_i}{C})^2] \times \frac{N}{N-1}$$

where c is the number of countries represented in the supplier's buyer network for the headquarters only and C represents the number of countries including the subsidiaries of the buyers. The HHI is then normalized by multiplying by n/n-1 or N/N-1, where *n* indicates the number of buyers per supplier and *N* indicates the total number of buyers' subsidiaries per supplier. This variable could range from 0 to 1 (maximum diversity).

4.6.4. Control Variables

Control variables were considered to account for potential omitted variable bias in the main effects. First, a common driver of performance and buyer network complexity is the size of the supplying firm. The literature shows evidence for the association between firm size and performance (Lanier *et al*., 2010; Lu and Shang, 2017). It is conceivable that more buying firms tend to supply from large suppliers. As a result, number of employees is used to control for supplier size. Second, supplier experience is controlled for and is operationalized as the difference between the year of establishment and the focal year of interest (2019) to consider knowledge and experience gained with time. Older firms are likely to have more experience in managing complexities arising from their buyer network, also, their bigger experience is invaluable as they learn more how to balance buyer network complexities. Third, the concentration of buyers' industries is considered, it is measured by the Herfindahl index of SIC codes represented in the data. Firm's HHI of SIC codes is used as a proxy to measure industry concentration of buyers which is an industry-level measurement. It is calculated as the sum of squared percentage of all firms in an industry, which are classified according to the three-digit SIC codes. This control variable is included to account for the different number of industries the buyers (parent companies) operate in, in other words, the diversification of industries across the buyers in the buyer network.

Table 5: Description, mean and SD of all variables of study 2

Variable	Description	Mean	SD
Supplier size	Number of employees	77502.25	106260.44
Supplier experience	2019 - Founding year	52.39	42.97
Industry concentration	Herfindahl index of SIC codes	0.144	0.184
HC	Horizontal Complexity	43.36	46.50
HC-N	Horizontal Complexity at the network-level	114.47	67.53
VC	Vertical Complexity	2.79	0.795
SC	Spatial Complexity	0.7608	0.1829
SC-N	Spatial Complexity at the network-level	0.8125	0.139
GM	Gross Margin	10,454,924	15,176,996
SV	Sales volume	26,823,859	39,651,146
CCC	Cash Conversion Cycle	89.61	70.61
OC	Operating Cycle	162.32	61.59
N	Sample size	96	

Table 6: Models Specification of Study 2

	Variables
Model 1	HC, HC-N, VC, SC, SC-N, GM
Model 2	HC, HC-N, VC, SC, SC-N, SV
Model 3	HC, HC-N, VC, SC, SC-N, CCC
Model 4	HC, HC-N, VC, SC, SC-N, OC

Table 7: The correlations for all the study 2 variables

No	Variable	1	2	3	4	5	6	7	8	9	10	11	12
1	Firm size	1											
2	Firm age	0.185	1										
3	Industry concentration	-0.111	-0.077	1									
4	HC	0.368**	0.177	-0.059	1								
5	HC-N	-0.070	-0.122	0.234*	-0.156	1							
6	VC	0.164	0.054	0.184	0.354**	0.477**	1						
7	SC	0.082	0.151	-0.165	0.207*	0.095	0.365**	1					
8	SC-N	0.164	0.071	-0.018	0.356**	0.108	0.524**	0.596**	1				
9	GM	0.374**	0.072	-0.012	0.836**	-0.171	0.219*	0.128	0.189	1			
10	SV	0.673**	0.080	-0.052	0.741**	-0.163	0.199	0.107	0.194	0.881**	1		
11	CCC	-0.201*	0.140	0.221*	-0.362**	0.231*	-0.115	0.096	0.106	-0.273**	-0.318**	1	
12	OC	-0.129	0.128	0.212*	-0.311**	0.235*	0.010	0.176	0.172	-0.261*	-0.324**	.863**	1

** Pearson correlation coefficients significant at p =0.05 level*
*** Pearson correlation coefficients significant at p =0.01 level*

4.6.5. Analysis

Table 5 presents the descriptive statistics for the variables: description, mean and SD and Table 6 includes the models' specifications that explain the different models with the different dependent variables. The models test for linear effects on sales performance (GM and SV), as well as on operational performance (OC and CCC). A multicollinearity analysis for the sample was conducted and Table 7 shows the correlation values for all the study variables. The results of the main analysis using multiple linear regressions, with supplier size, supplier age, and buyers industry concentration as control variables are presented in Tables 8 and 9.

Table 8: Hierarchical regression results on sales performance

	GM		SV	
	Model 1		Model 2	
Control Variables				
Firm size	0.662** (0.06)	0.464** (0.055)	0.809** (0.055)	0.659** (0.055)
Firm age	-0.041 (0.07)	-0.054 (0.05)	-0.073 (0.063)	-0.08 (0.05)
Industry Concentration	0.209 (0.162)	0.136 (0.166)	0.139 (0.146)	0.165 (0.135)
Intercept	3.763** (0.283)	6.388** (0.185)	3.517** (0.256)	6.672** (0.197)
Predictor Variables				
HC		0.005** (0.001)		0.004** (0.001)
HC-N		-0.001** (0.001)		-0.001** (0.001)
VC		0.108** (0.053)		0.129** (0.057)
SC		0.234 (0.200)		0.118 (0.213)
SC-N		-0.309 (0.296)		-0.180 (0.316)
R^2	56.9%	75.5%	70.7%	79.4%
Adjusted R^2	55.5%	73.2%	69.8%	77.5%
F statistic	40.552**	33.465**	74.056**	41.911**
Change in R2		18.6%		8.7%
N	96	96	96	96

** *p<0.05*
* *p<0.10*

Table 9: Hierarchical regression results on operational performance

	CCC		OC	
	Model 3		Model 4	
Control Variables				
Firm size	-51.92** (13.35)	-31.794** (13.63)	-23.07* (12.54)	-18.43 (13.14)
Firm age	57.04** (15.13)	61.49** (13.64)	36.27** (14.21)	39.00** (13.14)
Industry Concentration	64.45* (35.26)	72.83** (34.96)	62.225* (33.12)	61.36* (33.71)
Intercept	23.19** (61.65)	6.917 (7.383)	20.382** (57.91)	6.193 (6.839)
Predictor Variables				
HC		-47.93** (15.82)		-45.76** (15.25)
HC-N		55.59** (20.49)		40.275** (19.75)
VC		-31.63** (10.89)		-17.88* (10.495)
SC		20.271 (40.30)		34.94 (38.85)
SC-N		199.86** (65.06)		162.82** (62.72)
R^2	24.3%	43.2%	12.2%	30.6%
Adjusted R^2	21.8%	37.9%	9.3%	24.2%
F statistic	9.831**	8.254**	4.256**	4.79**
Change in R2		18.9%		18.4%
N	96	96	96	96

** *p<0.05*
* *p<0.10*

4.6.6. Results

<u>Horizontal complexity</u>

With respect to the first hypothesis H1a, which postulated a positive relationship between horizontal complexity and supplier's sales performance, the results show support for a significant positive linear effect suggesting an increase in supplier's sales performance (in terms of GM and SV) as the number of buyers in their buyer networks increases (Table 8: $\beta = 0.005$, $p < 0.05$ for GM and $\beta = 0.004$, $p < 0.05$ for SV).

As for H1b that postulated a negative effect on operational performance, no support was found. The results suggested a significant negative linear effect between horizontal complexity of buyers and OC and CCC (Table 9: $\beta = -47.93$ for CCC and $p < 0.05$ and $\beta = -45.76$, $p < 0.05$ for OC), which implies a shorter OC and CCC.

As for H2a that argued for a positive impact of horizontal complexity at the buyer network-level on sales, it was not supported but suggested a significant negative linear effect on GM and SV (Table 8: $\beta = -0.001$, $p < 0.05$ for both GM and SV), therefore, as the average number of subsidiaries in the buyer network increases, the sales performance at the supplier-level would decrease.

With respect to H2b, the results show a significant positive linear effect on OC and CCC (i.e., longer OC and CCC), meaning that horizontal complexity at the network-level hurts operational performance (Table 9: $\beta = 55.59$, $p < 0.05$ for CCC and $\beta = 20.275$, $p < 0.05$ for OC), as expected.

Thus, the results show that horizontal complexity, measured by the total number of buyers, is associated with superior cash cycle and operating cycle performance, higher gross margin, and sales volume while the horizontal complexity at the network-level, that includes the internal network of the buyers, reduces cash cycle and operating cycle performance and results in lower gross margin and sales volume.

Vertical complexity

In the case of H3a, it was supported, and the results implied that there is a positive linear relationship between vertical complexity of buyers' networks and supplier's sales performance (Table 8: $\beta = 0.108$, $p < 0.05$ for GM and $\beta = 0.129$, $p < 0.05$ for SV). Similarly, the results suggested a positive linear effect on supplier's operational performance (Table 9: $\beta = -31.63$, $p < 0.05$ for CCC and $\beta = -17.88$, $p < 0.1$ for OC). Therefore, H3b is not supported, and the effect is opposite.

Spatial complexity

With respect to the impact of spatial complexity at the buyer level on supplier sales performance (H4a) and on supplier operational performance (H4b), no support was found. Similarly, the suggested positive effect of spatial complexity at the network-level

(H5a) on supplier sales performance was not significant and, hence, the hypothesis is not supported.

Finally, the results show empirical support for a positive linear effect which pertains to spatial complexity of buyers' internal network on OC and CCC (Table 9: $\beta = 199.86$, $p < 0.05$ for CCC and $\beta = 162.82$, $p < 0.05$ for OC), thus a longer OC and CCC with higher levels of spatial complexity at the network-level. Thus, H5b is supported.

4.6.7. Robustness test

Moreover, this study runs a robustness analysis to confirm the results when considering wholly owned subsidiaries only. The argument based on the greater and stronger influence that parent companies have on their wholly owned subsidiaries (Stendahl, 2018). Running the model again in a setting in which all subsidiaries are wholly owned allows to hold ownership constant and test whether the results stay robust. Other patterns might appear in different settings as the level of influence and hierarchical control that the parent company has over the subsidiaries may differ. In line with this, wholly owned subsidiaries would demand higher control from the parent company and a great resource contribution which would make the internal network an even more critical structure to the parent company (Peng and Beamish, 2014) which is, in this study, the buyer. The results are presented in Tables 10 and 11. As shown in both tables, the results remain identical which indicates including subsidiaries that are 51% owned and above in the internal network results in the same network effect as wholly owned subsidiaries. This confirms even more the argument that the consideration of internal network matters in SC studies.

Table 10: Robustness test results on sales performance

	GM		SV	
	Model 1		Model 2	
Control Variables				
Firm size	0.662** (0.06)	0.469** (0.056)	0.809** (0.055)	0.669** (0.056)
Firm age	-0.041 (0.07)	-0.049 (0.055)	-0.073 (0.063)	-0.079 (0.055)
Industry Concentration	0.209 (0.162)	0.305 (0.137)	0.139 (0.146)	0.191 (0.138)
Intercept	3.763** (0.283)	4.434** (0.260)	3.517** (0.256)	4.024** (0.261)
Predictor Variables				
HC		0.006** (0.0012)		0.006** (0.001)
HC-N		-0.002** (0.001)		-0.002** (0.001)
VC		0.08** (0.052)		0.098** (0.063)
SC		0.220 (0.185)		0.181 (0.223)
SC-N		-0.089 (0.240)		-0.150 (0.290)
R^2	56.9%	72.6%	70.7%	78.9%
Adjusted R^2	55.5%	74.9%	69.8%	76.9%
F statistic	40.552**	32.53**	74.056**	40.582**
Change in R2		15.7%		8.2%
N	96	96	96	96

** *p<0.05*
* *p<0.10*

Table 11: Robustness test results on operational performance

	CCC		OC	
	Model 3		Model 4	
Control Variables				
Firm size	-51.92** (13.35)	-28.273** (14.08)	-23.07* (12.54)	-14.736 (13.37)
Firm age	57.04** (15.13)	54.384** (13.86)	36.27** (14.21)	34.108** (13.14)
Industry Concentration	64.45* (35.26)	66.35** (34.68)	62.225* (33.12)	64.40** (32.94)
Intercept	23.19** (61.65)	10.417 (6.58)	20.382** (57.91)	6.289 (6.25)
Predictor Variables				
HC		-39.31** (15.52)		-42.81** (14.27)
HC-N		29.0** (15.21)		19.30** (14.5)
VC		-25.39** (10.17)		-11.01** (9.66)
SC		58.591 (36.287)		72.81 (34.47)
SC-N		67.011* (45.653)		42.46* (43.36)
R^2	24.3%	40.4%	12.2%	29.4%
Adjusted R^2	21.8%	34.9%	9.3%	22.9%
F statistic	9.831**	7.378**	4.256**	4.521**
Change in R2		16.1%		17.2%
N	96	96	96	96

** $p<0.05$
* $p<0.10$

<u>Study 3</u>

4.7. Interrelation of Shared SN and Supplier Centrality

As previously mentioned, the third study aims to examine the extent of shared suppliers in a network and its impact on buyer innovation, the centrality of these shared suppliers and its impact on innovation as well as the interaction effect of both: extent of shared suppliers and supplier centrality.

The theoretical understanding associated with the existing studies is that a firm gains information and knowledge from local and distant relationships with suppliers, which helps the buying firm to cultivate innovation. However, this information sharing creates dilemma between pressure to innovate and unintended knowledge spillovers that can serve and benefit other direct competitors of the firm (Muthulingam and Agrawal, 2016). Therefore, it is still unclear whether a focal firm's innovation benefits or becomes adversely affected due to sharing suppliers with its peers. One example that illustrates this is Pratt and Whitney's investment in their shared supplier, Dynamic Gunver Technologies, to develop an innovative product that improves quality and their worry that their competitor, Rolls Royce, would also benefit from it (Spekman and Gibbons, 2006). In other words, a focal firm is embedded in a complex web of relationships with its suppliers, customers, and competitors (Pathak *et al*., 2007). Each of these relationships can act as a conduit for knowledge flow that the focal firm can leverage for its own innovations (Borgatti and Li, 2009). The extent of shared suppliers in a supply network represents a shared network structure that a focal firm operates in and therefore, it becomes a key variable of interest.

On the other hand, given that central firms in a network have access to knowledge sources from their ties with suppliers or customers, it becomes particularly important to examine what happens when a supplier is simultaneously shared with other buyers and central in its network. This becomes particularly beneficial if a new innovation being designed relies on other materials, components, and modules in the supply network. In contrast, firms that are not brokers or central in their network may not have reputations as important network partners, thus they might not be able to exert the necessary control to leverage their network ties to foster innovations (Carnovale and Yeniyurt, 2015). Indeed, researchers have gravitated toward understanding and linking the structural characteristics of a supply network to a firm's innovation efforts but (1) the extent of suppliers sharing in this network did not receive any attention, (2) most of the analytical papers that considered shared suppliers limited the competing buyers to two for modelling purposes, and (3) none of these studies have investigated contingency effects such as shared suppliers' centrality on innovation.

This moderation effect is of particular interest to the relationship between the extent of sharing suppliers and its innovation benefits, because within such shared supply networks, central supplying firms have been associated with social status (Freeman, 1978), power (Marsden, 2002), and prestige (Burt, 1992). This allows the firm to be more visible in the network (Freeman, 1978; Marsden, 2002) which creates innovation benefits to the buying firm (Ahuja *et al*., 2013). Therefore, this study proposes that a shared supplier's centrality in the network of suppliers enhances the focal buyer's innovation and also plays the role of a moderator between the extent of shared supplier in a network and focal firm innovation. Please see model in Figure 8.

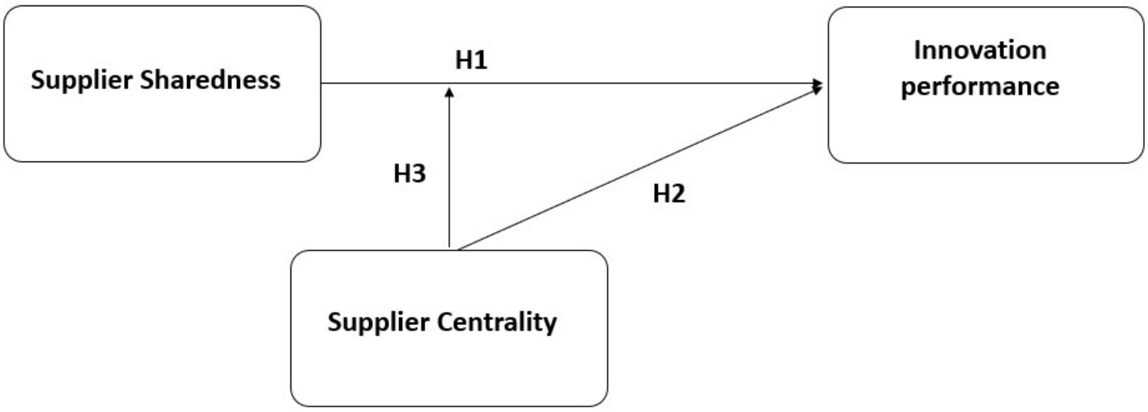


Figure 8: Research Model 3

4.8. Hypothesis

Main effect of shared suppliers on innovation output

Past literature in organizational learning has emphasized the potential knowledge gain from external sources, such as suppliers, customers, service providers, and alliance partners in a firm's supply network (Gao *et al*., 2015). Thus, supply networks serve as important conduits and sources of information and knowledge access, and act as catalysts for the development and dissemination of new ideas, applications, and supply chain practices. Typically, and frequently, suppliers are not exclusive and may also accommodate the needs of other buyers, some of whom may be competitors, thus they become shared suppliers. When a firm invests to improve quality at shared suppliers, the improved quality performance can spill over to benefit other firms because the shared suppliers may serve as informal channels for knowledge transfer (Alcacer and Chung 2007). Therefore, as the number of shared suppliers increases, a firm can gain access to more new information that is derived from a bigger pool of buyers (Martinez-Noya and Canal, 2018), which may help to create unique combinations of knowledge and increase innovation. In other words, a shared supplier may act as a hub of positive knowledge transfer where quality knowledge gets developed and spilled over to benefit the buyer, as shown in Muthulingam and Agrawal (2016).

Moreover, the growing paradigm of open innovation suggests that innovations are also derived outside a firm's internal endeavours, and that greater, more novel learning is often gained from external sources (Chesbrough, 2003). Accordingly, firms are recognizing the advantages of leveraging the innovativeness of their supply network partners to influence their own innovation output.

In addition, having multiple shared suppliers with other buying firms allows the firm to benefit from accessing more refined capabilities of the supplier due to the specialisation advantages resulting from the aggregation of demands from buyers (Jacobides and Winter 2005; Mesquita and Brush, 2008). Second, given that suppliers can act as a hub for knowledge transfers (Ahuja 2000), firms can benefit from the spillover effects stemming from competitors. Indeed, it has been demonstrated that there are firms that show a preference for suppliers that also deal with their competitors so as to benefit from these potential sources of knowledge spillovers (Alcacer and Chung, 2007).

Therefore, having higher levels of shared suppliers in a firm supply network allows the firm a wider reach and access to knowledge and information in the network, which would enhance their potential to receive knowledge spillovers better than others, and thus increases the possibility of higher innovation output.

Hypothesis 1: The more the shared suppliers in a firm's supply network, the more the firm's innovation output.

Direct effect of shared supplier centrality

Another factor that strongly influences buyer innovation in this context is how central shared suppliers are in the supply network (Ahuja *et al*., 2013). This shared supplier centrality can reflect the position of the supplier with respect to available knowledge residing in the supply network and the potential access to knowledge that has spilled over from other firms sharing this supplier, which would consequently benefit the buying firm's future innovation-based activities (Bellamy *et al*., 2020). Bellamy et al (2014) show that if a firm can effectively access information from an interconnected supply network, it can improve its innovation performance. This is facilitated if the buying firms works directly with suppliers having a high centrality in the network. In line with this, the more central a supplier position, the more likely it is to have better information about a larger pool of potential partners in the network (Gulati and Garguilo, 1999). Shen et al (2019) found that manufacturing firms with a high degree of network centrality tend to be connected to many partners.

Prior research has shown that centrality leads to creativity and promotes exploratory learning aimed at developing better product features. For example, Idiagbon-Oke and Oke (2020) found that there is a positive relationship between centrality and new product development outcomes in a dynamic manufacturing network.

Establishing network connections with central partners is likely to offer the potential for a firm to access their information and resources. It is important for firms to gain access to information and knowledge spillovers from other companies, which enhances innovation (Kim and Fortado, 2021; Martinez-Noya and Canal, 2018). This should facilitate access to information from multiple overlapping communication channels and develop complementary knowledge bases to increase the depth of learning and research. Rachinger et al (2019), in a case study of media and manufacturing industries, examined a central position in a network and its positive relationship with innovation.

Central firms are eager to establish infrastructures for innovative activities, enabling high-quality innovation (Kim and Fortado, 2021). They also learn about how others take part in innovative activities. Thus, a supplier with a high centrality is likely to leverage its ability to access external knowledge and increase the quality and impact of innovations. Therefore, the level of external knowledge available to a focal firm via the centrality of its shared suppliers beneficially influences its innovation output.

Hypothesis 2: *The centrality of a firm's shared suppliers positively influences the buying firm innovation output.*

Moderating effects of supplier's centrality

Suppliers' centrality also influences the relationship between the level of shared suppliers in a firm's supply network and the firm innovation. In other words, shared suppliers centrality indicates to the extent to which the buyer's suppliers connects them to other buyers or other suppliers. Kim and Fortado (2021) found that supplier centrality has a significant positive relationship with innovation value. Supplier centrality acts as a source of innovative activities because it allows a supplier to have access to external information and knowledge pools that cannot be easily obtained in a market (Kim and Zhu, 2018). The effectiveness of a firm's innovation output, due to its shared suppliers, will be influenced by how many other buying firms are sharing the supplier too. This reasoning stems from the idea that the more the supplier is being shared with direct competitors, the more accidental knowledge leakages are likely to happen (Alcacer and Chung, 2007), which would result in higher innovation benefits to the buying firm. This centrality measure suggests that as the number of buyers supplying from this shared supplier increases, the centrality of the supplier increases. This allows the shared supplier to gain access to new knowledge and information and it would be a determinant of the amount of information embedded in that shared supplier (Hutt and Walker, 2006). Moreover, a firm's innovativeness may be the result of interactions between a buyer and a supplier (Roy *et al.*, 2004). Through its interactions with several buyers within the same industry, a shared supplier can activate its own resources and develop new capabilities (Chowdhury, 2011).

In addition, the position of a firm in the supply network can influence the way in which the firm innovates (Ahuja, 2000; Narasimhan and Narayanan, 2013). More particularly, the position of a shared supplier within a supply network is important in realizing success in innovation efforts as the firm's position dictates knowledge flows and innovation potential outcomes. The number of direct ties that firms have with their network partners is a significant factor in superior innovation performance. Gulati and Garguilo (1999) argued that holding a central position in a network provides a firm with access to the knowledge held by their direct partners as well as their partners' partners.

Therefore, this study posits a moderating effect of the shared suppliers' centrality on the relationship between the buying firm's level of shared suppliers and its innovation output.

Hypothesis 3: The centrality of a firm's shared suppliers positively moderates the association between its level of shared suppliers and its innovation output.

4.9. Methodology

4.9.1. Data

The main purpose of this study is to understand whether the extent of shared suppliers that the buyer has in its supply network influence its innovation performance. This study also aims to assess whether the centrality of these shared suppliers influences the innovation of the buyer and whether it also influences the relationship between the level of shared suppliers and buyer innovation performance. For this reason, the sample for this study was drawn from the electronics and computers industry, which are industries that put pressure on firms to utilise the knowledge and technology of their partners to continually build product and process innovations that add customer value (Bellamy *et al.*, 2014; Kumar *et al.*, 2020; Basole and Bellamy, 2014). The electronics and computers sectors are very competitive and can benefit positively from partnerships with suppliers for innovation. For instance, Apple is a good example of a computer company that encourages supplier innovation. With the introduction of Apple's new chip, its supplier Adobe has quickly adapted and innovated new ways in their software to run natively on Apple computers with this new chip.

Thus, the supply networks of firms in the computers, electronics, and semiconductor manufacturing industries make a suitable setting since the interest is in the knowledge flow that arises from a series of buyer-supplier relationships. (Bellamy *et al.*, 2014).

These industries are knowledge-intensive, where firms increasingly rely on their knowledge assets and that of specialized suppliers in their supply network to produce innovative products (Sturgeon and Lee, 2001; Narasimhan and Narayanan, 2013). Firms like Hewlett-Packard and IBM have outsourced large parts of their manufacturing operations to contract manufacturers such as Solectron and Flextronics (Sturgeon and Lee, 2001). Also, these industries are characterized by macro-environmental factors that facilitate and encourage rapid technological change at the component, process, and final product levels as well as rapid industry growth (Sturgeon and Lee, 2001). Morever, they have an overlapping set of customers or, in other words, an increase in shared supplier networks along with a rise of strategic outsourcing.

This study builds on a dataset containing 96 public buying firms (focal firms) with their supply networks, resulting in a total of 4713 suppliers. From the 4713 suppliers, there are duplicates (due to same suppliers sourcing to several buyers); thus, 1933 is the number of unique suppliers in this dataset with 883 shared suppliers.

The largest public manufacturing firms were identified in Orbis in a way that they had a market capitalization above $6bn and had a primary business Standard Industry Classification (SIC) code of either SIC 35 (Industrial and Commercial Machinery and Computer Equipment), or SIC 36 (Electronic and other Electrical Equipment and Components (except Computer Equipment)). In total, 104 companies that matched the outlined criteria were obtained. In the data collection process, eight buying firms had to be dropped from the sample due to missing data or outliers which resulted in a final sample of 96 buying firms. The supply networks of these 96 focal firms were then identified using FactSet, which is a global database that collects interfirm relationship data from primary public sources such as investor reports, SEC 10-K annual filings and press releases. Both the relationships disclosed by the company as well as reverse relationships which are reported by their suppliers are included in the database. In the 96 supply networks, the shared suppliers were identified for all the buyers, this resulted in a total of 2012 shared suppliers. For all companies, focal firms, and suppliers, the innovation information was retrieved from Orbis. The variables are described below and the details about the multiple regression analysis is discussed in the next sections.

4.9.2. Dependent Variables

Firm innovation is captured as the firm's count/level of patent stock, also referred to as technological capital in prior literature, which represents the depth of a firm's technological resources (Bellamy *et al*., 2014). Patents are a widely used measure of the innovation performance of different companies (Liu *et al*., 2014; Potter and Wilhem, 2020). Patent stock has been used in previous studies looking at the technological impact, calculated as a firm's patenting activity during a specific period (e.g., Ahuja, 2000;

Bellamy *et al*., 2014; Carnovale and Yeniyurt, 2015; Sharma *et al*., 2019; Potter and Wilhelm, 2020). Patents are a commonly used measure of innovation output that reflect advancements over existing technology and are externally validated.

Consistent with the innovation literature in strategy journals (Singh, 2008; Alcacer *et al*., 2009; Lahiri, 2010; Funk, 2014), innovation performance can be understood by using the volume of patents that the firm has at a specific time. Therefore, the patent stock information was downloaded from Orbis. However, only 2019 innovation information could be collected before the university discontinues its subscription to Orbis. Thus, as an alternative way to capture innovation over the years was to use Espacenet which is a database that includes data on more than 130 million patent documents from around the world. Patent count per year was collected from Espacenet from 2015 to 2019 and averaged equally over the 5 years. The model run using Espacenet will be considered as a robustness test as it is regarded a good tool for searching for patent rather than analysis (Jürgens and Herrero-Solana, 2015). The results of the study using the data collected from Espacenet (which is considered as a robustness test) are presented in section 4.9.7.

Logarithmic transformation was used because there are some extreme values and a large range within the data. This is a common method to deal with extreme values within a dataset (Wooldridge, 2010).

4.9.3. Independent Variables

Commonality or sharedness percentage[4]

For each buyer, commonality is computed as such: it is the percentage of suppliers with a sharing degree of at least k. For instance, if k=2, this means that the supplier is shared by 2 companies, that is, the buyer and one other peer. For this study k=2, and the metric is defined as follows:

$$\text{sharedness percentage} = \sum 1_{k\geq 2} \Big/ \sum 1_{k \geq 0}$$

[4] adopted from Yixin (Iris) Wang, Jun Li, Di (Andrew) Wu, Ravi Anupindi (2021) When Ignorance Is Not Bliss: An Empirical Analysis of Subtier Supply Network Structure on Firm Risk. Management Science 67(4):2029-2048. https://doi.org/10.1287/mnsc.2020.3645

Intuitively, a zero value indicates no sharing of supplier with anyone, where a value between zero and one indicates the existence of some shared suppliers, and a value of one indicates that all of the buyer's suppliers are shared by at least one other company in the 96 buying firms peer network.

For example: If Amphenol has 9 suppliers and k=2

- 6 of these 9 suppliers, supply only to Amphenol
- Sogeclair supply to 1 other company too, hence a degree $k = 2 \geq 2$
- Monolithic supply to 5 other companies too, hence a degree $k = 6 > 2$
- Leoni AG supplies to 11 other companies too, hence a degree $k = 12 > 2$

Amphenol Corp	Eaton Corporation public LTD company	1
	Leoni AG	12
	Monolithic power systems, INC	6
	Sogeclair	2
	Brennan industries INC	1
	Penflex Corp	1
	Schroeder industries LLC	1
	Stucchi SPA	1
	Galileo Japan Trust	1

In this study, k=2

$$\text{sharedness degree} = \sum 1_{k \geq 2} \Big/ \sum 1_{k \geq 0} = 3/9 = 0.3333$$

Shared Supplier Centrality

Supplier degree centrality is the number of direct ties that flow to a firm (node) from its suppliers in the supply network. Adapting the approach used by Kim et al (2011), this can be defined as:

$$C_D(n_i) = \sum_j x_{ij} = \sum_j x_{ji}$$

where x_{ij} is the binary variable equal to 1 if there is a link between n_i and n_j but equal to 0 otherwise (Freeman, 1978). To account for the impact of network size g, degree centrality is normalized as the proportion of nodes directly adjacent to n_i:

$$C'_D(n_i) = (C_D(n_i)) / (g-1)$$

For each supply network, the shared supplier degree centrality was measured as the average degree centrality by taking the sum of the degree centralities of all shared suppliers and then diving the sum by the total number of shared suppliers for each buyer.

4.9.4. Control Variables

To capture any unobserved heterogeneity in the relationship between centrality, sharedness and innovation, some key control variables were considered.

For buying firm-level controls, the analysis includes buying firm's absorptive capacity, age, size, and its total number of suppliers (Bellamy *et al.*, 2014; Gao *et al*, 2015; Sharma *et al.*, 2019).

A firm's absorptive capacity is its ability to recognize, assimilate, and deploy outside knowledge and is a crucial element affecting its innovation output levels. Chu et al (2019) found that the positive effects of buyer-supplier proximity on supplier innovation are stronger when buyers are more innovative themselves. The own internal know-how will increase the marginal return to external knowledge acquisition strategies. This is indicative of the notion of absorptive capacity, introduced by Cohen and Levinthal (1990), which stresses the importance of a stock of prior knowledge to effectively scan, screen, and absorb external know-how. Research has suggested that a firm's absorptive capacity is largely a function of its investment in R&D and its level of prior related knowledge (Cohen and Levinthal,1990). The rationale is that firms conducting their own R&D are better equipped to make use of externally available information. Therefore, the measure of absorptive capacity relies on the readily available measure of investment in R&D as a proxy for a firm's ability to recognize and exploit new knowledge from external sources in their supply network (Cohen and Levinthal, 1990). Thus, R&D intensity was included as it can contribute to a firm's ability to absorb outside knowledge (Kim and

Zhu, 2018). R&D intensity was calculated as the R&D expenditures measured as percentage of total sales.

Firm size was also included, which is measured as the natural logarithm of the number of employees. Firm size may influence a firm's level of innovation output, as larger firms have more financial means and greater resources to invest in innovation-related activities than smaller firms (Bellamy *et al*., 2014).

Firm age was measured as the number of years elapsed between the year of the data collection and the founding date. It was included to account for knowledge and experience gained over time. Long-established firms may have a better understanding of how to utilize their shared supply network and derive valuable knowledge from them over the years. Also, older firms are expected to utilize more of their existing technological capabilities derived from their experience while younger firms are expected to experiment more with new technologies (Sharma *et al*., 2019).

Lastly, the firm's total number of suppliers was considered. A firm with more suppliers is more likely to have access to more knowledge which may result in better innovation performance (Sharma *et al*., 2019). Also, a firm with more suppliers is likely to have a higher degree of shared supplier in its supply network, allowing for improved access to information and resources, which more likely increases the innovation performance.

For the robustness test, shared supplier- level controls were added, the analysis includes main shared supplier's absorptive capacity and main shared supplier's innovation. Similar to the buyer level controls in the main model, R&D intensity was calculated as the R&D expenditures measured as percentage of total sales at the shared supplier level. As for shared supplier innovation, it was captured as the main shared supplier's level of patent stock.

4.9.5. Analysis

Table 12 presents the descriptive statistics and bivariate correlations of the variables. To reduce the concern of multicollinearity, and in line with established procedures, especially in the presence of interaction terms, related variables were mean centred before calculating the proposed interaction term that is used to test the hypotheses (Aiken and West, 1991). There is no observed issue of multicollinearity in this study. A multilevel hierarchical regression analysis was used to test the hypotheses, three models were constructed as follows: first, Model 1 is constructed, which is the baseline model, by only including the control variables. Second, the main effect variables were added to Model 1 to construct Model 2. Finally, the proposed interaction term was added to Model 2 to construct Model 3.

4.9.6. Robustness test data and analysis

This study also runs a multilevel data analysis to confirm the results in a way that for each supply network, one main shared supplier is selected. This selection criterion is based on the supplier that is mostly shared by the peer buyers. The reasoning behind running this robustness model is to confirm the results using another statistical test. The total number of main shared suppliers becomes 36 as some buying firms have the same main shared suppliers. Thus, the multilevel dataset contains 96 public buying firms or focal firms (level 1) nested within 36 main shared suppliers (level 2).

The nested data structure violates the assumption of the non-independence of observations in OLS and MANOVA (Aguinis *et al*., 2013). Therefore, a multilevel modelling (MLM) approach is used, and regression models are run with random intercepts and random first-order autoregressive slopes to test the hypotheses. Such techniques explicitly model the statistical dependence in the data and, therefore, provide reliable estimates (Aguinis *et al*., 2013). The random intercepts in these models capture shared suppliers' baseline values on the outcome variables: buyer innovation, and thus control for variance due to the nesting of buyers within shared suppliers (De Vries *et al*., 2021).

The regression estimates are, as such, corrected for any differences across shared suppliers that may partially explain an inherently higher or lower buyer innovation. Adopting MLMs, thus, enable to control for omitted Level 2 variables and, as such, address a leading cause of endogeneity (Ketokivi and McIntosh, 2017). The nature of the collected data further reduces endogeneity concerns regarding reverse causality.

To correctly apply MLMs, the steps recommended by Aguinis et al. (2013) were followed. First, the intercept only was modelled in Model 0, and subsequently the study covariates were added in Model 1. Next, to test H1, the main effect of shared suppliers' degree was added in Model 2. Then, the direct effect of supplier sharedness and supplier innovation was entered in Model 3 prior to entering their interaction effects, respectively, with shared suppliers' degree (H2) and (H3) in Model 4 (See Table 14).

To evaluate the fit of each model, the An Information Criterion was computed (AIC, typically referred to as Akaike's Information Criterion). The AIC is a measure of the goodness of fit and is used to evaluate MLM model fit given a set correlation structure, where a smaller AIC indicates better model fit (Aguinis *et al*., 2013). In addition to the AIC, the overall model fit based on the $R^2$and the change in R^2 were evaluated. Similar to ordinary least squares analyses, it denotes the amount of variance in buyer innovation that is explained by the estimated model compared to the intercept-only model.

Another reason for selecting this multilevel analysis as a robustness test for the main model is the importance of multilevel perspective in the SC domain (Carter *et al*., 2015; Ketokivi and McIntosh, 2017) that has been discussed in the SCM literature. In fact, SCM encompasses phenomena that exist both within and across organizations. As such, these phenomena often involve two or more hierarchically ordered levels. Consider, for example, a buyer–supplier relationship, this phenomenon has been largely examined from a macro perspective, in which the unit of analysis has been the organization or the relationship between organizations (Lanier *et al*., 2010; Bellamy *et al*., 2014). More recently, research has examined buyer–supplier relationships from a micro perspective, with individual relationships or team leaders as the unit of analysis (Easton and Rosenzweig, 2015). However, more than just these levels exist, the levels and constructs could be an individual (characteristics of a supply chain manager), a team, a function, a firm, a buyer–supplier relationship, or a supply network (see Figure 9). In the buyer–supplier relationship example, the analyses of these phenomena have mostly been confined to a single level, while one salient characteristic of buyer–supplier relationships is that these organizations whether buyers or suppliers are nested within networks. Therefore, in this study's context, it is suggested that buying firms are nested in networks of shared suppliers and the characteristics at one level (macro level or Level 2 or higher level) might influence characteristics at another level (micro level or Level 1 or lower level). This multilevel approach allows for an investigation of the impacts of both direct and interaction effects of continuous higher-level variables on lower-level outcomes (Aguinis *et al*., 2013). In this study, it is proposed that characteristics at the buyer level such as its degree of shared suppliers might be influenced by characteristics of the shared supplier, itself.

Although the use of multilevel research in SCM has increased in recent years, it is still highly underrepresented, particularly considering the complex nature of SCM phenomena and systems. A recent systematic literature review[5] from Carter et al (2015) where they performed a keyword search of the full texts of the articles in SCM journals revealed that only 40 SCM articles were published using a multilevel approach from 2002 to 2014.

Another way to check the robustness of the results in the third study was to compute the relative innovation performance of each buyer with respect to its closest competitor, this was done by using two criteria: firm size and firm three-digit SIC code. To search for the most competitor buying firm for each buyer in the 96 dataset, two steps were used, First, a rival buyer has to have an identical primary three-digit SIC Code as the focal firm. Second, the closest buyer in terms of firm size would be considered the focal firm's most competitor and therefore, the relative innovation of each buyer was computed relatively to the innovation performance of its rival. This allows to identifying whether the effects are more pronounced when looking at the how well the buyer performs in terms of innovation relatively to its closest competitor rather than taking the face value of its innovation output. The results of this robustness test are presented in Table 16.

[5] The related keywords: "multilevel," "multilevel analysis," "hierarchical linear modelling," "HLM," "nested data," "cross-level data," "level of measurement," "random coefficients models," and "Raudenbush" (because of the common application of HLM software in multilevel research) (Ozkaya et al., 2013). The journals include Decision Sciences Journal (DSJ), IEEE Transactions on Engineering Management (IEEE), International Journal of Logistics Management (IJLM), International Journal of Operations and Production Management (IJOPM), International Journal of Physical Distribution and Logistics Management (IJPDLM), International Journal of Production Economics (IJPE), International Journal of Production Research (IJPR), Journal of Business Logistics (JBL), Journal of Operations Management (JOM), Journal of Purchasing & Supply Management (JPSM), Journal of Supply Chain Management (JSCM), Manufacturing & Service Operations Management (MSOM), Management Science (MS), Production and Operations Management Journal (POMS), Transportation Journal (TJ), and Transportation Research Part E (TRE).

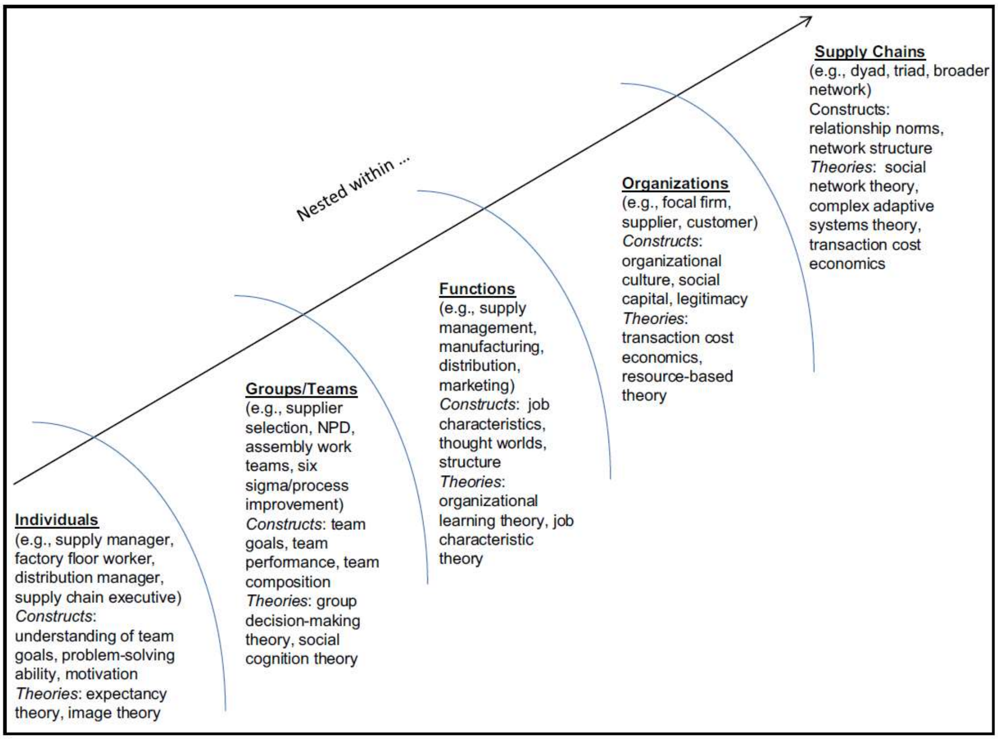


Figure 9: Hierarchical Nesting of SCM adopted from Carter et al 2015

4.9.7. Results

Table 12: Correlations, Mean and SD of all variables of Study 3

	Firm size	Firm age	Number of suppliers	R&D intensity	Shared Suppliers	Shared Suppliers Degree Centrality
Firm size	1					
Firm age	0.223*	1				
Number of suppliers	0.405**	0.279**	1			
R&D intensity	-0.277**	-0.255*	-0.125	1		
Shared Suppliers	-0.067	-0.013	-0.083	0.381**	1	
Shared suppliers Degree Centrality	-0.072	-0.247*	-0.203*	0.532**	0.458**	1
Mean	71850.52	53.13	49.09	8.63	0.806	0.003299
SD	101675.39	43.144	58.25	7.437	0.1688	0.00102

** $p<0.05$
* $p<0.10$

Table 13: Hierarchical regression results on buyer innovation performance

	Buyer Innovation		
	Model 1	Model 2	Model 3
Control Variables			
Firm size	0.789** (0.141)	0.728** (0.140)	0.720** (0.142)
Firm age	0.377** (0.110)	0.438** (0.110)	0.432** (0.111)
Nbr of suppliers	0.501** (0.114)	0.565** (0.115)	0.558** (0.117)
R&D intensity	0.028** (0.008)	0.019** (0.009)	0.019** (0.009)
Intercept	-0.565 (0.605)	-0.395 (0.605)	-0.321 (0.627)
Predictor Variables			
Shared Suppliers		-0.897** (0.376)	-1.088** (0.557)
Shared Suppliers Degree Centrality		141.638** (67.214)	189.681** (76.024)
Shared x Centrality			-129.591 (278.390)
R^2	65.5%	68.3%	68.1%
Adjusted R^2	64.0%	66.1%	65.9%
F statistic	42.783**	31.587**	26.865**
Change in R2 related to moderator	-	2.8%	0.1%
F statistic for change	-	3.825**	0.217
N	96	96	96

** *p<0.05*
* *p<0.10*

Robustness Test Result -1-

Table 14: MLM Results on buyer innovation

	Model 1	Model 2	Model 3	Model 4
Intercept	-0.506 (0.623)	-0.437 (0.635)	0.441 (0.663)	0.466 (0.666)
Independent Variables				
Shared suppliers		0.157 (0.319)	-0.185 (0.315)	-0.394 (0.433)
Main Shared Supplier Centrality			113.75**(34.50)	111.63** (34.54)
Shared suppliers X Main Shared Supplier Centrality				-72.508 (104.04)
Control Variables				
Buyer size	0.952** (0.131)	0.946** (0.132)	0.821**(0.131)	0.817** (0.131)
Buyer age	0.346** (0.106)	0.334** (0.108)	0.37** (0.102)	0.373**(0.103)
Buyer's total number of suppliers	0.0034** (0.001)	0.0034** (0.001)	0.0026** (0.001)	0.0024**(0.001)
R&D intensity (buyer)	0.031** (0.009)	0.0294**(0.009)	0.0214** (0.009)	0.0226**(0.009)
Main Shared supplier Innovation	-0.10* (0.049)	-0.106* (0.051)	-0.162**(0.05)	-0.166** (0.05)
R&D intensity (supplier)	0.0037 (0.0036)	0.0037 (0.0037)	0.0016 (0.0033)	0.0021 (0.0033)
Model Fit				
AIC	142.65	142.60	123.118	111.51
$adjR^2$	66.8%	66.9%	70.1%	72.8%
$\Delta adjR^2$		0.1%	0.2%	2.7%

** *p<0.05*
* *p<0.10*

Robustness Test Result -2-

Table 15: Robustness test results with Espacenet Data

	Buyer Innovation collected from Espacenet		
	Model 1	Model 2	Model 3
Control Variables			
Firm size	0.874** (0.249)	0.766** (0.254)	0.806** (0.255)
Firm age	0.004 (0.195)	0.057 (0.198)	0.084 (0.199)
Nbr of suppliers	0.421** (0.202)	0.527** (0.208)	0.560** (0.210)
R&D intensity	0.040** (0.014)	0.022 (0.017)	0.02 (0.017)
Intercept	-2.45** (1.071)	-2.044* (1.093)	-2.371** (1.127)
Predictor Variables			
Shared Suppliers		-0.640 (0.403)	-1.210 (0.506)
Shared Suppliers Degree Centrality		230.886** (121.5)	158.406 (136.554)
Shared x Centrality			577.378 (500.042)
R^2	34.0%	36.7%	37.7%
Adjusted R^2	31.1%	32.4%	32.6%
F statistic	11.612**	8.506 **	7.509**
Change in R2 related to moderator	-	2.7%	1.0%
F statistic for change	-	1.853*	1.333
N	96	96	96

** *p<0.05*
* *p<0.10*

Robustness Test Result -3-

Table 16: Robustness test results with relative innovation performance

	Buyer Relative Innovation		
	Model 1	Model 2	Model 3
Control Variables			
Firm size	-0.095 (0.243)	-0.134 (0.251)	-0.151 (0.254)
Firm age	0.473** (0.190)	0.513** (0.196)	0.501** (0.198)
Nbr of suppliers	0.494** (0.198)	0.535** (0.206)	0.521** (0.209)
R&D intensity	0.025** (0.013)	0.019 (0.017)	0.020 (0.017)
Intercept	-1.237 (1.046)	-1.125 (1.082)	-0.985 (1.122)
Predictor Variables			
Shared Suppliers		-0.571 (0.671)	-0.939 (0.994)
Shared Suppliers Degree Centrality		114.857 (119.664)	146.178 (135.344)
Shared x Centrality			-249.189 (495.114)
R^2	20.3%	21.2%	21.4%
Adjusted R^2	16.6%	15.7%	15.0%
F statistic	5.593**	3.859 **	3.315**
Change in R2 related to moderator	-	0.9%	0.2%
F statistic for change	-	0.513	0.253
N	96	96	96

** *p<0.05*
* *p<0.10*

Table 13 summarizes the multiple regression results. H1 predicted a positive association between the degree of shared suppliers in a supply network and buyer innovation output. The results did not support this hypothesis, the results suggested a negative significant relationship, instead ($B = -1.227$, $p < 0.05$; Table 13, Model 3). H2 posited that the relationship between shared suppliers' degree centrality and buyer innovation would be positive. The results support this hypothesis ($B = 180.746$, $p < 0.05$; Table 13, Model 3). With respect to H3, it posited that the relationship between shared suppliers' degree and buyer innovation would be positively moderated by the main shared supplier centrality. The results did not support the moderation effect ($B = -294.288$, $p < 0.05$; Table 13, Model 3).

Table 14 summarizes the MLM results. The model fit indices in Table 14 indicate that each of the estimated models fitted significantly better than the null model (Aguinis *et al.*, 2013). Each model further notably adds to the variance explained in buyer innovation as reflected in the ΔR^2 of each model, with the full model explaining a total of 72.8% of this variance.

H1 predicted a positive association between the degree of shared suppliers in a supply network and buyer innovation output. The results did not support this hypothesis ($B = 0.157$, $p < 0.05$; Table 14, Model 2). H2 posited that the relationship between shared suppliers' degree centrality and buyer innovation would be positive. The results support this hypothesis ($B = 111.63$, $p < 0.05$; Table 14, Model 4). With respect to H3, it posited that the relationship between shared suppliers' degree and buyer innovation would be positively moderated by the main shared supplier centrality. The results did not support the moderation effect ($B = -72.508$, $p < 0.05$; Table 14, Model 4).

With respect to Table 15 that presents the results using Espacenet database to collect patent data, the only significant result is shown in Model 2 ($B = 230.886$, $p < 0.05$) which further confirms the positive relationship between shared suppliers' degree centrality and buyer innovation. However, the results did not support the other hypothesis. This could probably be justified by the argument provided by City Library and Jürgens and Herrero-Solana (2015) that Espacenet is not the most common or ideal tool for analysing patent data mainly because of its number of limitations in the search interface. In regard to Table

16 that shows the results using relative innovation performance of each buyer with respect to its rival, the results did not support the hypotheses and were insignificant. A possible explanation could be the identification of rivals through industry standards using SIC codes which can be misleading given that one company can have multiple primaries SIC codes (Kim and Henderson, 2015).

Chapter 5: Discussion

5.1. Study 1

While the manifold benefits of physical proximity to suppliers such as reduced asset intensity, eased coordination and control or improved supplier relationships have been discussed in the literature (Dou *et al*., 2018; Bray *et al*., 2019), the effect of internal geographic dispersion on the relationship between physical proximity to suppliers and financial performance remains still unexplored. A more comprehensive understanding of this effect, however, is vital for the increasingly complex and global structures in which large firms operate (Lorentz *et al*., 2012). As shown by the results, spatial characteristics of the focal buying firm's internal operations may not only demand for simultaneous consideration of a firm's external supply network and its internal network as highlighted by the dual embeddedness literature, but it also requires assessing the financial implications of different external and internal network structures as complexity in the form of geographic dispersion can alleviate the benefits attainable from physical proximity to suppliers.

Previous studies on the performance impact of physical proximity have found that supply chain proximity is positively associated with the formation of strategic alliance programs and in turn, exerts a significant impact on the firm's ROA (Narasimhan and Nair, 2005). The results, however, reveal that physical proximity between the parent companies does not improve ROA for geographically dispersed focal firms, on the contrary, the cumulative effect is negative. This can be explained by the diminishing marginal profitability of the firm's total assets. While the operating revenue tends to increase with increasing global dispersion of operations, the operational cost related to inventory holding, warehousing and logistics are also increasing (cf. Lorentz *et al*., 2012), as are the firm's total assets. Given that no significant effect was found with regard to PMP, the overall effect is predominantly driven by a disproportionate increase in total assets (note that ROA can be decomposed in two interdependent factors, profit margin and asset turnover) which, in turn, reduces the asset productivity of the focal firm and, in consequence, its ROA. The disproportionate increase in assets can be traced back to the increase in the firm's global infrastructure of fixed assets that cannot be utilised as productively to leverage the benefits from physical proximity of the parent companies in terms of utilisation of suppliers' assets or knowledge spill-over. This is consistent with the assertion that lessened integration in highly dispersed internal networks hinders the effective processing of information which, in turn, compromises effective decision making with regard to the deployment of resources and the alignment of plans (Swink and Schoenherr, 2015). Similarly, in increasingly dispersed internal networks, coordinating production schedules with suppliers and collaboratively managing the flow of materials and information at the firm-level becomes much more challenging, which is likely to alleviate the benefits of physical proximity of the parent companies in terms of current assets. Consequently, geographically dispersed focal firms experience comparatively higher levels of current assets within the internal network, mainly in the form of inventories held across an increasing number of locations to balance less effective production coordination and less synchronised material and information flows (Johnson and Templar, 2011).

Considering firm performance through cash flow to sales ratio, the same negative moderation effect was observed for the proximity of supplier and focal buyer networks as a whole, accounting for the focal firm, its suppliers and all their subsidiaries. Thus, physical proximity between the suppliers' and internal networks does not benefit geographically dispersed focal firms as much in terms of CFSR which can be explained in a similar way as the ROA effect. An increasingly global internal network of the focal firm that exhibits a high level of physical proximity to the supply networks requires a larger amount of infrastructure in terms of fixed assets. This, in turn, affects the firm's capital expenditures necessary to acquire and maintain these assets. According to the results in this paper, the necessary capital expenditures of globally dispersed internal networks cannot be compensated by a comparable increase of the focal firm's operating revenue which leads to a lower CFSR. Thus, even when there is physical proximity to suppliers at the network-level, the attainable benefits do not seem to pay off when the level of dispersion is too high. Moreover, given that the overall effect seems to be driven by investing activities and more precisely the capital expenditures (please note that a similar effect for the cash flows from operating activities was not observed), negative moderation effect of internal global dispersion seems to be predominantly caused by the amount of fixed assets required (as compared to current assets).

Previous literature has mainly highlighted that physical proximity to suppliers seems to be essential to guarantee the coordination of physical and information flows between the supply chain activities and to acquire shared resources that allow for an efficient solution of the day-to-day problems (Narasimhan and Nair, 2005; Cousins *et al*., 2008). An increasing dispersion of the internal network, however, may counterbalance these efficiency effects at the network-level. Colotla et al. (2003) suggested the existence of interdependencies between plant level and network-level capabilities and demonstrated that factory and network capabilities may complement or offset one another, depending on the international manufacturing structure adopted by the firm. In line with this, the results show that when spatial complexity of the internal network continues to grow, the relative benefits of physical proximity to the supply network are impeded, and in turn, the efficiency of activities is reduced. One of the driving forces of subsidiaries is to increase access to markets (Rugman *et al*., 2011) but they could also play an important role in the company's efforts to access the suppliers' resources and capabilities (Demeter *et al*., 2016). An increased spatial dispersion of the buying firm's internal network of subsidiaries could thus offer location advantages at the output side by fostering sales through the subsidiary network as well as at the input side by mediating the firm's access to supplier's knowledge and capabilities and improving communication and coordination through the subsidiaries' proximity to their suppliers. At the same time, however, the increased structural complexity at the network-level will eventually exhaust managerial capacity leading the firm to face difficulties and increasing expenses (Lu and Shang, 2017). Operating a globally dispersed network, the focal firm's supply chain management needs to be capable of bundling location advantages of a larger number of countries with internal resources controlled by the subsidiaries and of coordinating a more granular value chain across specialised subsidiaries located in different countries (Rugman *et al*., 2011). If there is not sufficient managerial capacity and expertise to handle these increasing requirements, established processes and schedules can no longer be maintained and the efficiency decreases. Moreover, decisions related to internal and supply networks are often made independently at different times and by different people which imposes additional challenges in terms of integration and alignment.

This is not trivial. Companies that take advantage of the physical proximity with their suppliers through increased knowledge flows are also those that tend to be more geographically dispersed (Whittington *et al*., 2009). Not considering that trait of the firm ignores the pressure on investing in getting a benefit from the physical proximity with suppliers, while at the same time, operating in a global context. This point is particularly salient in this paper's sample of computer and electronics manufacturers. These results also relate to the concept of structural embeddedness, which indicates that the network configuration might allow for important new information to reach the network (Uzzi, 1997). However, a complex configuration can invite more ambiguities than benefits (Kim *et al*., 2011). Therefore, it is important for multinational companies to be aware of potential high levels of internal complexities and to actively manage their networks to avoid negative effects.

5.2. Study 2

The second study is an attempt to better understand the structural complexity of buyers' networks and its effects on operational and sales performance of suppliers. Overall, as expected, the findings reveal a significant relationship between the complexity of buyer networks and supplier performance. The results show that the consideration of complexity at the downstream side is important and offers new insights to the supply chain complexity literature. Also, as expected, the results support the argument that the significance of the internal complexity of buyers' networks does result in a differential effect when looking at the structure of these networks.

Horizontal complexity

At the horizontal complexity level, the greater structural complexity stemming from the direct links to the buyers as parent companies results in more sales benefits to the supplier. This result is consistent with the marketing literature (Achlor and Kotler, 1999; Lee *et al*., 2011; Lee *et al*., 2015), yet it does not necessarily harm operational performance as suggested in the operations literature (Bozarth *et al*., 2009; Vachon and Klassen 2002) and in the hypothesis. The results show the opposite; the horizontal complexity of downstream networks is beneficial in terms of both sales and operational performance of the supplier. These positive effects of having a wide base of direct Tier 1 buyers can be related to the more transactional relationships and simpler exchange contexts that the supplier operates in with a very wide buyer base, rather than a supplier that concentrates on exchange with a more restricted number of major buyers (Kim, 2017; Jhang *et al*., 2021). However, the operations literature overlooks the positive impacts because the focus is on product complexity (Wan *et al*., 2012; Blome *et al*., 2014), supply network complexity (Lu and Shang, 2017; Sharma *et al*., 2019), and supply chain complexity (Vachon and Klassen 2002; Bozarth *et al*., 2009) rather than detail or structural complexity of downstream, in isolation. The results prove that distinguishing upstream and downstream complexity is of great importance as these different levels of observation maintain idiosyncratic features.

At the network-level horizontal complexity, that includes the internal networks of downstream buyers, the results suggest that the greater the internal network complexity that the supplier experiences in its buyer networks, the less efficiency benefits with regards to cash and sales performance. This additional structure that is not always visible to the supplying firm forms additional complexities that have a large negative impact on the supplier's sales and operational performance. This can be due to the potential higher volume of orders that may strain a firm's ability to cope, resulting in lower sales and longer operating and cash cycles. This goes in line with the discussion in the international business literature on the negative impacts of a firm's increased commitments to bigger subsidiary structures (Tallman and Li, 1996; Lu and Beamish, 2001) which focuses on the increased number of internal transactions and costs that can outweigh potential benefits. This translates to the supplying firm as these buyers' subsidiaries require additional adoption, coordination, and communication costs, making it difficult to the supplier to obtain the gains associated with widening its buyer network to benefit from the access to larger number of entities (Achlor and Kotler, 1999). Thus, this research proves that managing the increasing internal network complexity of downstream entities is a burden for supplying companies (Bozarth *et al*., 2009) and understanding these structural links among its buyers, the buyers' subsidiaries, and itself is crucial.

<u>Vertical complexity</u>

From a vertical complexity perspective, complexities due to a layered structure of internal network were expected to contribute to negative operational effects. The results, however, show the opposite. In fact, they show that positive effects are derived from vertical complexity which relate to the layered or tiered ownership links of buyers and their subsidiaries. This ownership structure can benefit the supplier as it gives them the ability to request upfront payments or deposits from their direct buyer which govern this layered structure below. Indeed, as mentioned previously, this type of layered network allows the parent company to have a more influencing role (Achrol and Kotler, 1999) and would, in a lot of cases, govern the subsidiaries' activities and operations. In other words, when suppliers work with buyers that oversee higher number of tiers of subsidiaries, the agreement on credit terms becomes easier and more straightforward in comparison with dealing with multiple buyers having less tiers in their internal network (Cen *et al*., 2017). The results show the same effects on sales and operational performance.

Prior studies of supply chain complexity have largely focused on network complexity at the upstream level with different tiers of suppliers. Vertical structures captured by the depth of upstream supply networks were found to cause failures for the focal firms (Bode and Wagner, 2015; Lu and Shang, 2017). Although vertical complexity is captured at the downstream level and is related to the tiers of subsidiaries, the results were able to uncover another side of vertical complexity, where the impacts are advantageous to the focal firm. As previously noted, the effects of vertical complexity at the downstream level are not well understood. This study offers evidence that buyer base vertical structure which includes the internal layers of several subsidiaries significantly influences the supplier's sales and operational performance and therefore, reinforces the perspective that complexity is not always bad. The depth of the subsidiary structure, in contrast to its breadth, results not only in more sales, but also, in operational efficiencies to the supplying firm. The results imply that there are more nuanced outcomes when studying downstream complexity and considering these different dimensions.

Spatial complexity

In terms of spatial complexity, higher buyer network variety stemming from geographical dispersion of buyer's internal network is found to increase operating cycle and cash-to-cash cycle times, thus slowing cash turnover for the supplier. With diverse buyer network consisting of various subsidiaries spread over the world, turning over inventory becomes slower, and just-in-time inventory management becomes harder to manage (Lorentz *et al*., 2012). As expected, these negative effects could be triggered by the highly dispersed internal network of these buyers for several reasons such as increased transaction costs (e.g., production, inventory, logistics, and communication), reduced efficiency, long and unreliable lead times, and difficulty in schedule attainment (Choi and Krause, 2006; Lu and Shang, 2017; Vachon and Klassen, 2002). These results contribute and add to the previous literature on spatial complexity (Lorentz *et al*., 2012) that higher heterogeneity intensified from geographical dispersion at the buyer internal network-level increases cash-to-cash cycle times. This downstream complexity reduces the supplier's ability to maintain high levels of buyer satisfaction and meet a variety of demands and requirement with buyer having high levels of internal complexity. In addition, extending payment time may be unavoidable in an international business context where regional and cultural differences may affect the process of turning inventories into cash (Lu and Shang, 2017). For example, less advanced payment methods and a culture of extended payment times may increase the average amount for accounts payable (Farris and Hutchinson, 2002), particularly when subsidiaries are considered as part of the process. The results suggest that the increased geographic dispersion in downstream networks that include the internal network of subsidiaries may expose the focal firm to nationally fluctuating payment standards and practices and an increased buyers' payment time. Subsequently, this may also increase average payment times to suppliers. Additionally, as inventories are expected to increase with increased geographic dispersion (Lorentz *et al*., 2012), the results also prove that the operating cycle time and cash-to-cash cycle time increase as the dispersion in the buyer network is introduced by the internal network.

Furthermore, establishing collaborative relationships with geographically dispersed entities becomes harder and highly consuming in terms of resources and time, as a firm can develop only a limited number of close relationships (Kim *et al*., 2013; Kim, 2017). In transactional exchange, the buyer and supplier tend to be independent, their relationship relatively weak and several alternatives typically exist, making partner switching easier (Terho and Halinen, 2012). In relational exchange, however, adaptations to the relationship-specific investments and social exchange build a strong relationship and create interdependencies between the parties making partner switching much more difficult (Kim and Kumar, 2018). This type of relationship/exchange could be explored even further in future research.

In addition, the results support the argument that not all sources of complexity produce negative effects and need to be reduced to lowest possible levels (Blome *et al*., 2014). In particular, this study prove that direct buyers' complexity may create sales and operational efficiencies for supplying firms, but this effect would not be the same when considering it at the internal network-level of buyers. In line with this, the results show that supplying firms that have high levels of complex buyer internal networks should intensely manage their downstream side of the supply chain (Romo and Schwartz, 1995) and know specifically who their buyers are.

5.3. Study 3

The third study brings attention to the simultaneous consideration of supplier sharedness and centrality that may, <u>together</u>, increase the innovation benefits to the buyer. The results offer new insights into the relationships among shared suppliers, suppliers' centrality and buying firm innovation.

First of all, contrary to the hypothesis, the extent of shared suppliers in the SN has a negative effect on buying firm innovation output. Whereas prior literature highlights the benefits of sourcing from shared suppliers (Qi *et al*., 2015), this research indicates that exclusive supplying firms may be better able to leverage their ties with other network members to support buyer innovations. This could be because working with a supplier that also works with other buying firms can sometimes impede or delay the development of new products. This indicates that sharing suppliers can be a double-edged sword that might help to facilitate access to quality knowledge but has a negative effect on the development of breakthrough new products. This also implies that buying firms that do not have too many shared suppliers in their SN might make better use of their exclusive suppliers to access valuable knowledge for the development of their ideas and innovations. Moreover, this negative result signals the importance of paying more attention to the role of exclusive versus more shared supplying firms in the SN, as a less studied topic in the supply chain innovation literature (Kim and Fortado, 2021; Muller and Peres, 2019). The negative effect also might arise because buyers with multiple shared suppliers tend to be allocators that distribute standardized requirements and needs to multiple suppliers, without truly fostering effective interfirm innovations (Sharma *et al*., 2019). Furthermore, with large number of shared suppliers to handle, a buying firm may be flooded with information coming from them and this might direct the buyer to focus on a limited set of alternatives that might narrow innovation outputs (Ethiraj and Levinthal, 2004). Moreover, due to the uncertain and complex nature of the innovation process (Sharma *et al*., 2019), it is not that easy to evaluate innovation benefits that result from a large network of suppliers that are being shared with other buyers. In other words, new product development and establishing novel ideas with suppliers can be highly consuming in terms of resources and time (Chae *et al*., 2019), thus, a large, shared supply network will not necessarily contribute to a better innovation outcome in comparison to a smaller one.

Second, this study sheds lights on supplier centrality when buying firms search for critical input on innovative technologies and processes. Supplier centrality, which is linked not only to direct connections but also to indirect connections, can serve as a source of access to knowledge spillovers and external resources. This is crucial for buyers as the advantages of sharing suppliers with their peers are only fully realized when multiple channels in the network of shared suppliers are tapped. This is because performance in supply chains is deeply embedded in other suppliers and buyers that are operating in the connected networks. In other words, buying firms must be aware that a partner's partners in a network are part of the supply network and the associated innovation process (Kim and Fortado, 2021). The results of this study confirm the argument on the importance and the positive effect of the shared suppliers centrality in enhancing the impact of innovation. This study shows that a supplier has to be shared and has to hold a central position in the network to be able realize the potential innovation benefits. Muller and Peres (2019) argue that the growth of an innovation in a social network is shaped by the network's structure. At the aggregate buyer's SN level, networks with many high-degree centrality nodes are more connected. At the individual supplier level, a node's degree centrality in the network is positively correlated with its ability to spread content and ideas throughout the network (Muller and Peres, 2019). The more central the member of the network is, the stronger will be the innovation adoption pathway. For example, an opinion leader with high degree centrality will have more access to information and therefore his/her impact on awareness and network externalities will be stronger than that for a peripheral network member. This applies directly to the supplier context, when the shared supplier is more central, or when the number of direct ties to the shared supplier increase, it will likely provide a marginally higher quantum of new information that was not already available to the buyer (Ahuja, 2000; Kim *et al*., 2020). Recently, given that innovation efforts are primarily driven by the buyer's SN, the results show that it is not only about the extent of shared suppliers in the network, but the benefit is also more related to the how central these shared suppliers are. It is important to note that these two network features in the third paper research setting, together, make it attractive to analyse the innovation outcome domain. Shared suppliers with high centrality are often regarded as navigators that can quickly reach other organizations within the supply network, including those with which they are not directly connected, using relatively few path lengths within the supply network (Kim *et al*., 2011; Marsden, 2002). These centrally positioned firms often have the ability to efficiently absorb knowledge from hard-to reach parts of the network, which they then can use for their own innovation activities (Potter and Wilhelm, 2020).

5.4. Endogeneity issues

With respect to the first study, certain measures were taken to account for potential issues of endogeneity arising in the model. There is a possibility that firms exhibiting high returns may select or come to occupy a close location to their suppliers and their subsidiaries and influence its suppliers to become geographically and physically closer. This type of endogeneity is usually called reversed causality. The analyses are based on observational data in a pooled cross section; thus, the results should be treated carefully. Statistical methods cannot resolve questions of causality, i.e., we cannot imply whether physical proximity to suppliers leads to higher performance, whether firms with outstanding performance are more likely to collocate with their suppliers, or whether the relationship is of a reciprocal nature. However, a common practice in applied econometrics work involves replacing a suspected endogenous variable with its lagged values. Lagged performance variables might infer certain causality in this relationship, i.e., there are performance gains attributable to physical proximity. This means including the lag of the dependent variable on the right-hand side to account for any possible dynamic endogeneity. In this paper, the lag of the performance variables was included in the model to make sure the relationships still hold after adjusting for past performance, which is the case in the test. Results are summarized in Table 21. Hence, reverse causality in study 1 may be viewed as less of a concern.

Another empirical strategy used in the literature (Lu and Shang, 2017; Shang *et al*, 2017) is to collect and construct control variables that are claimed in the literature to affect both financial performance and physical proximity to supply networks. Control variables provide an important method for controlling for endogeneity in statistical models with multidimensional heterogeneity and can be used instead of instruments. In other words, this approach attempts to include variables in the regression that if omitted, could cause endogeneity concerns. The models in the second and third studies contain many controls for such confounding effects.

In their paper to tackle the issue of endogeneity in operations management research, Ketokivi and McIntosh (2017, pp. 6-7) suggested two important points: "Applying instrumental variables amounts to trading one set of untestable assumptions for another, and using a bad instrument may well make things worse than sticking to OLS" and "Because consistent estimation under instrumental variables rests on this correlation being zero, there is no way to guarantee that the instruments have actually provided any protection against endogeneity." Therefore, instrumental variables can be useful, but the difficulty in their assumptions and application might outweigh their rewards. However, even with a set of controls, it is unlikely to completely eliminating endogeneity (Avgoustaki and Frankort, 2019).

Chapter 6: Conclusion

6.1. Theoretical Implications

The first study offers two theoretical contributions. With respect to research on supply networks, this study has helped move the discussion beyond the impact of supply network complexity on performance. Supply network complexity has negative consequences on responsiveness (Choi and Krause 2006), delivery speed (Vachon and Klassen, 2002) and frequency of supply chain disruptions (Bode and Wagner, 2015). However, when studying supply network complexity, previous studies have not considered the geographically dispersed internal network of the focal firm that captures the internal complexity. In the first study, this consideration has allowed to draw a more complete picture of these networks because internal networks do not only play a key role in managing the supply network but also, can complicate the overall coordination of material and information flows with suppliers. This study has shown that, for multinational companies, proximity to the supply network may be matched by an internal network spatial complexity that negatively impacts firm-level performance as the marginal profitability of the additional subsidiaries decreases.

With respect to dual embeddedness, this study has revealed that the improved subsidiary performance, that has been shown in previous studies, may be offset by the increased spatial complexity of the subsidiary network at the firm-level. By using a large secondary dataset, this research is the first empirical study that examines the firm-level effects of this dual embeddedness considering firm-level financial performance, thus extending previous findings of operational performance in the literature (e.g., Stock *et al*., 2000; Kim, 2014; Demeter *et al*., 2016) and relational embeddedness of the subsidiaries (e.g., Golini *et al*., 2016; Achcaoucaou *et al*., 2014; Demeter *et al*., 2016; Cenamor *et al*., 2019). Furthermore, the reducing financial returns reveal an explanation for the conflicting results of the effects of embeddedness on performance in the past literature. From this standpoint, the seemingly inconsistent findings can be reconciled as follows: a buyer's internal spatial dispersion can slow down the expected returns from collocating with suppliers. In other words, the complexity emerging from dual embeddedness in supply and internal networks can lead to actual financial repercussions at the firm-level. The costs to manage business complexity can greatly affect the focal firm's operations and hurt its financial performance. Thus, these results warrant further investigation of embeddedness across various contexts of supply chain relationships and networks.

Moreover, the second study makes three major theoretical contributions to the existing literature. First, it expands the understanding of supply chain structure by channelling the focus from the supply base dimensions to the buyer base level. The buyer network has important performance impacts on the supplier (Kim, 2017), a side of the network that has been ignored empirically. Thus, this study may address calls from existing literature to examine how buyer network complexity dimensions relate to supplying firm performance (Patatoukas, 2012; Kim, 2017).

Second, by also emphasizing the buyer's not-so-visible internal links that have been ignored in the past, this study extends the conceptualization of network complexity and provides a more comprehensive set of structural dimensions. This study further verifies the benefits of network complexity to analyse sales performance in a new industrial context (Lau and Zhao, 2022).

Third, this study suggests that unlike the more dominant perspective on supply networks, that complexity hinders performance, the relationship on the buyer network side is more complex and often not so straightforward, especially when looking at both supplier's sales and operational performance. The results show that the complexity of the subsidiary structure overwhelms suppliers sales and operational performance whereas complexity at the parent company structure benefits both.

While the second study support the complexity perspective, it suggests that the outcome at which complexity is examined (sales vs operational performance), also matters. However, the results of the second study reveal that the sales and operational outcomes are complementary rather than conflicting and their value is evident in different dimensions of network complexity. Horizontal and vertical complexity of buying firms may be effective only when dealing with the parent company per se, in comparison to a network of buying parent companies and their subsidiaries. Thus, when dealing with large network of subsidiaries, the complexity of managing all these entities outweigh its benefits. Uncovering accurate reasons for these changes in impacts due to the subsidiary structure would be an interesting avenue for future study in relation to downstream networks.

With respect to the third study, the results suggest that there exist considerable benefits to gaining visibility into a shared supplier position in the extended network of suppliers and peer buyers.

First, this study contributes to the supply chain management literature, especially within the area on common/shared suppliers as it is one of the first empirical studies to employ large-scale data on firm-to-firm relationships by focusing on the shared linkages. Despite the rich analytical literature on common/shared suppliers, empirical research in supply chain management—particularly the innovation outcomes due to a shared supplier network—is relatively scarce.

Second, this study expands the supply network literature by exploring how supply network characteristics influence buyer innovation outcomes. Starting from the argument that suppliers retain knowledge that is often not available to buyers (Cassiman and Veugelers, 2006; Chowdhury, 2011), buyers can leverage supplier knowledge to create innovative products (Narasimhan and Narayanan, 2013; Wagner, 2006b) and ultimately improve their own innovation performance (Azadegan and Dooley, 2010). A lot of the previous studies looked at network characteristics as a key influence for supplier innovation performance whereas a few of them considered how this gain translates to buyer innovation. There are two reasons for this: 1) knowledge transfer from buyer to supplier has been studied repeatedly in the supplier development literature stream (e.g., Krause and Ellram, 1997a; Wagner, 2006b) and has been the main focus rather than supplier to buyer, 2) although existing research provide rich insights into how suppliers can contribute to a buyer firm's competitive advantage, most focus on the dyadic relationship between the buyer and its key supplier (Zhou *et al*., 2014; Gao *et al*., 2015) and less attention has been paid to the broader supply network, which consists of multiple suppliers.

Third, the third study presents one of the first empirical papers to combine two network features: sourcing from a network of shared suppliers and shared supplier centrality. This study drives the network characteristics debate further and brings to the SN literature an additional network effect which is the centrality of these shared suppliers that significantly influences the buyer innovation performance. While both sharedness and centrality in networks have been examined separately (Muthulingam and Agrawal, 2016; Wen *et al*., 2021; Potter and Wilhelm, 2020), none of the past studies considered them together and explored the impact of both.

6.2. Managerial Implications

From a managerial perspective, the results of the first study invite managers to carefully weigh the advantages of having physical proximity to suppliers, including those through their subsidiaries, and the challenges of having an extensive internal network of subsidiaries. These results suggest a need for strategic planning that considers the interaction of internal and supply network. Moreover, managers should think of the firm-level impact of dual embeddedness, in addition to subsidiary-level performance as a result of it. This paper, therefore, provides insights into aligning supply and internal networks more effectively. Another interesting issue highlighted by the results is one that is not discussed enough in the operations and supply chain management literature, which is the extent to which multinational companies, whether buyers or suppliers or any entity in the supply chain, must reflect on the challenges of internal complexity and the associated consequences on performance. Managers must be aware of the source of complexity in order to identify complexity reduction tools to simplify their strategies and processes. As visibility of the supply and internal networks as well as of the interconnections between them is essential to identify and reduce complexity, managers need to systematically obtain information about their upstream and internal operations.

By understanding the spatial complexity of internal networks and managing them consciously, firms can benefit from physical proximity to their network partners and put into practice successful mechanisms for an efficient interaction with them (Dyer and Nobeoka, 2000). This is useful- not only for the focal firm, but for supply network partners as well, as it may enhance their own performance. In line with this, the first paper offers an understanding of supply chain management challenges when network complexities increase.

The second study allows to uncover additional network complexities due to the subsidiary structure that must be accounted for carefully by managers. “If you are in supply chain management today, then complexity is cancer you have to fight.” This statement is from a previous supply chain operations’ vice president of Coca-Cola’s in the region of North America (Gilmore, 2008). Therefore, complexity is not a relevant topic among academics only, but also among managers of large companies. By attracting large buying firms and, subsequently, their subsidiaries around the world, managers of supplying firms tend to ignore the unobserved complexities associated with that, although not necessarily unobservable. Understanding the operational and sales implications of having large networks of buyers allows suppliers to set reasonable expectations and hence reduce frustration when it comes to their relationships with their buyers. The findings of the second study of this dissertation suggest that structural complexity at the buyer parent company level is not issue, however, when these complexities occur at the subsidiaries' level, the supplier starts seeing inefficiencies in terms of sales and operational outcomes. To reduce such risks, the supplier needs to understand the multidimensional structure of the buyers networks beyond immediate ties and the ownership composition of the buyer's internal network, if possible. This is important as it encourages managers to pay more attention to their customers side, i.e., the buying firms' network structure that includes the subsidiary structure.

The third study brings novel managerial insights and suggests that buyers need to be aware of the potential impacts resulting from the collaboration with suppliers. Buyers may choose to buy products from a shared supplier, from an exclusive supplier or make the product inhouse. The findings suggest that while collaborating with shared suppliers seemed to be a strategic decision for buyers, managers of these buying firms should pay attention to the supplier's overall position in the network and its degree centrality. Specifically, a buyer that shares suppliers with its peer buyer will have a higher innovation value only if these shared suppliers hold a central position in the network. Additionally, the findings suggest that a decision to outsource to a shared supplier without accounting for the centrality of this shared supplier might be misleading and may miss an opportunity to derive the capabilities needed from a shared and a central supplier that are needed for innovation outcomes. These insights are relevant for managers because they provide indirect awareness about the impacts of spillovers that occur at shared and central suppliers. Extending these key points in the context of SCs, the third study advances the notion of supplier network position relative to peer buyers and other suppliers in the network, which is of crucial importance when it comes to innovation as it can be related to the stock of innovation outcome of the buyer.

In sum, the three studies provide specific network structural considerations that can help inform the focal firm whether the supplier or the buyer about selection practices for developing a favourable network structure for better firm financial, operational and innovation performance.

6.3. Limitations and Future Research Directions

The first study has demonstrated the importance of considering a multinational corporation's supplier and internal networks simultaneously to understand their impact on financial performance. The complexity of the subsidiary network may overwhelm the benefits gained from the physical proximity of the firm with its suppliers. This is perhaps even a bigger issue when subsidiaries help the firm connect to its suppliers. Although several past papers have studied the relationship between proximity of the firm with its suppliers and performance, the internal networks of subsidiaries have mostly been ignored. The possible interaction between the internal and supply network has been acknowledged in dual embeddedness research. Yet, the structural embeddedness of this subsidiary network and even further the firm-level impact of dual embeddedness has not been explored. The first research of this dissertation has investigated this discord. This study has empirically shown the interaction between supply and internal network and its effect on firm-level financial performance in the supply chain context. It also has offered new insight into the impact of dual embeddedness at the firm, rather than the subsidiary-level. The results proved that a firm has to consider the spatial complexity of its internal network beyond just building relationships and collocating with suppliers.

While the first paper uncovers insightful findings, it has also limitations. One limitation is that it did not consider the issue of absorptive capacity since knowledge or information transfer between internal and supply networks was not measured. Therefore, the results are conservative implying a potential for knowledge flow and transfer when networks are collocated. However, whether knowledge is successfully shared is also dependent on additional factors such as absorptive capacity, communication channels and joint innovations. Future studies can examine the aspects of the interaction between the two networks by measuring absorptive capacity of subsidiaries and dig further into other characteristics that may impact a subsidiary's ability to grasp knowledge from internal and supply networks.

In addition, other contextual factors were not taken into consideration in this study. In this respect, this study underscores the need for further investigations of internal and supply network complexity as well as further considerations of the multi-dimensional nature of complexity by looking at more or other measures such as product, cultural or subsidiary type complexity. Indeed, while various types of subsidiaries can be found within a global network, future research could offer a more thorough examination by explicitly focusing on the type or level of subsidiaries per se. To obtain more insights on how to manage dual embeddedness at the firm-level, future research can use qualitative studies that map the processes and capabilities that MNCs need to ensure that the benefits of dual embeddedness are not offset by the complexity of an extensive subsidiary network.

Last but not least, the use of cross-sectional data in this paper limited the ability to examine a causal relationship among variables and infer the time lag between physical proximity, geographic dispersion, and changes in performance. Future empirical studies may conduct a longitudinal study that would allow researchers to understand the causal effect of embeddedness on desirable outcomes and outline the progress of a company. The use of longitudinal data would be a suitable starting point for generalizing the results of this study.

With respect to the second study, future studies could consider the buyer-supplier relationship quality and time to assess whether these impacts stay the same in such context. The investigation of the impact of buyer-supplier relationship quality and/or time on the link between downstream complexity and operational performance is crucial as both could play a key role in moderating the complexity level resulting from these downstream entities. The relational dimension, in contrast to the structural dimension, describes the quality of relationship between the two parties (Kim *et al.*, 2014) and is necessary because it influences behaviours in dyads and in networks. Considering this relational side, which includes the duration and quality of this relationship allows to map the discrepancies and provide a basis for exploring new insights on downstream networks. Rauyruen and Miller (2007) suggested that relationship quality includes trust, commitment, satisfaction, and service quality and found that these factors influence B2B customer loyalty. Hence, future research should investigate the interplay/interaction among these factors to obtain a better understanding of trade-off relationships. Second, the current study underlines the downstream complexity on sales volume and gross margin as measures of sales performance, while operating cycle and cash conversion cycle were measures of operational performance. Future research can implement a similar analysis strategy with similar complexity dimensions but consider a broader set of critical performance metrics such as cost, quality, delivery, and flexibility as measures of operational performance (Lu and Shang, 2017). Third, Tier 1 buyers for the 96 supplying focal firms were only considered since, for many firms, it is hard to collect supply chain data beyond Tier 1 level. Considering more buyers' tiers per supplying firm could help future researchers better understand the impact of downstream network complexity on performance (Bode and Wagner, 2015; Sharma *et al.*, 2019). Furthermore, complexity in a network may increase considerably when considering the buyers of these buyers in the supply chain, therefore, future research may attempt to overcome this limitation in the data. In addition, the results show that the subsidiary structure in the buyer network influences the supplier performance by increasing the burden on the operations and negatively affecting the sales. However, a limitation in this study is that it did not capture whether the subsidiaries of the buyers are actually also buying from the supplier. This is a limitation related to the data collection that did not allow to tap into the flows between subsidiaries and suppliers. The argument in this study relies on the potential of MNCs to influence their subsidiaries to source from the same parent companies' supplier or the possibility of buyers ordering on the behalf of their subsidiaries in different countries. This presents an opportunity to future studies to address this limitation and explore whether the relationship between subsidiaries as direct buyers from the suppliers would result in similar findings. Research questions could explore the effect of the network of buyers and their subsidiaries that all source from suppliers while considering variables related to the nature of parent company-subsidiary relationship such as autonomy, influence, and various ownership structures.

Regarding the third study, the results should be interpreted while keeping their limitations in mind. First, the supply network data in this study is based on company-level supply-chain data, whereas a full mapping of the input–output dependencies between companies is usually at the product-part level. Therefore, one should note that the existence of a firm-level relationship that is retrieved by Factset would not capture the economic or product importance. For instance, a relatively small and inexpensive part could be a critical production component supplied by a shared supplier. At the firm-level relationship, the magnitude of this "small" component would appear insignificant. Second, one limitation of this study is that it did not capture whether knowledge has been spilled over or not since spillovers at shared suppliers nor central suppliers were not measured. Therefore, the results are conservative implying a potential for innovation transfer at central suppliers that are shared. Future researchers can explore whether the significant innovation benefit is actually only derived from peer buyers or other network partners that suppliers are accessing by holding a central position in the network. This can be captured by measuring the innovation flows or knowledge spillovers similar to the work of Muthulingam and Agrawal (2016). Another limitation lies in the independent variable: *Sharedness Percentage* which is measured using k=2, the measure refers to the number of suppliers shared by at least one more peer buyer relative to the total number of suppliers in the buying firm's supply network. Increasing the value of k would allow to incrementally assess the effect as shared suppliers become more highly shared, however, this is not possible because the measure would then become highly correlated with the second independent variable which is the *Shared Supplier Centrality.* This becomes an issue as the two measures would then sound to be interrelated and somehow measuring a similar network characteristic, however, this is not a concern in the current state of the measures. Thus, this motivates future studies interested in these two characteristics to qualitatively assess the distinction between centrality and sharedness as they might seem similar but yet they are quite different. Moreover, as mentioned before, there are several motivations or incentives behind sharing suppliers that may not necessarily include innovation benefits, these incentives could be cost savings, quality performance or simply the fact that the shared supplier could be the only supplier available in the market for a specific component. A limitation in this study is that it did not investigate the motivation behind sharing suppliers, which can be an interesting topic for further research. For future studies, one extension is to examine whether the strategy behind sharing suppliers with peers along with the consideration of network characteristics of buying firms reveal a positive outcome aligned with the incentive to source from a shared supplier. Finally, the third study focuses on a network of suppliers that are shared with peer buyers, an extension of this work could be to explore shared buyers and how this sharedness could influence different supplier performance measures. A lot of analytical papers explore different incentives to source from shared suppliers (Qi *et al*., 2019; Arya *et al*., 2008; Agrawal *et al*., 2016; Qi *et al*., 2015; Wang *et al*., 2014; Wen *et al*., 2021), however, little is known when looking at the other side of the network. Future work could look at the incentives as well as the different impacts when sourcing to shared network of customers. Overall, all three studies in this thesis offer several fruitful opportunities for research related to upstream as well as downstream networks in the SC.

Appendix A

Literature Review Tables

Table 17: The most common conceptualization modes for internationalization and performance from Bausch and Krist (2007)

Internationalization		**Performance**[a]	
Operationalization	Times used	Operationalization	Times used
Foreign sales to total sales[b]	21	Return on assets (ROA)	26
Number of foreign countries	13	Return on sales (ROS)	15
Various entropy measures	10	Return on equity (ROE)	13
Foreign subsidiary sales to total sales	4	Sales growth	11
		Various capital market oriented measures	8
Number of foreign direct investments	4		
		Market share	6
Various indices	4	Return on investment	3
Export sales to total sales	3	Other return oriented measures	9
Foreign assets to total assets	3		
Other	6	Other growth oriented measures	4

[a] Thirteen of 41 samples measured performance time-lagged with a range of four years time-lag (K = 1) to one year time-lag (K = 8).

[b] The difference in the number of operationalizations reported in this table (k = 21) to the number of samples included in Table 2 (k = 16) is due to five samples that did not report foreign sales to total sales means and therefore could not be analyzed in Table 2.

Table 18: Relevant literature on structural network complexity on the supplier side

Study	IV	Definition
2002 Choi and Hong JOM	Horizontal complexity	the number of suppliers in each tier, measured by the average number of entities across all tiers
	Vertical complexity	the number of tiers measured by the average number of entities in all possible vertical supply chains
	Spatial complexity	the average geographical distance between companies in the top two tiers in the network
2015 Bode and Wagner JOM	Horizontal complexity	the number of first tier suppliers of the focal firm.
	Vertical complexity	If one compared your firm with an automotive supply chain which of the following would be your supply chain position
	Spatial complexity	How was the annual purchasing volume approximately split among the following geographic regions?
2017 Lu and Shang JOM	Horizontal complexity	a firm's number of 1st tier suppliers divided by a weighted sum of its product groups
	Vertical complexity	the average number of 2nd tier suppliers per 1st tier supplier
	Spatial complexity	the number of countries represented in the supply base.
2019 Sharma et al JOM	Horizontal complexity	the total number of Tier-1 suppliers in a firm's BS network
	Vertical complexity	the average number of Tier-2 buyers and suppliers per Tier-1 supplier
	Spatial complexity	the total geographical distance between the focal firm and BSN members
2020 Adhikary et al IJPE	Horizontal complexity	the total number of Tier-1 (direct) suppliers
	Vertical complexity	the average number of Tier-2 suppliers per Tier-1 supplier
	Spatial complexity	total geographical distance between the focal firm and its BSN members located in different countries

Table 19: Different performance measures used in SC studies

Authors and Title	Journal	Dependent Variable
Hendricks and Singhal 2005: Association Between Supply Chain Glitches and Operating Performance	Management Science	**Operating performance measures**: Sales (million $) Total assets (million $) Operating income (million $) Return on sales (%) Return on assets (%) Total costs (million $) Total inventory (million $).
Lorentz et al 2012: Effects of geographic dispersion on intra-firm supply chain performance	Supply Chain Management: An International Journal	Intra-firm supply chain performance includes: **Logistics costs** Warehousing costs (% share of turnover) Inventory costs (% share of turnover) Logistics administration costs (% share of turnover) Transportation costs (% share of turnover) **Service performance** Perfect order fulfilment (% of customer orders on time, at the right place, with correct documentation, in the right quantity, and without damage) Order fulfilment cycle time (average days from order to delivery) **Asset utilisation** Inventory days of supply (average days material owned, from purchase to sale) Cash-to-cash cycle time (in days; inventory days of supply + accounts receivable - accounts payable)
Stock et al 2000: Enterprise logistics and supply chain structure: the role of fit	Journal of Operations Management	**Operational and financial performance**: **Cost performance** (Cost) **Service performance** (Delivery performance, Flexibility performance, Quality performance) **Financial performance** (Sales growth, ROI, Market share)

Lorentz et al 2016: The effect of a geographically dispersed supply base on downside risk: Developing and testing the N-shaped theory	International Business Review	Sum of the following items measured on a 1 to 5 Likert scale: (1) suppliers' insufficient capacity and shortages, (2) suppliers' poor delivery reliability, including quality deficiencies, and (3) financial difficulties of suppliers, including bankruptcy (based on Wagner and Bode, 2008)
Lu and Shang 2017: Impact of supply base structural complexity on financial performance: Roles of visible and not-so-visible characteristics	Journal of Operations Management	Buyer **financial performance**: return on assets and Tobin's Q. ROA measures a firm's short-run profitability, tangible financial performance and has been widely studied. TQ captures the long-term, intangible aspects of financial performance, long-run market valuation and intangible assets
Narasimhan and Kim 2002: Effect of supply chain integration on the relationship between diversification and performance: evidence from Japanese and Korean firms	Journal of Operations Management	Sales growth and market share growth (Actual data) The growth ratio of the current level to three years ago **Profitability** (Seven-point Likert Scales): Return on investment, return on assets, revenue growth, financial liquidity, and net profit
Narasimhan and Nair 2005: The antecedent role of quality, information sharing and supply chain proximity on strategic alliance formation and performance	International Journal of Production Economics	In the questionnaire, the **performance indicators for competitive advantage** included: 1. Market share 2. Return on assets 3. Average selling price 4. Product quality 5. Competitive position 6. Customer service
Bozarth et al 2009: The impact of supply chain complexity on manufacturing plant performance	Journal of Operations management	**Operational measures** -Schedule attainment -Unit manufacturing cost **Market based measures**

		-Competitive performance -Customer satisfaction
Demeter et al 2016: The impact of subsidiaries' internal and external integration on operational performance	International Journal of Production Economics	**Operational performance**: Cost performance and differentiation performance. **Cost Performance** -Unit manufacturing cost improvement -Order cost improvement -Manufacturing lead time improvement **Differentiation Performance** -Quality performance improvement -Flexibility performance improvement -Delivery performance improvement
Kim and Henderson 2015: Financial benefits and risks of dependency in triadic supply chain Relationships	Journal of Operations management	**Financial performance** using accounting-based metrics: ROA: Return on Assets ROS: Return on sales ATO: asset turnover INV: ratio of total inventory to total assets GM: Gross margin SGA: selling, general and administrative expenses.
Kim 2014: Understanding supplier structural embeddedness: A social network perspective	Journal of Operations management	**Operational performance**: conformance to specification, product quality, on-time delivery, speed of delivery, flexibility, degree of product variety, overall operations costs, and competitive prices of our products. **Financial performance** was assessed with the extent to which a buying firm perceives its performance in terms of growth in sales, growth in return on sales, growth in profit, growth in market share, return on sales, and return on investment.

Lanier et al 2010: Concentrated supply chain membership and financial performance: Chain- and firm-level perspectives	Journal of Operations management	**Financial performance:** ROA, profit margin, asset turnover, and cash cycle

Table 20: VIF values

Study 1		
	Tolerance	VIF
Firm size	0.531	1.883
Firm age	0.763	1.311
Nbr of suppliers	0.643	1.556
D_j	0.574	1.743
P_j^1	0.707	1.415
P_j^1 x D_j	0.860	1.162
P_j^N	0.550	1.819
P_j^N x D_j	0.784	1.275
Study 2		
	Tolerance	VIF
Firm size	0.668	1.496
Firm age	0.927	1.076
Industry Concentration	0.758	1.319
HC	0.599	1.669
HC-N	0.620	1.613
VC	0.442	2.262
SC	0.621	1.609
SC-N	0.504	1.983
Study 3		
	Tolerance	VIF
Firm size	0.472	2.119
Firm age	0.847	1.181
Nbr of suppliers	0.599	1.669
R&D intensity	0.472	2.121
Shared Suppliers	0.233	4.295
Shared Suppliers Degree Centrality	0.283	3.531
Shared x Centrality	0.395	2.531

Table 21: Check for performance lag

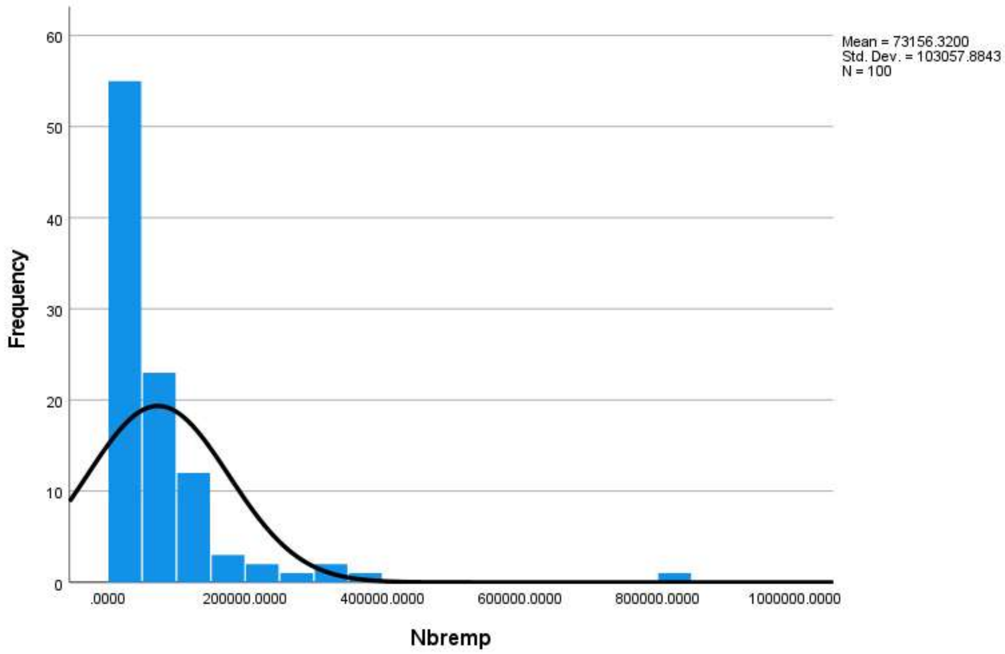
	ROA	CFSR
Control Variables		
Firm size	-0.728 (1.546)	-7.683** (2.595)
Firm age	-0.019 (0.015)	-0.055** (0.026)
Nbr of suppliers	0.001 (0.011)	0.029 (0.020)
Predictor Variables		
D_j	-0.241 (5.701)	-6.804 (11.525)
P_j^1	3.671 (2.54)	
P_j^1 x D_j	**-28.572* (20.01)**	
P_j^N		2.121 (6.294)
P_j^N x D_j		**-95.154** (47.39)**
lagROA	0.829** (0.073)	
lagCFSR		0.477** (0.061)
Intercept	7.707* (6.922)	47.123** (11.57)
R^2	65.7%	53.7%
Adjusted R^2	63.1%	50.1%
F statistic	24.947**	15.221**

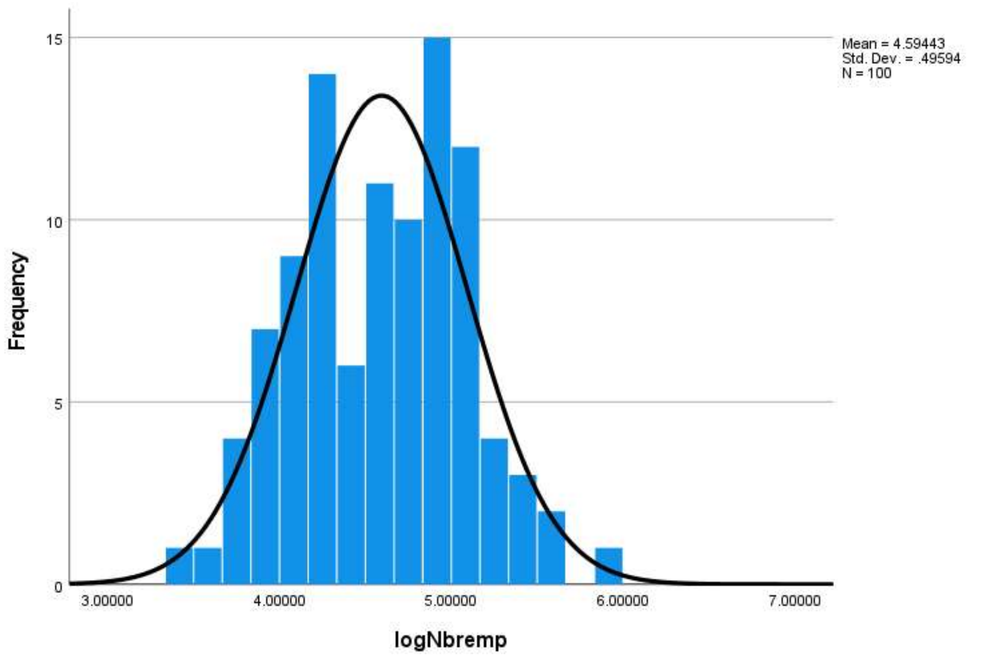
*** p<0.05*

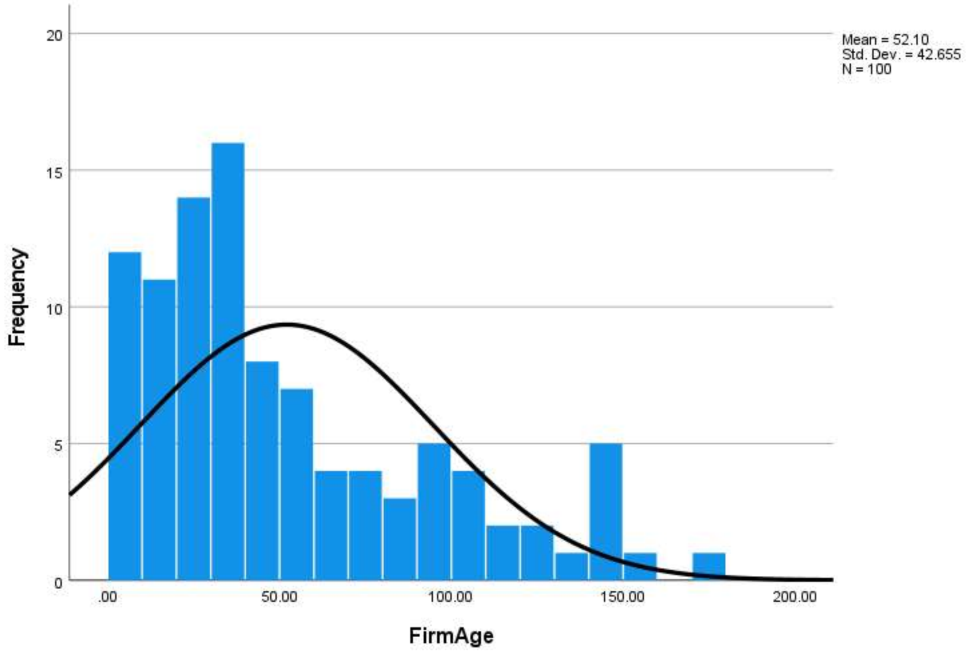
** p<0.10*

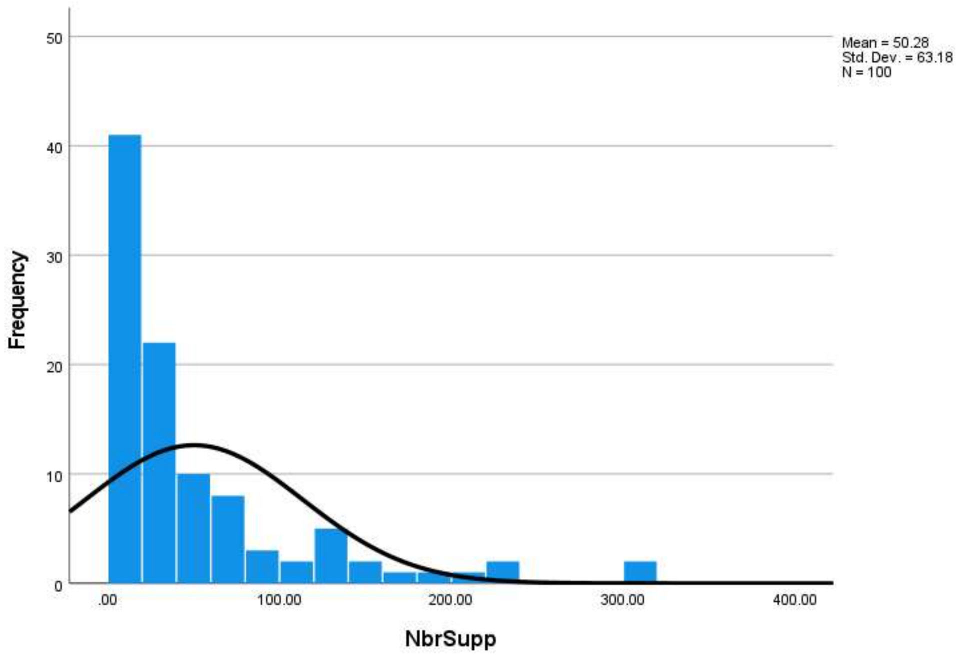
Diagrams

Histograms – Control Variables – Study 1






Mean = 52.10
Std. Dev. = 42.655
N = 100
Frequency
20
15
10
5
0
.00
50.00
100.00
150.00
200.00
FirmAge


Mean = 50.28
Std. Dev. = 63.18
N = 100
Frequency
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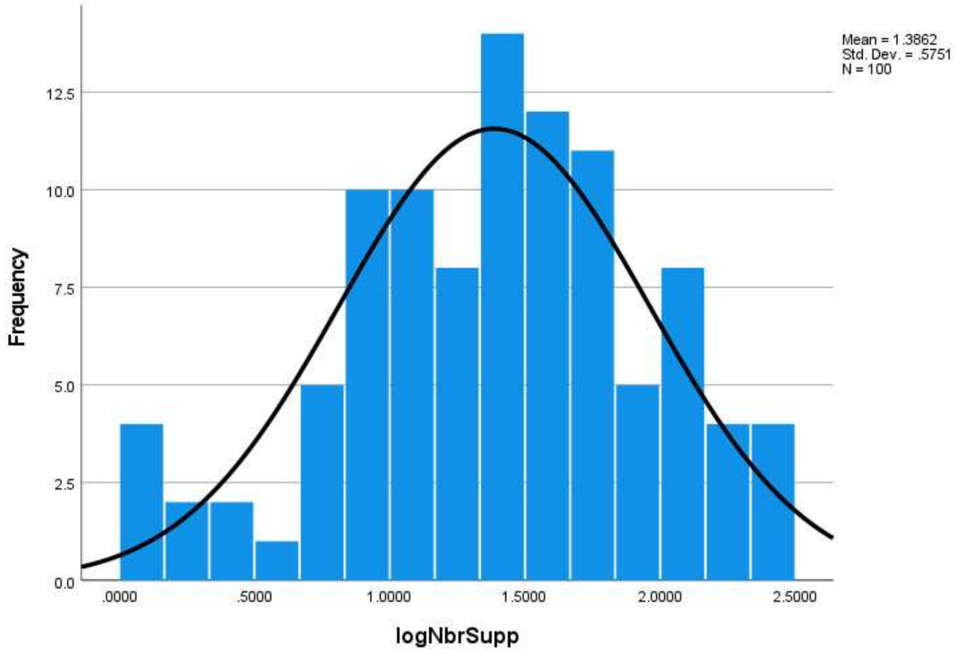
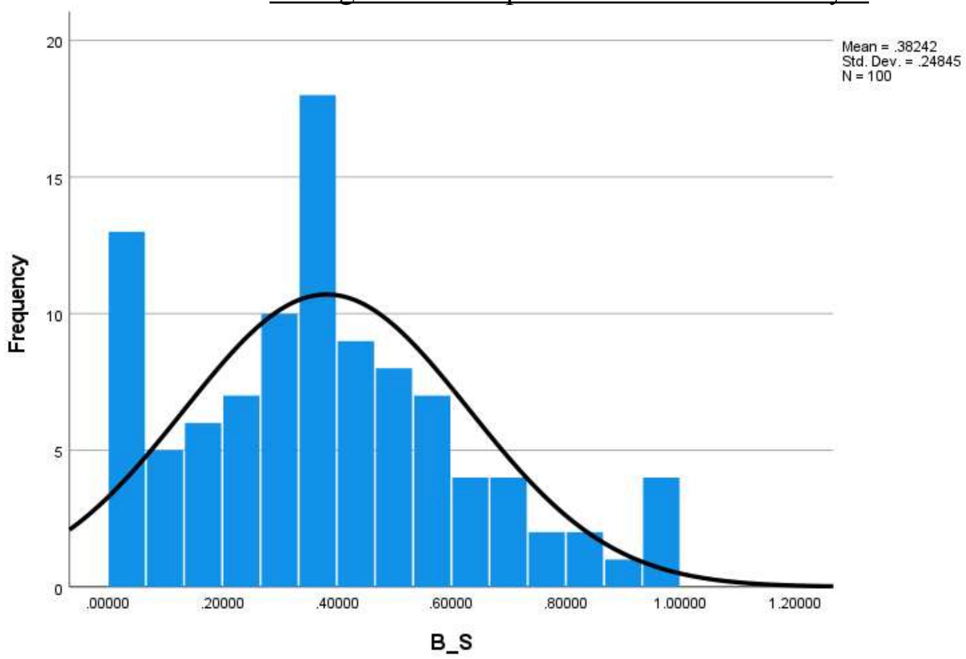
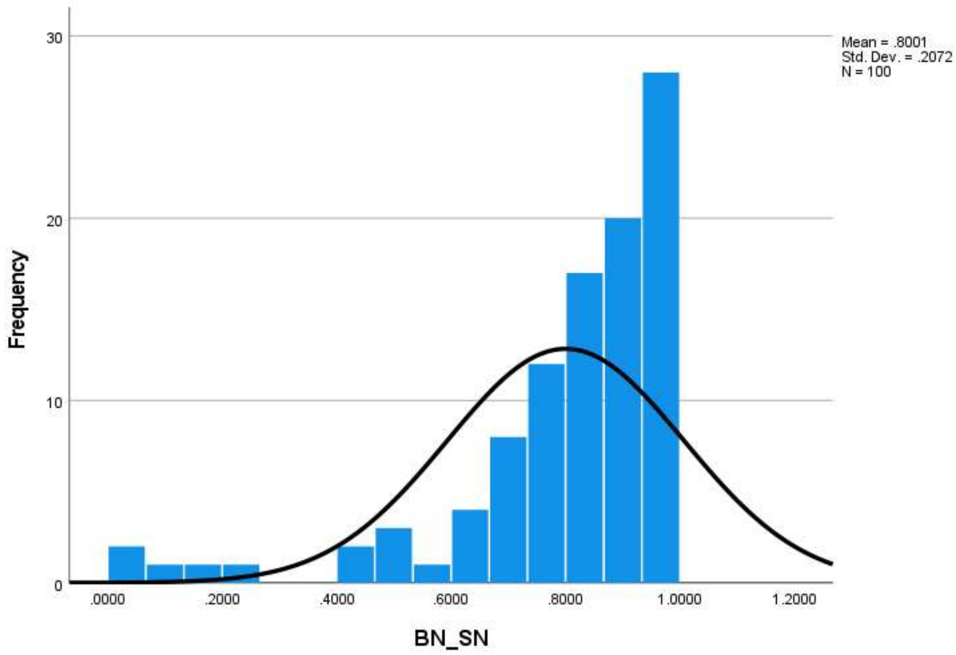
40
30
20
10
0
.00
100.00
200.00
300.00
400.00
NbrSupp

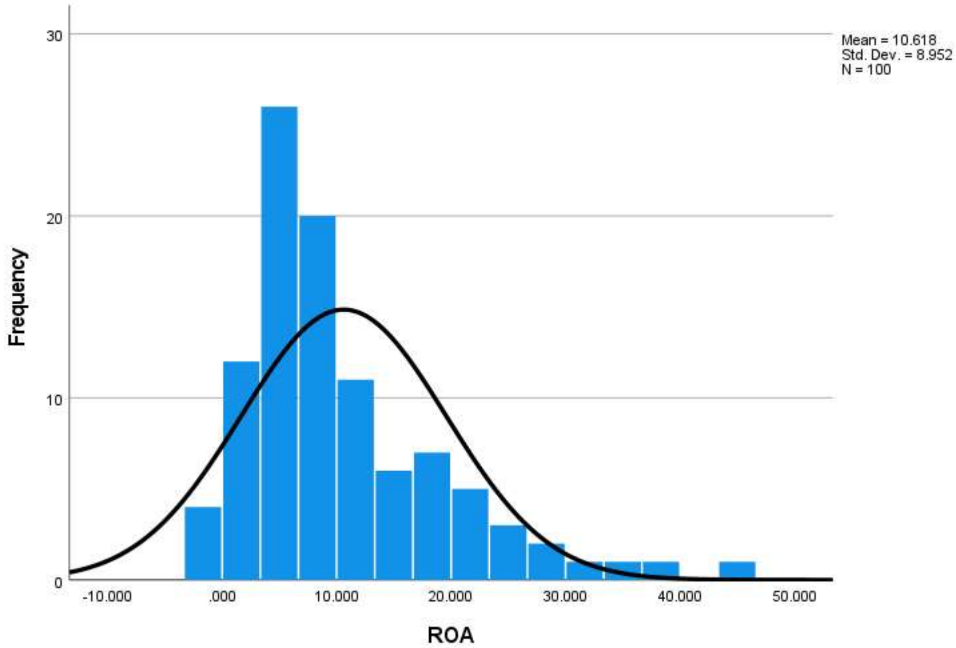


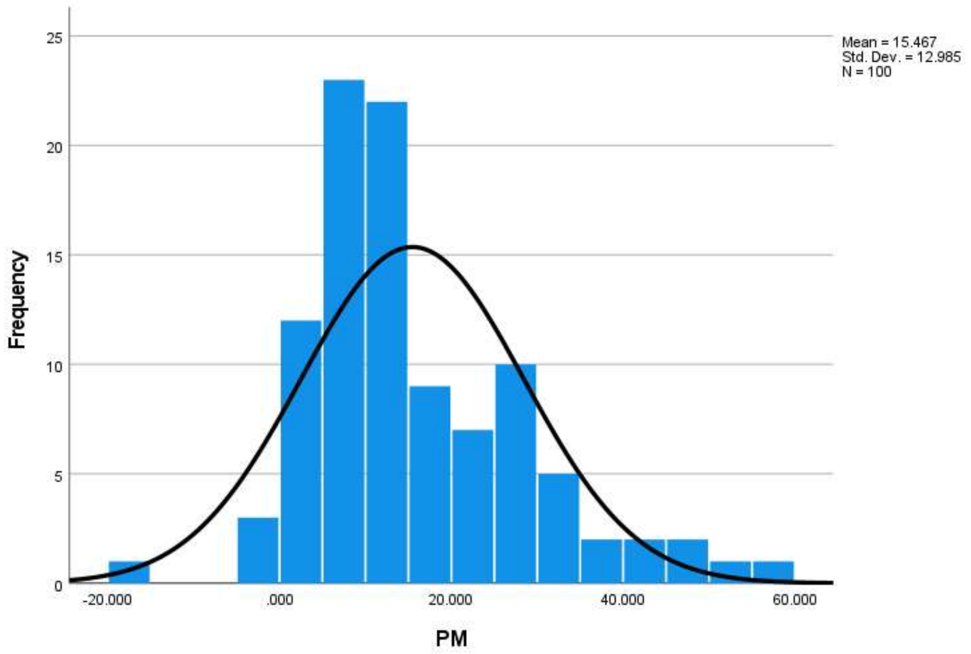
Histograms – Independent Variables – Study 1





Histograms – Dependent Variables – Study 1




Mean = 15.467
Std. Dev. = 12.985
N = 100
Frequency
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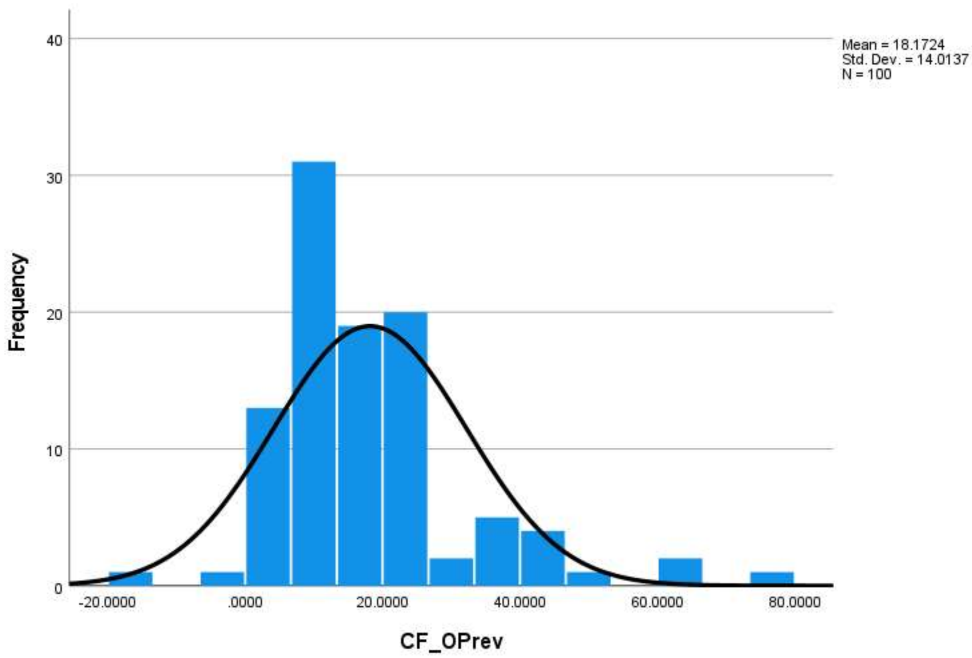
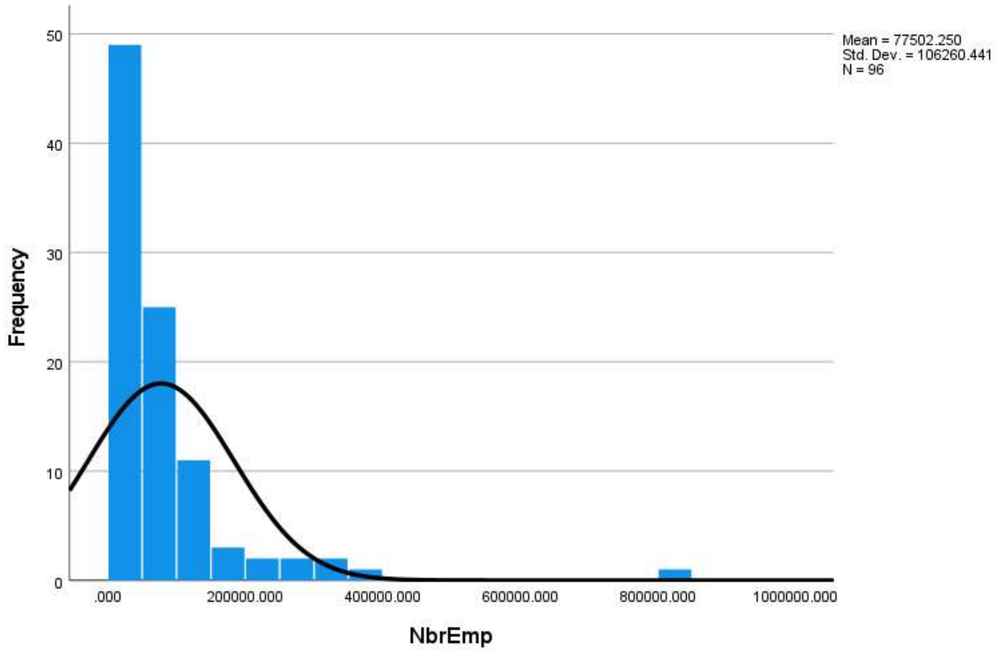
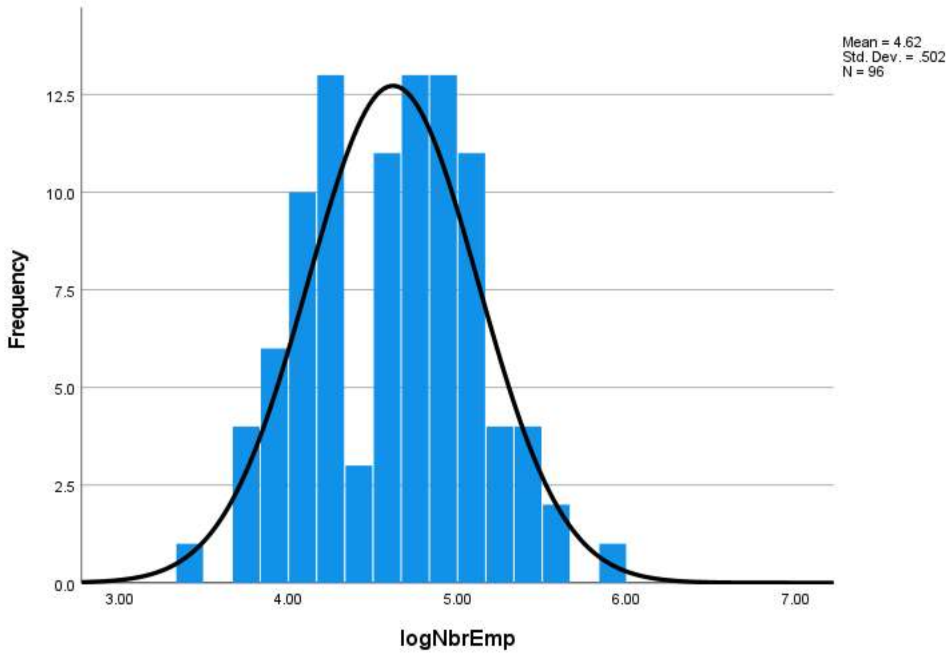
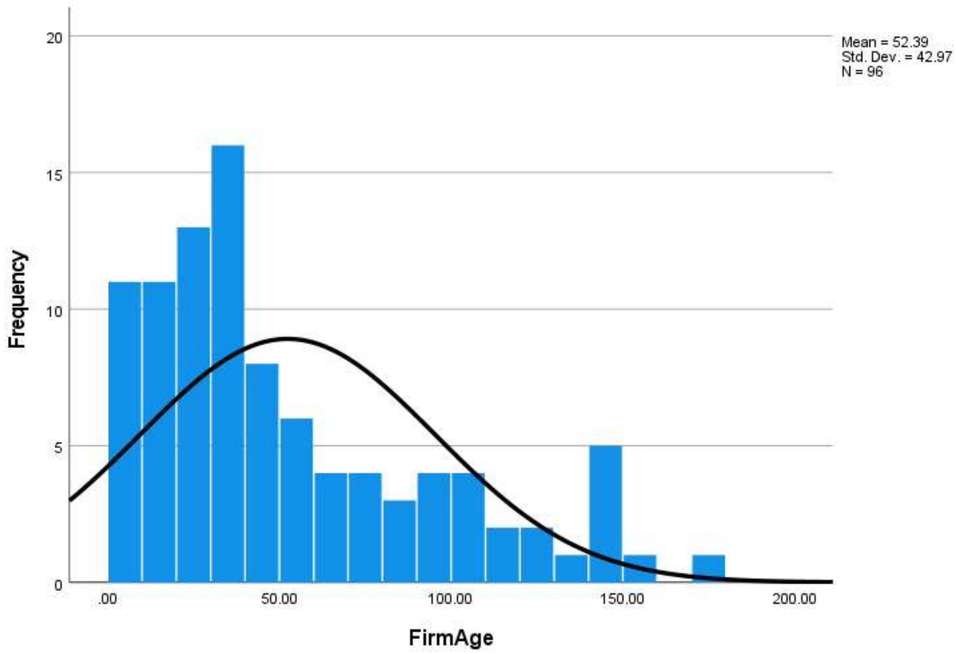
20
15
10
5
0
-20.000
.000
20.000
40.000
60.000
PM

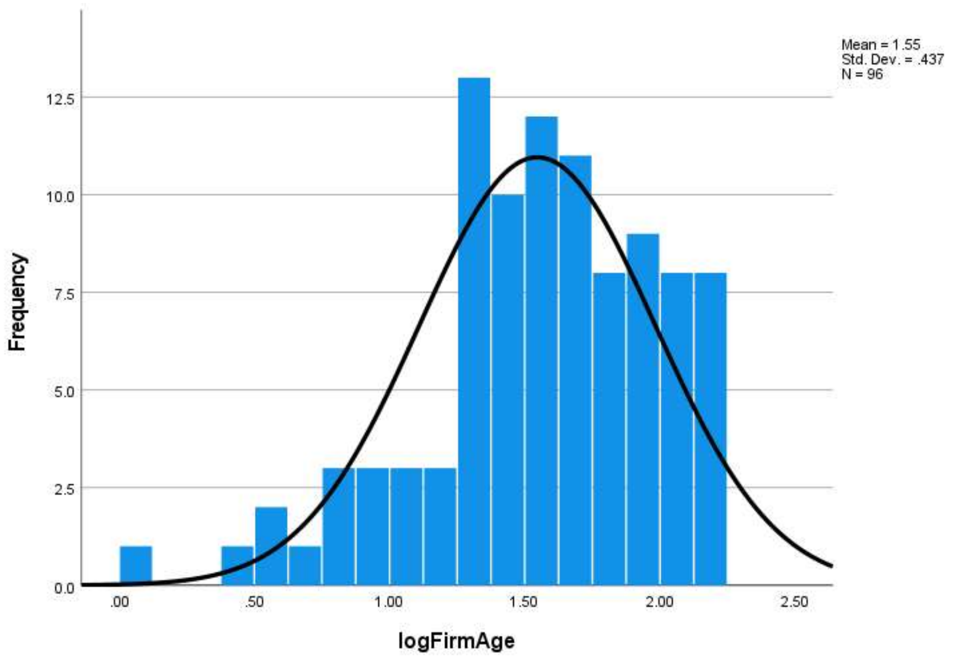

Mean = 18.1724
Std. Dev. = 14.0137
N = 100
Frequency
40
30
20
10
0
-20.0000
.0000
20.0000
40.0000
60.0000
80.0000
CF_OPrev

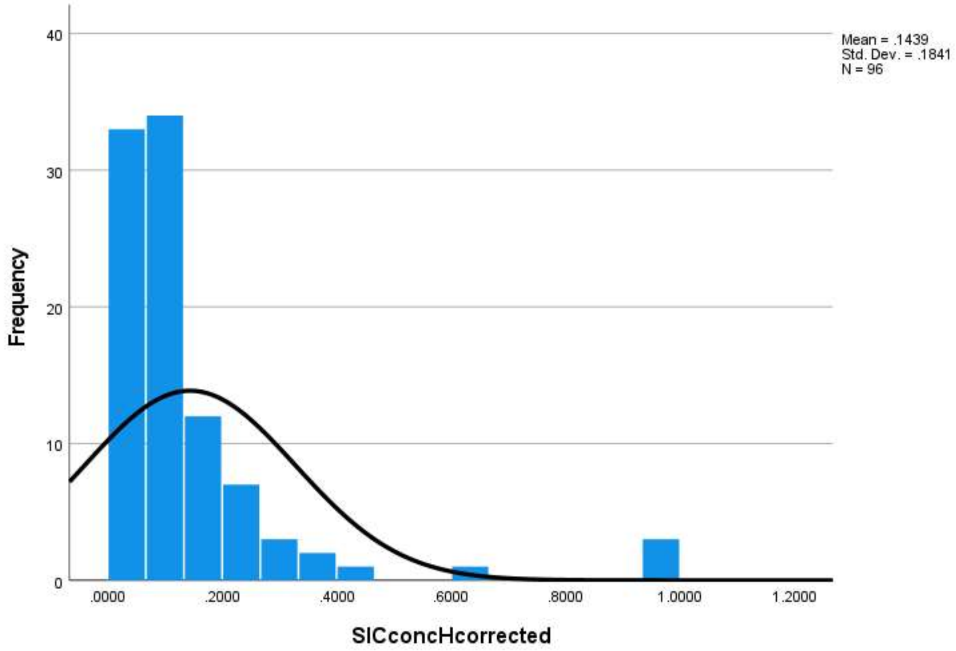
<u>Histograms – Control Variables – Study 2</u>






Mean = 52.39
Std. Dev. = 42.97
N = 96
Frequency
FirmAge
0
5
10
15
20
.00
50.00
100.00
150.00
200.00


Mean = 1.55
Std. Dev. = .437
N = 96
Frequency
logFirmAge
0.0
2.5
5.0
7.5
10.0
12.5
.00
.50
1.00
1.50
2.00
2.50


Mean = .1439
Std. Dev. = .1841
N = 96
Frequency
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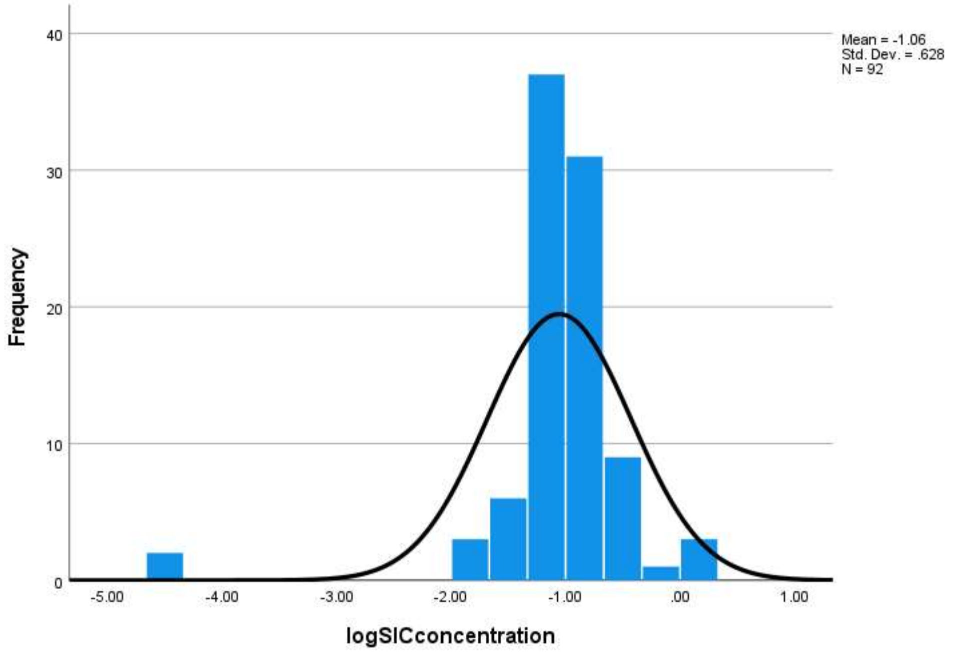
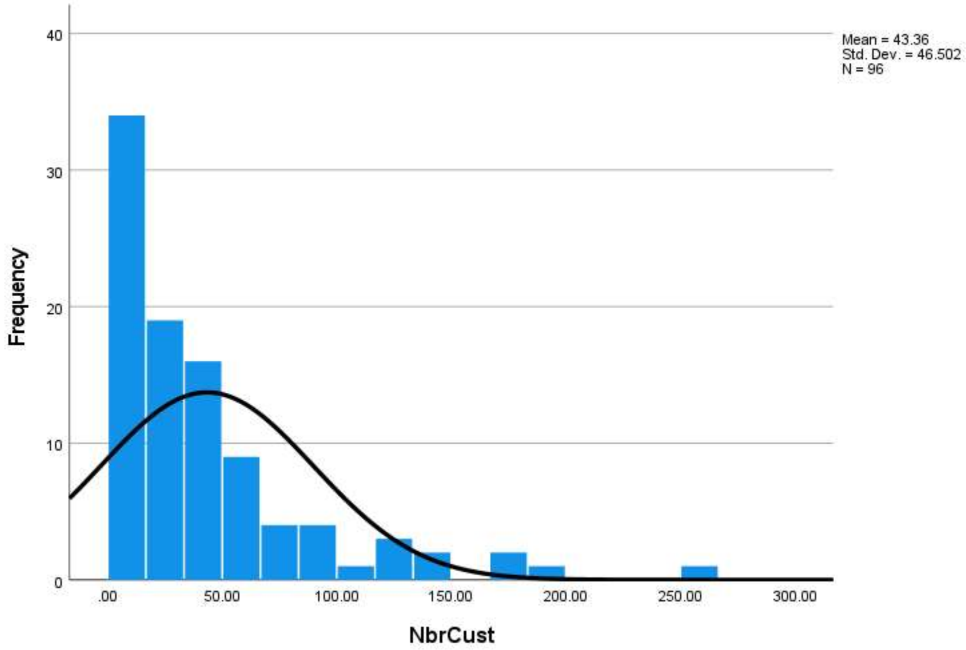
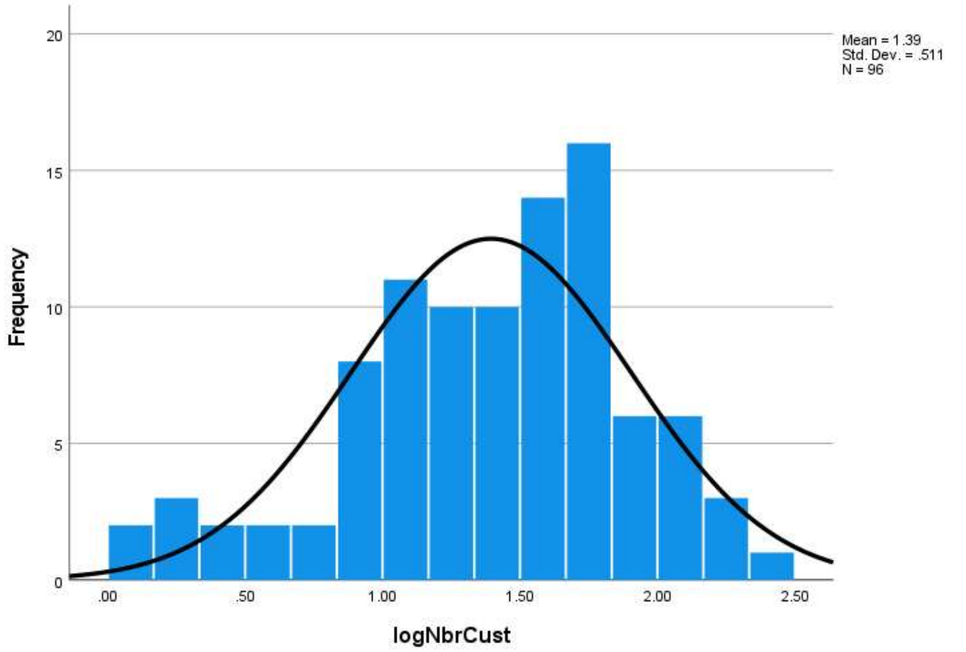
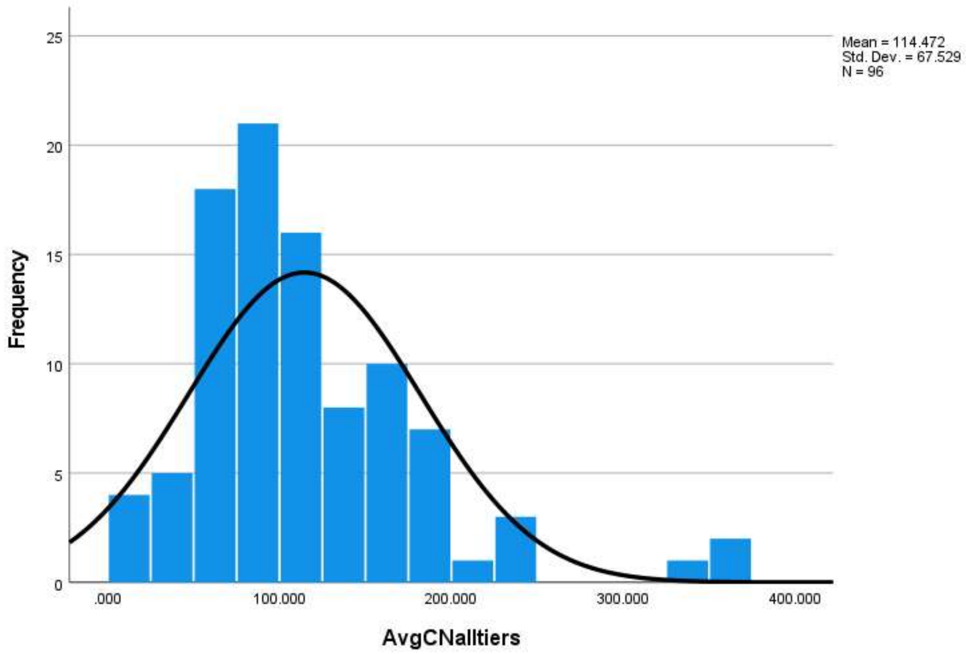
30
20
10
0
.0000
.2000
.4000
.6000
.8000
1.0000
1.2000
SICconcHcorrected

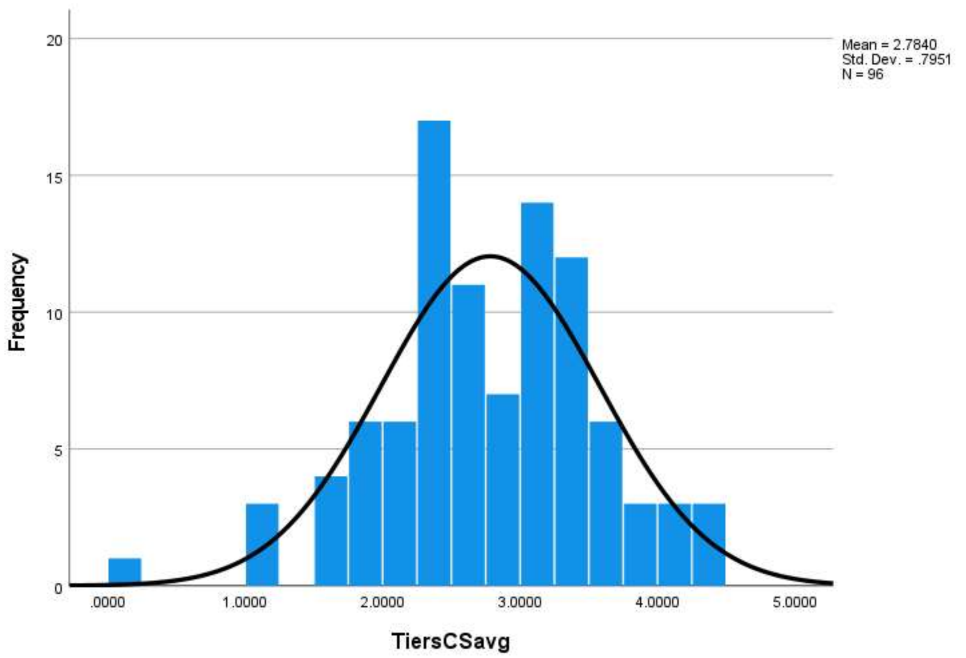

Mean = -1.06
Std. Dev. = .628
N = 92
Frequency
40
30
20
10
0
-5.00
-4.00
-3.00
-2.00
-1.00
.00
1.00
logSICconcentration

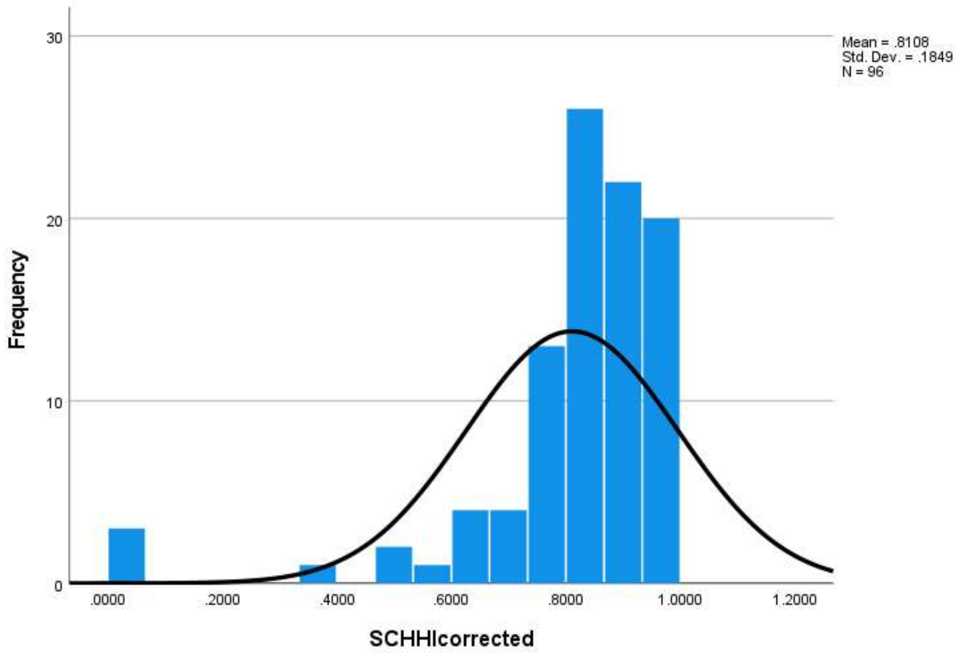
<u>Histograms – Independent Variables – Study 2</u>

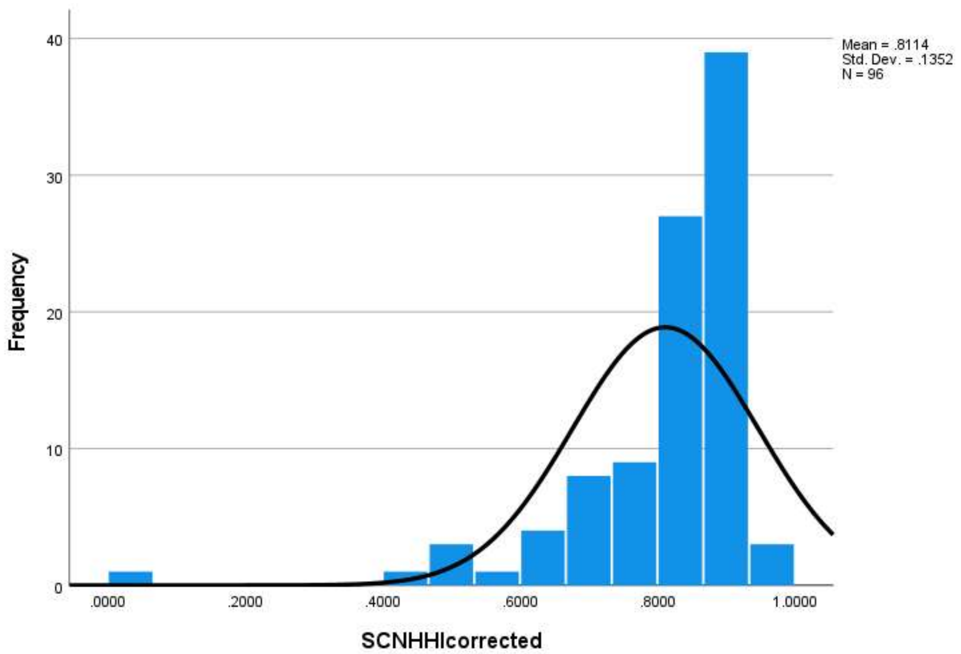




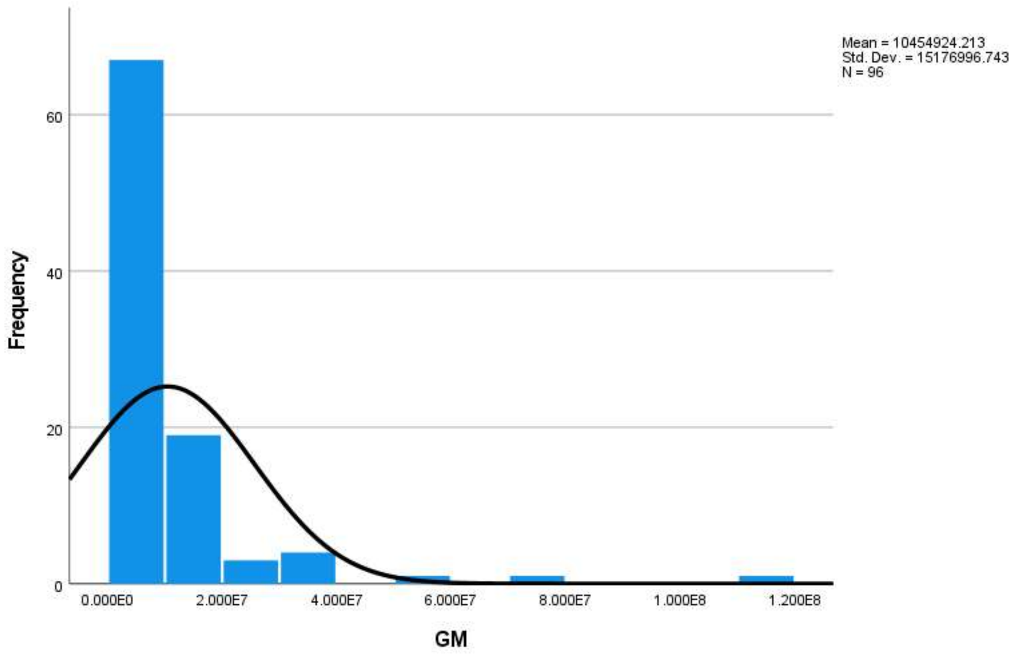

Mean = 114.472
Std. Dev. = 67.529
N = 96
Frequency
AvgCNalltiers

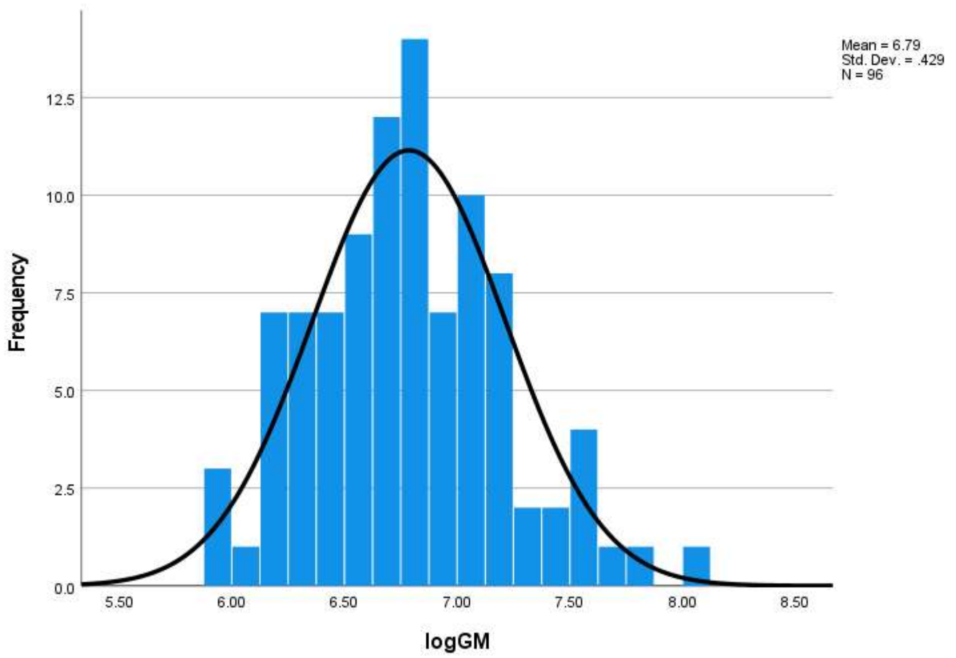

Mean = 2.7840
Std. Dev. = .7951
N = 96
Frequency
TiersCSavg

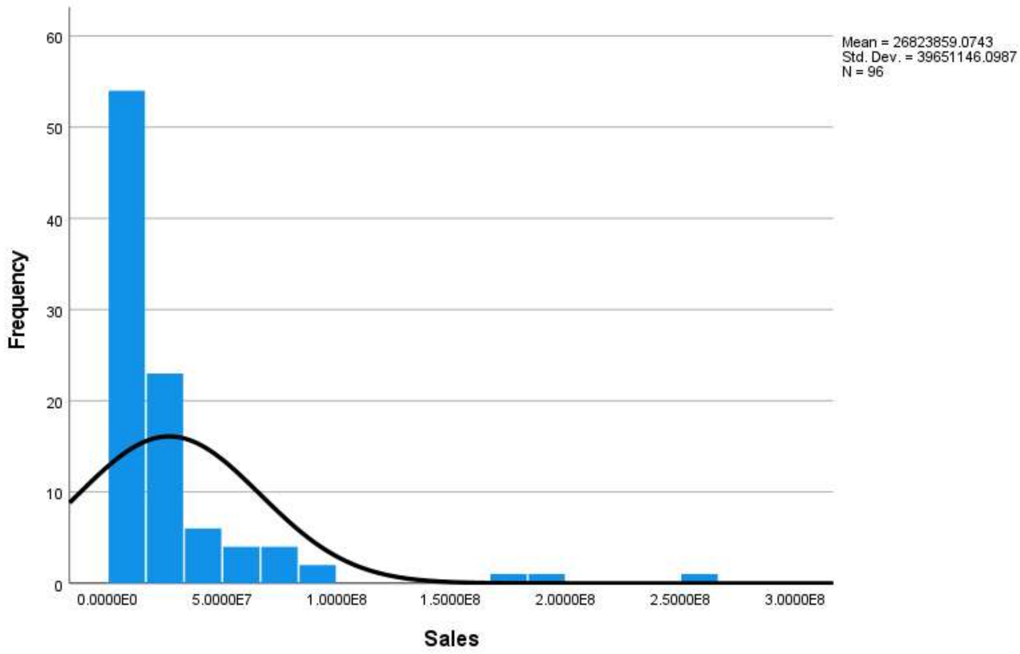

Mean = .8108
Std. Dev. = .1849
N = 96
Frequency
SCHHIcorrected

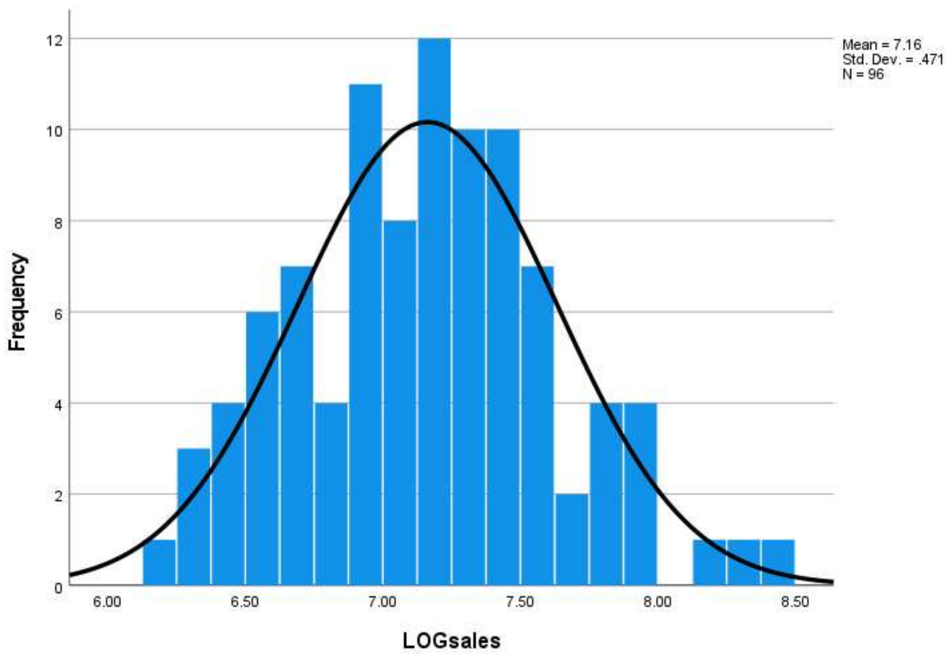

Mean = .8114
Std. Dev. = .1352
N = 96
Frequency
SCNHHIcorrected

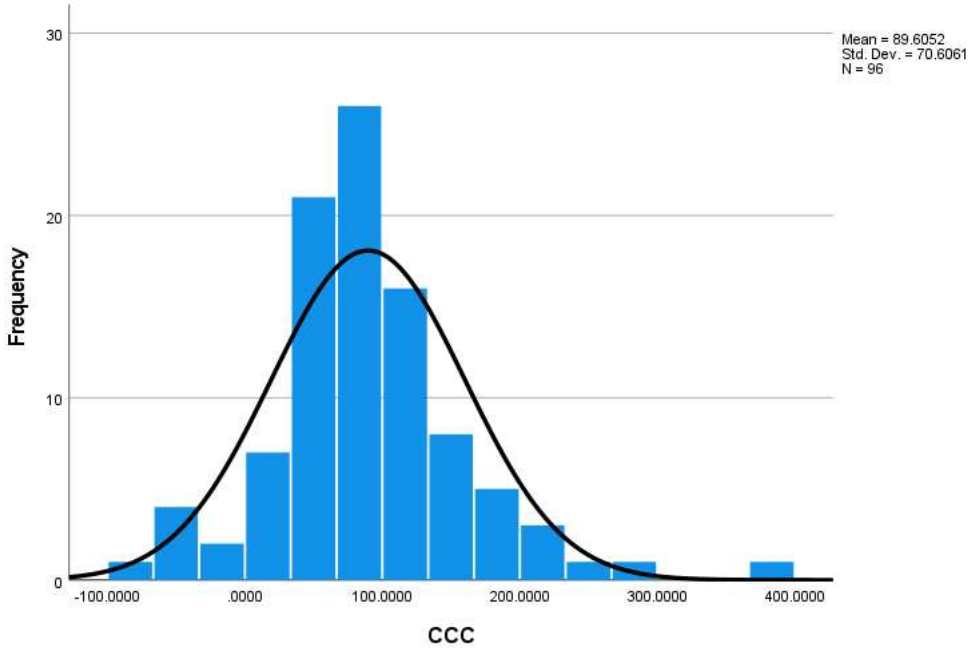
Histograms – Dependent Variables – Study 2

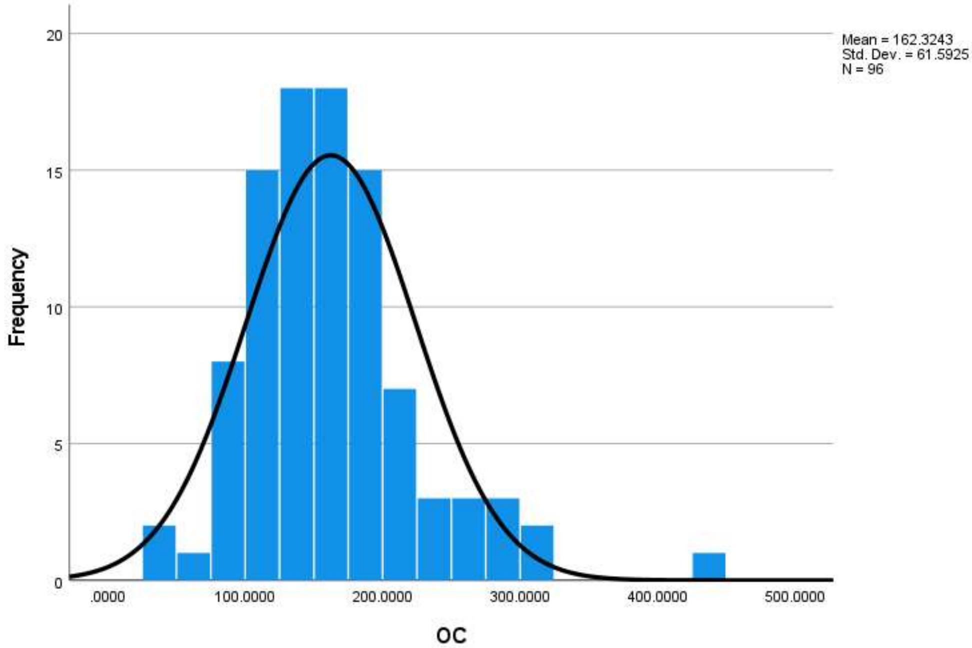




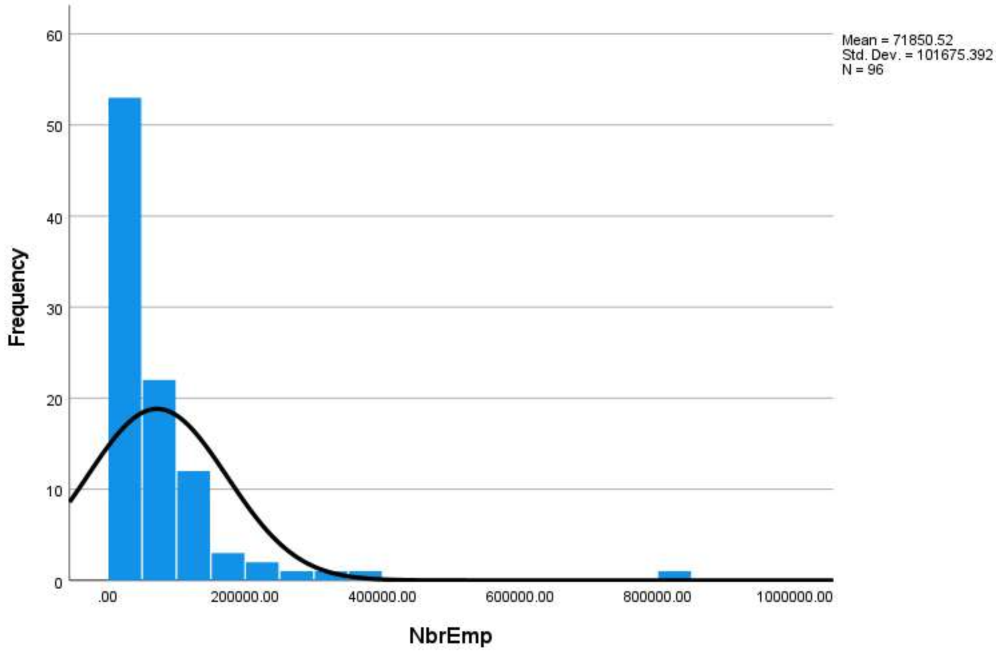

Mean = 26823859.0743
Std. Dev. = 39651146.0987
N = 96
Frequency
60
50
40
30
20
10
0
0.0000E0
5.0000E7
1.0000E8
1.5000E8
2.0000E8
2.5000E8
3.0000E8
Sales

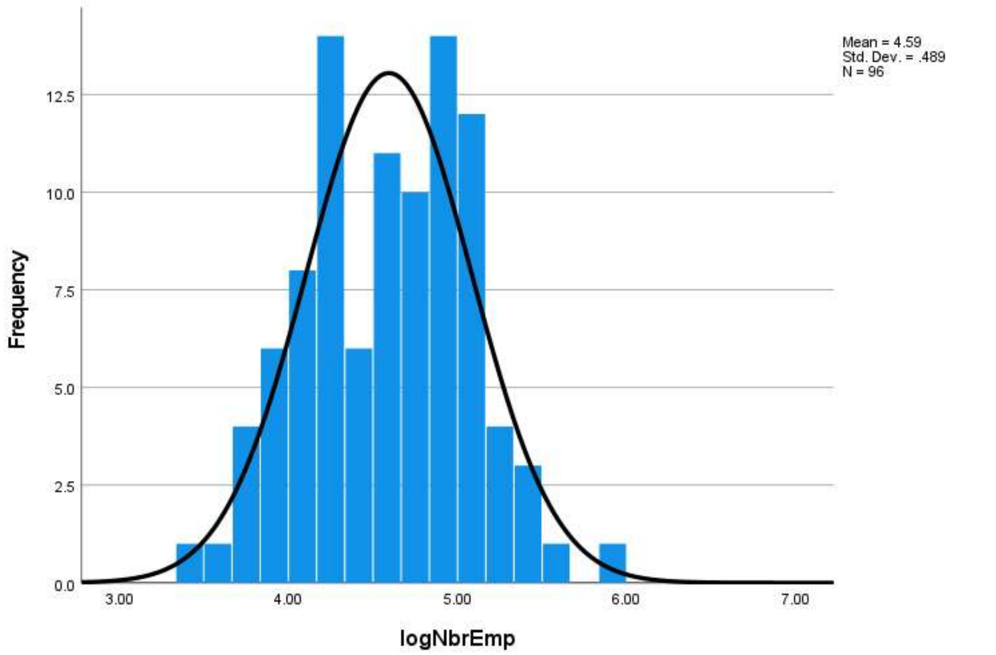

Mean = 7.16
Std. Dev. = .471
N = 96
Frequency
12
10
8
6
4
2
0
6.00
6.50
7.00
7.50
8.00
8.50
LOGsales

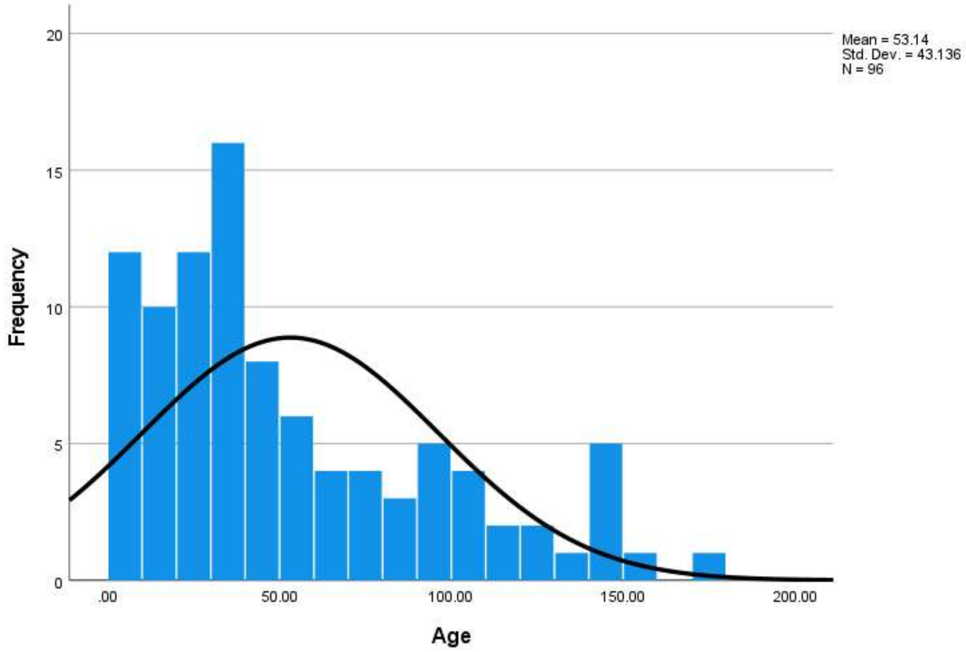

Mean = 89.6052
Std. Dev. = 70.6061
N = 96
Frequency
30
20
10
0
-100.0000
.0000
100.0000
200.0000
300.0000
400.0000
CCC

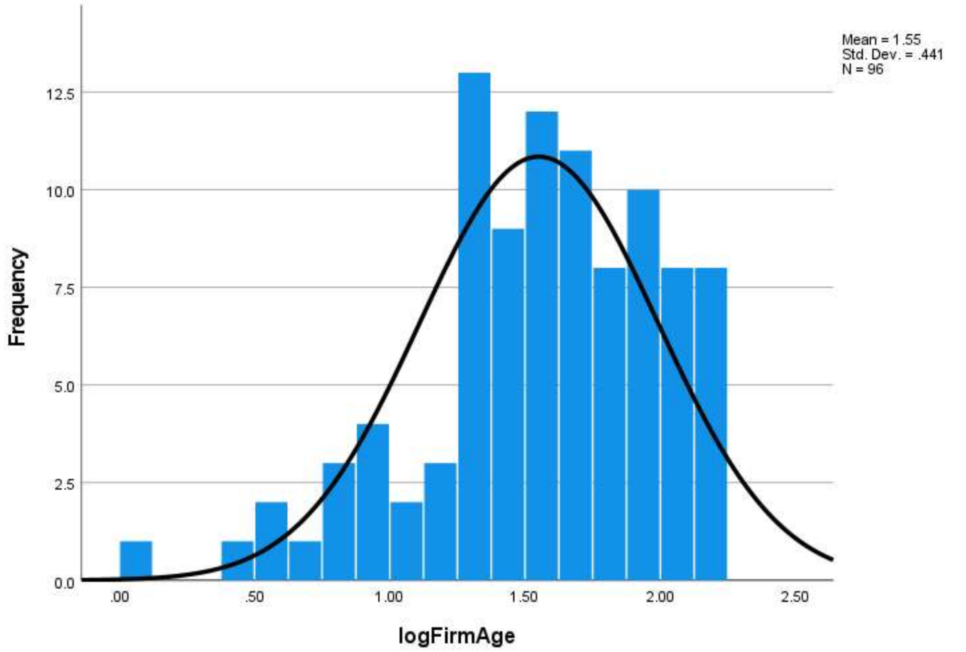

Mean = 162.3243
Std. Dev. = 61.5925
N = 96
Frequency
20
15
10
5
0
.0000
100.0000
200.0000
300.0000
400.0000
500.0000
OC

Histograms – Control Variables – Study 3






Mean = 53.14
Std. Dev. = 43.136
N = 96
Frequency
Age
.00
50.00
100.00
150.00
200.00
0
5
10
15
20


Mean = 1.55
Std. Dev. = .441
N = 96
Frequency
logFirmAge
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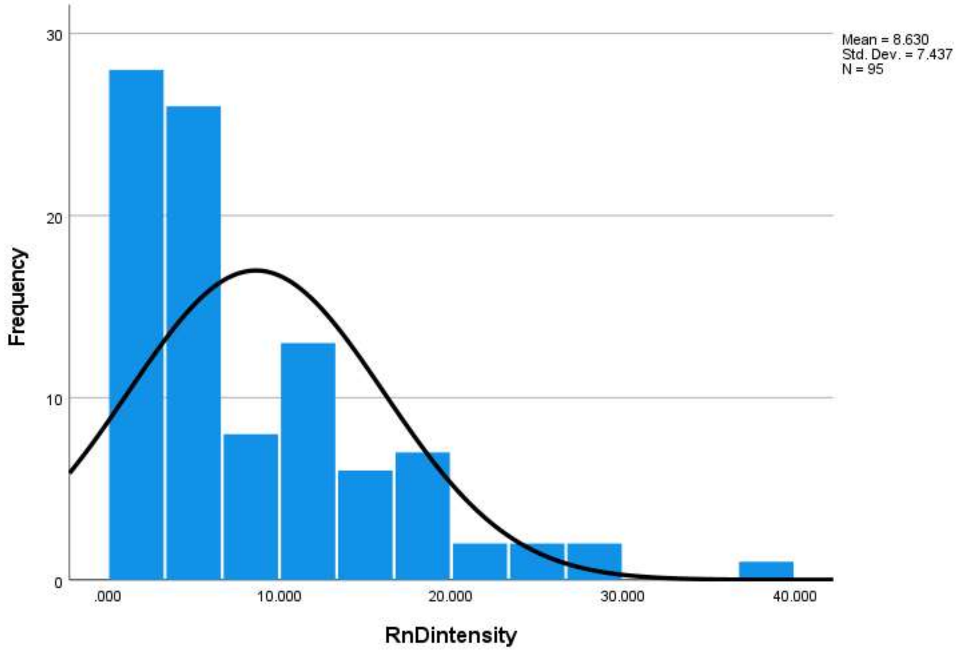
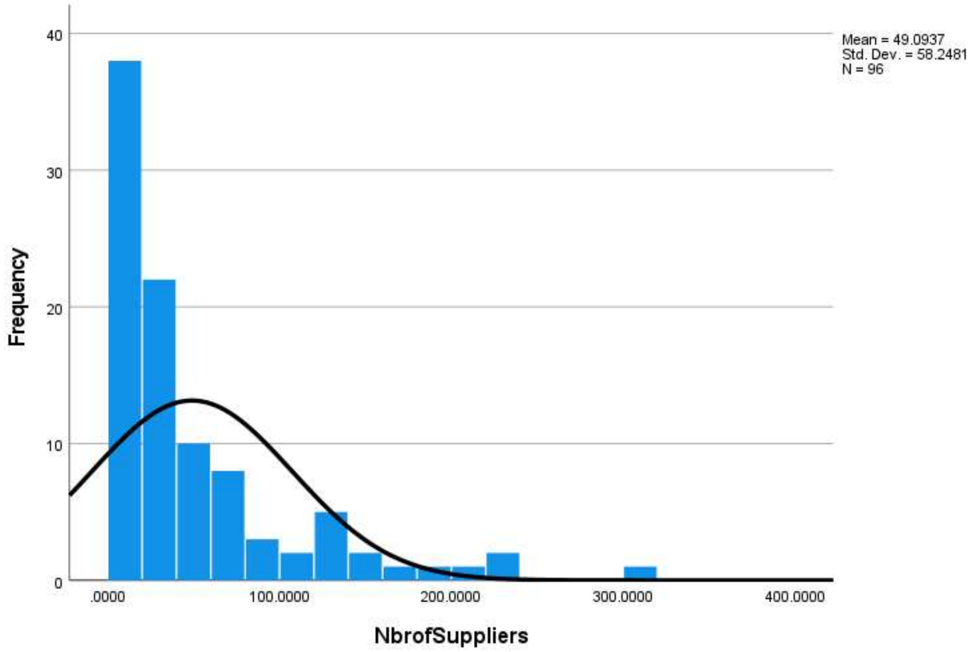
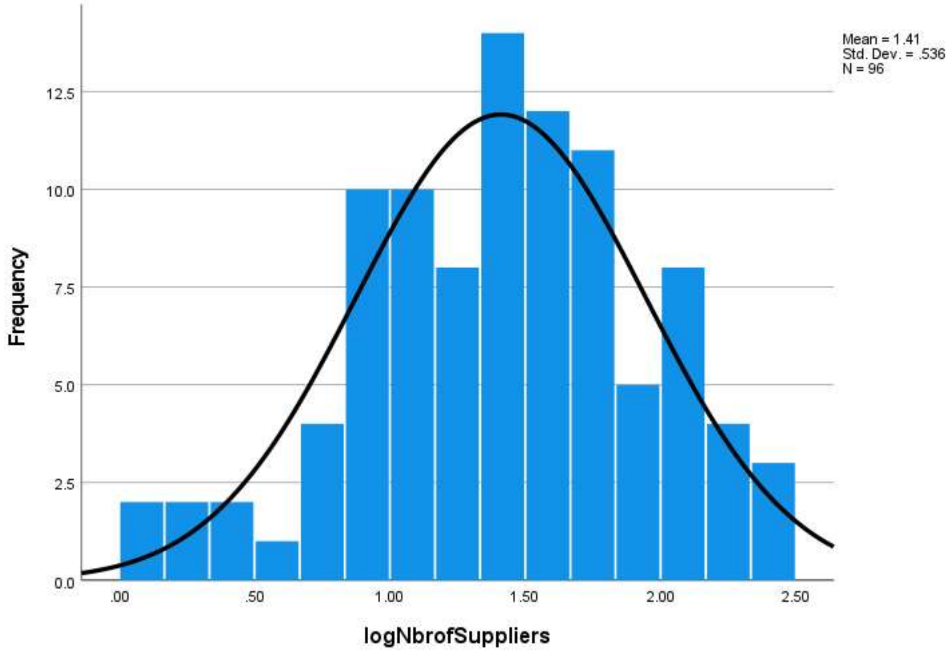
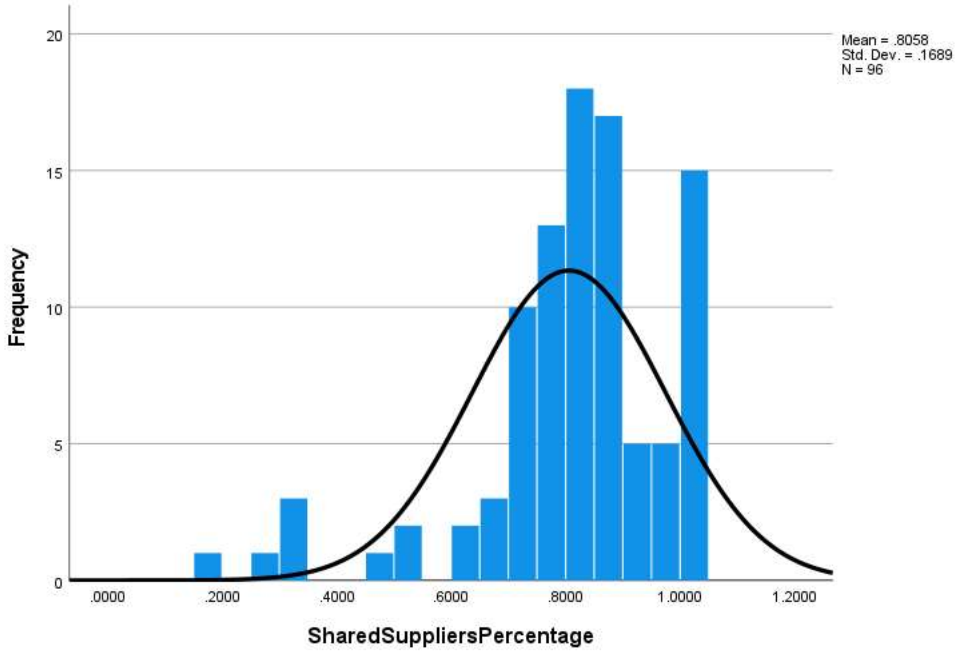
.50
1.00
1.50
2.00
2.50
0.0
2.5
5.0
7.5
10.0
12.5

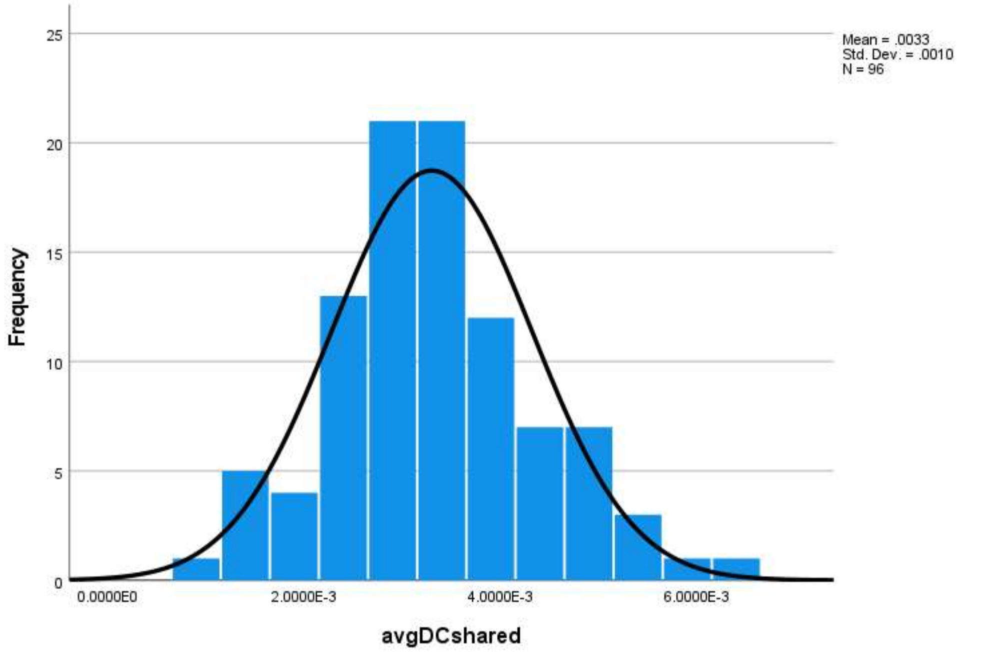

Mean = 8.630
Std. Dev. = 7.437
N = 95
Frequency
30
20
10
0
.000
10.000
20.000
30.000
40.000
RnDintensity


Mean = 49.0937
Std. Dev. = 58.2481
N = 96
Frequency
40
30
20
10
0
.0000
100.0000
200.0000
300.0000
400.0000
NbrofSuppliers

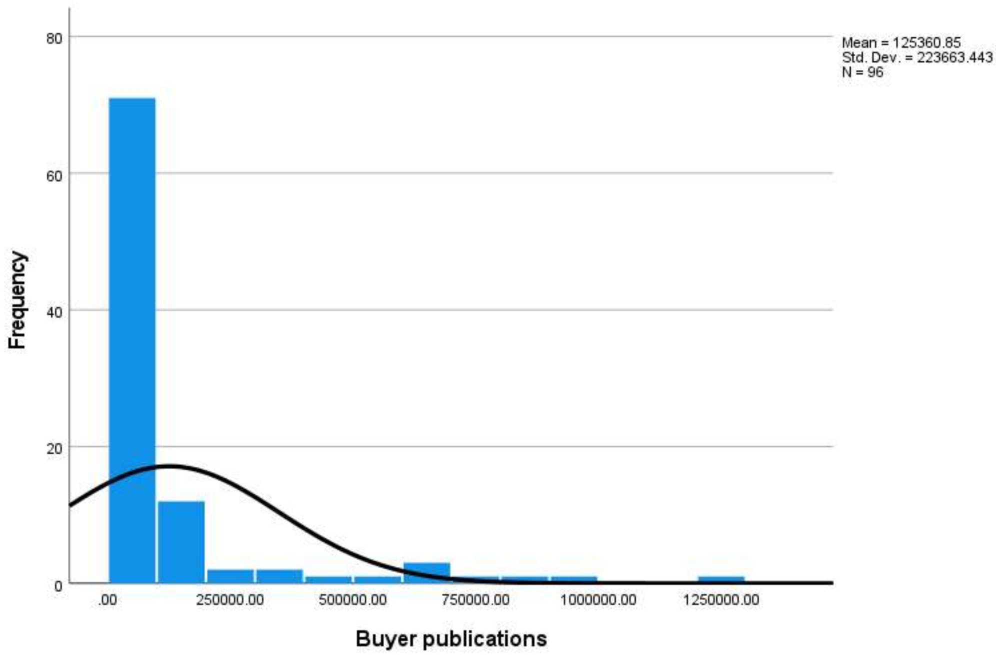


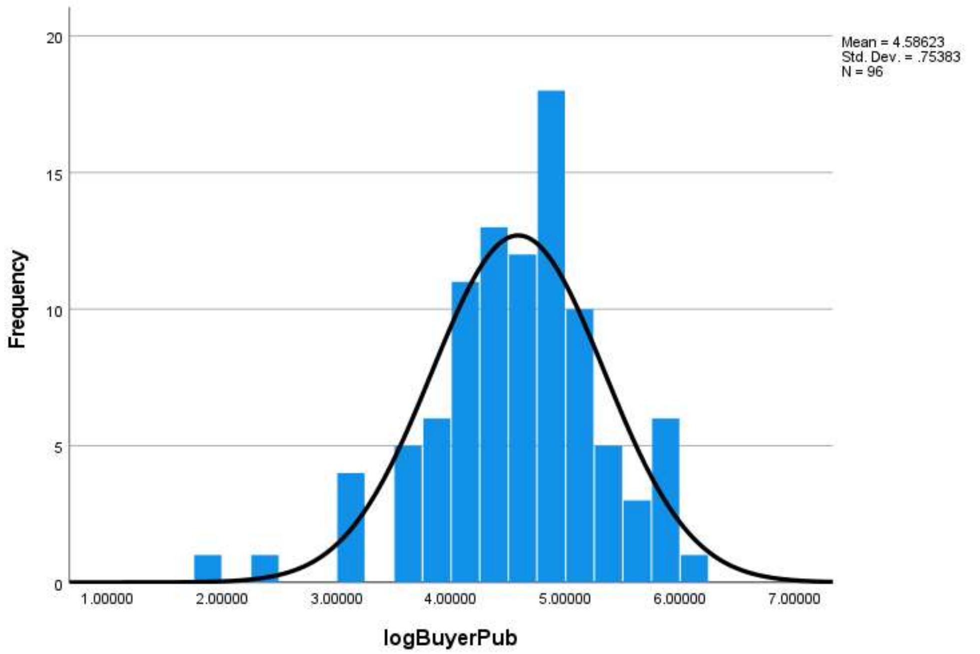
Histograms – Independent Variables – Study 3





Histograms – Dependent Variables – Study 3




Mean = 4.58623
Std. Dev. = .75383
N = 96
Frequency
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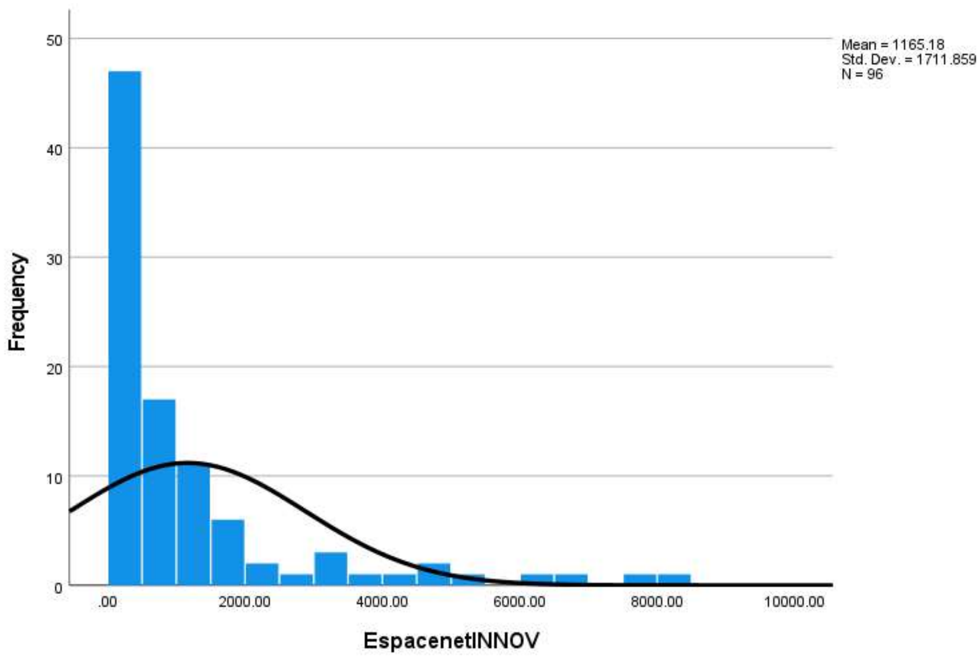
15
10
5
0
1.00000
2.00000
3.00000
4.00000
5.00000
6.00000
7.00000
logBuyerPub


Mean = 1165.18
Std. Dev. = 1711.859
N = 96
Frequency
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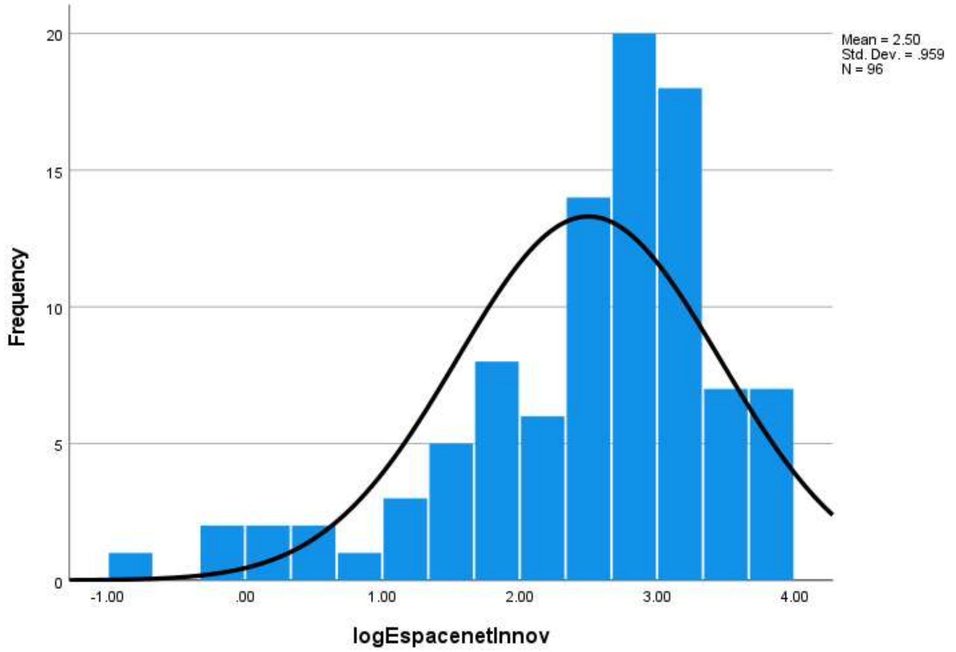
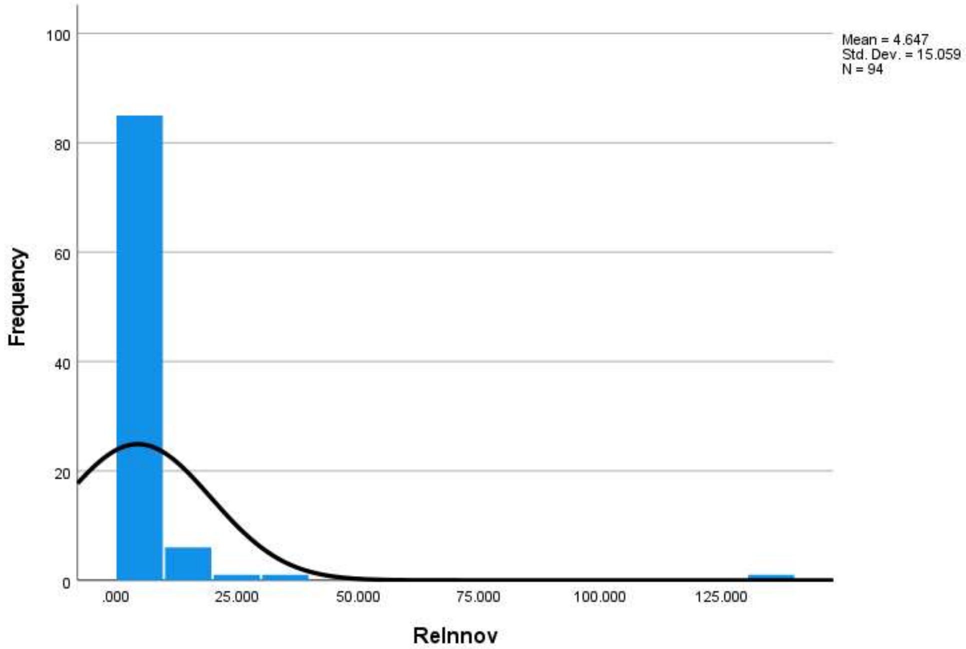
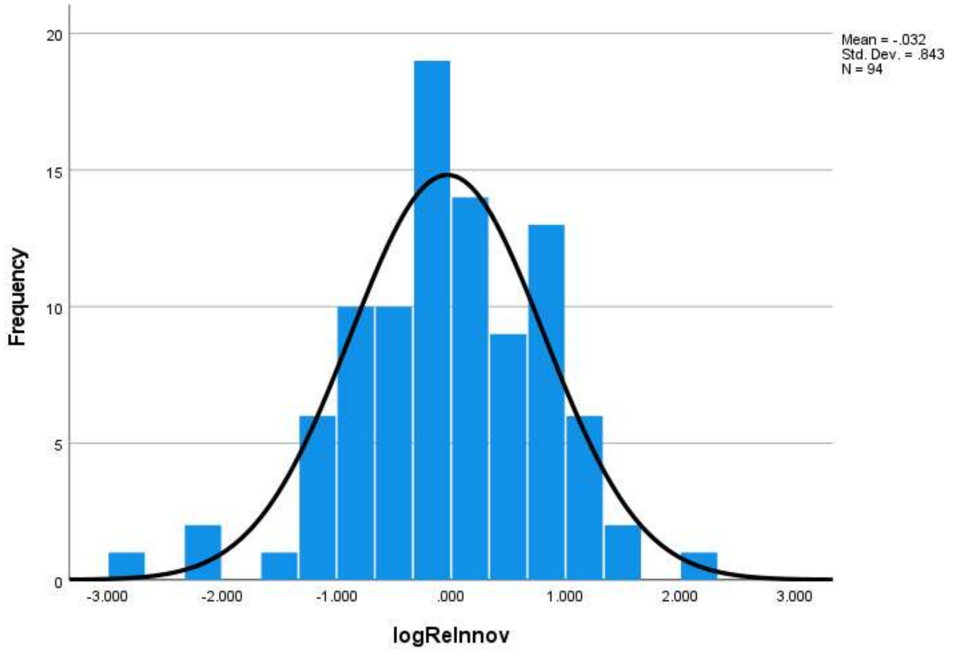
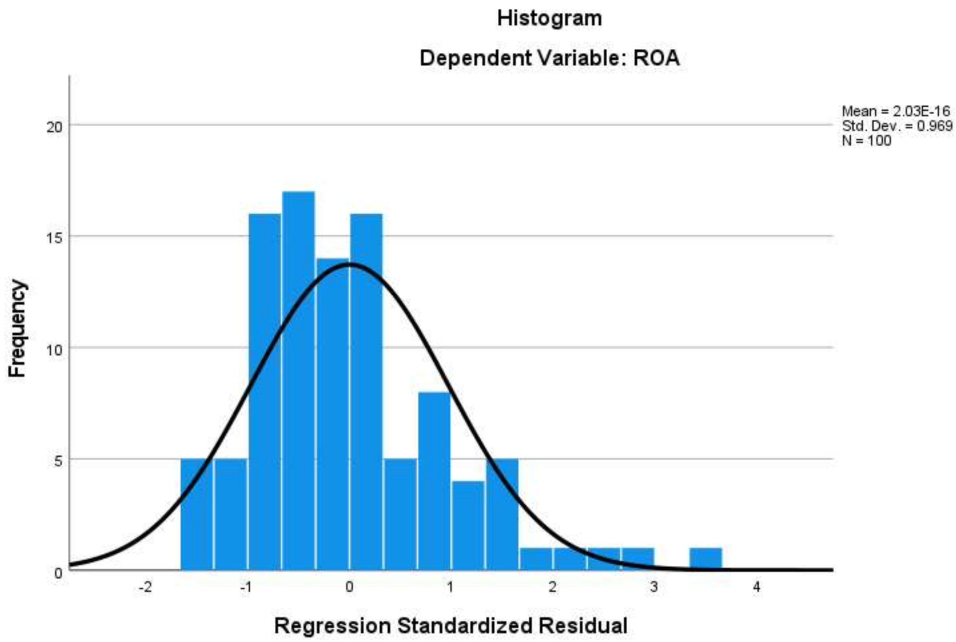
40
30
20
10
0
.00
2000.00
4000.00
6000.00
8000.00
10000.00
EspacenetINNOV

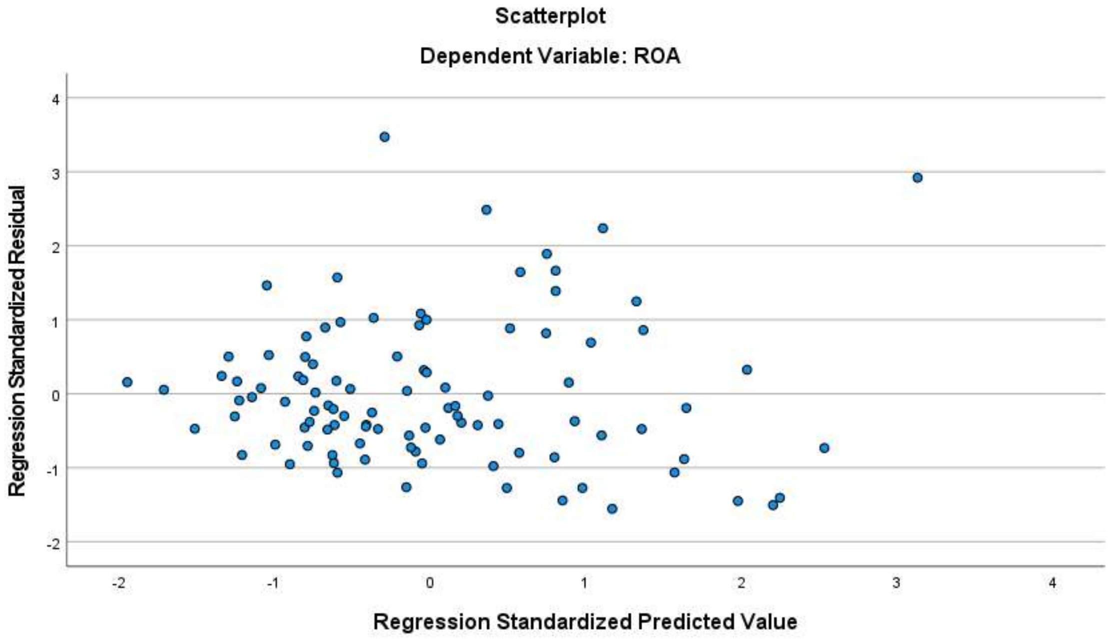

Mean = 2.50
Std. Dev. = .959
N = 96
Frequency
logEspacenetInnov
-1.00
.00
1.00
2.00
3.00
4.00
0
5
10
15
20


Mean = 4.647
Std. Dev. = 15.059
N = 94
Frequency
ReInnov
.000
25.000
50.000
75.000
100.000
125.000
0
20
40
60
80
100

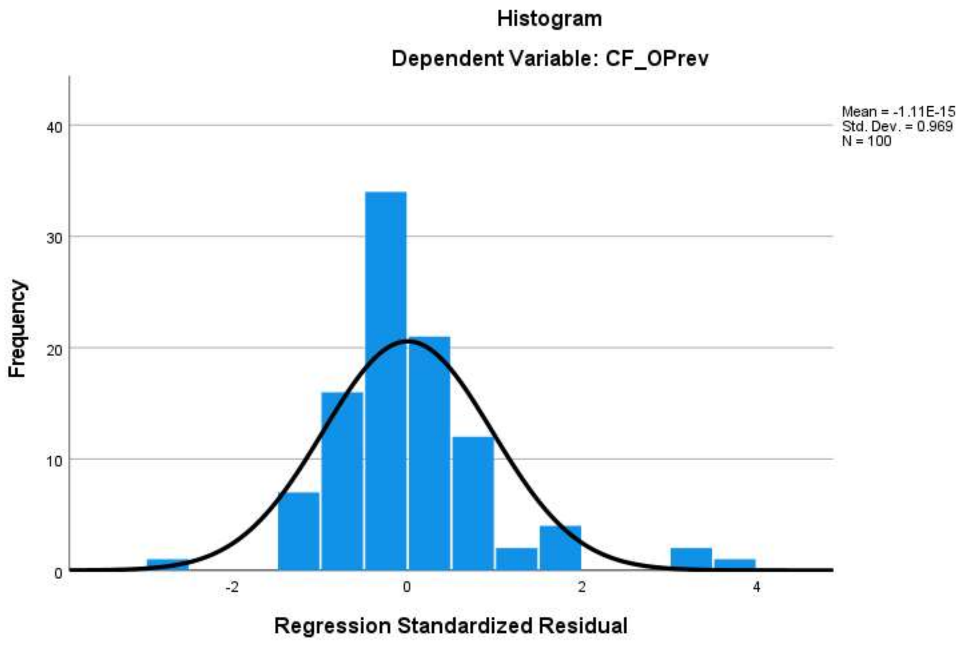


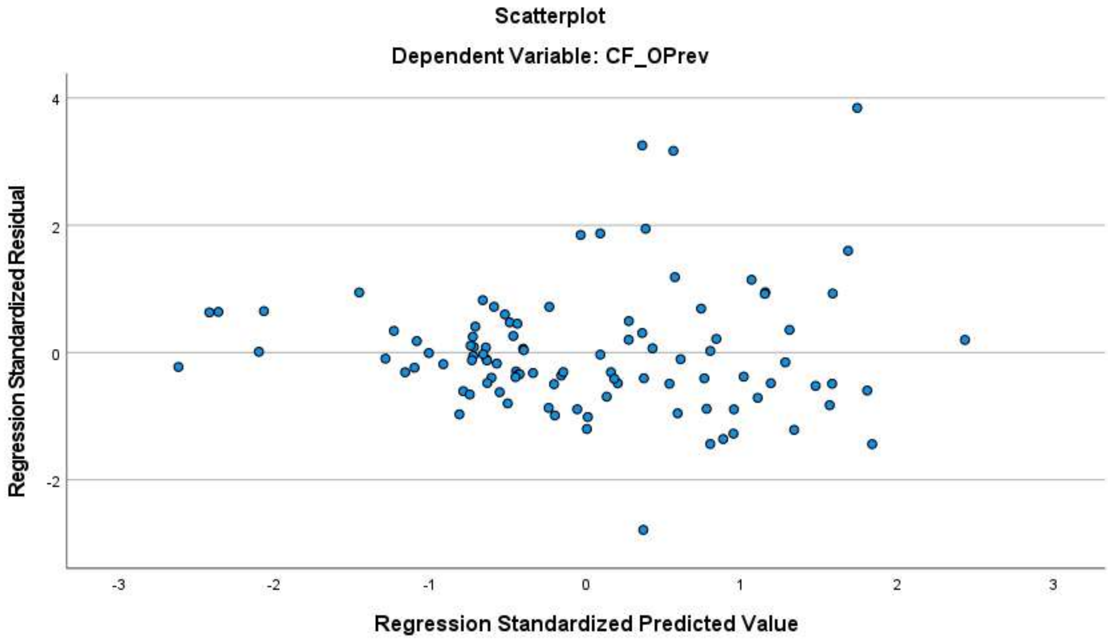
<u>Testing Heteroscedasticity – Study 1- Model 1</u>



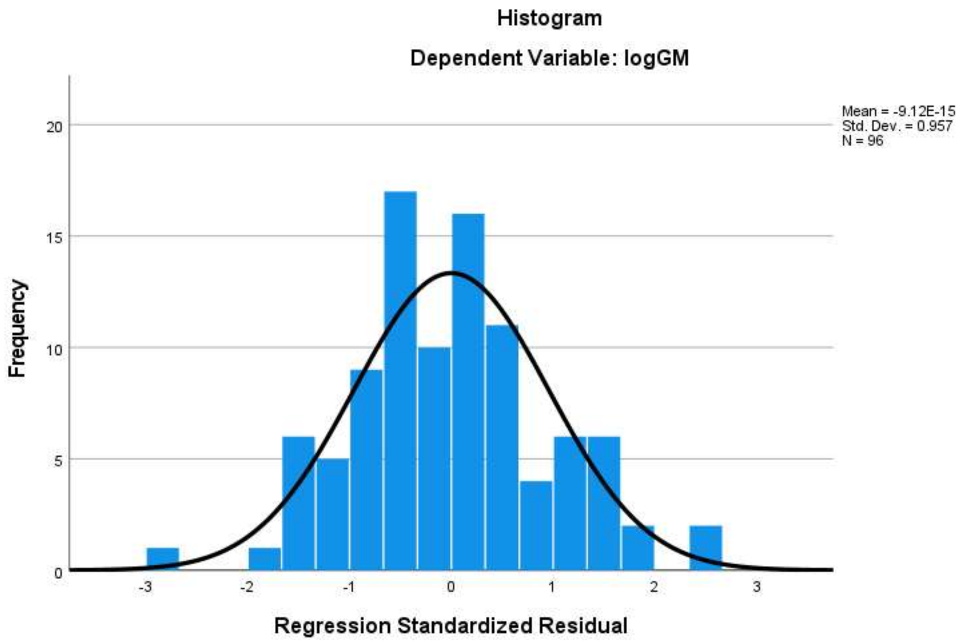


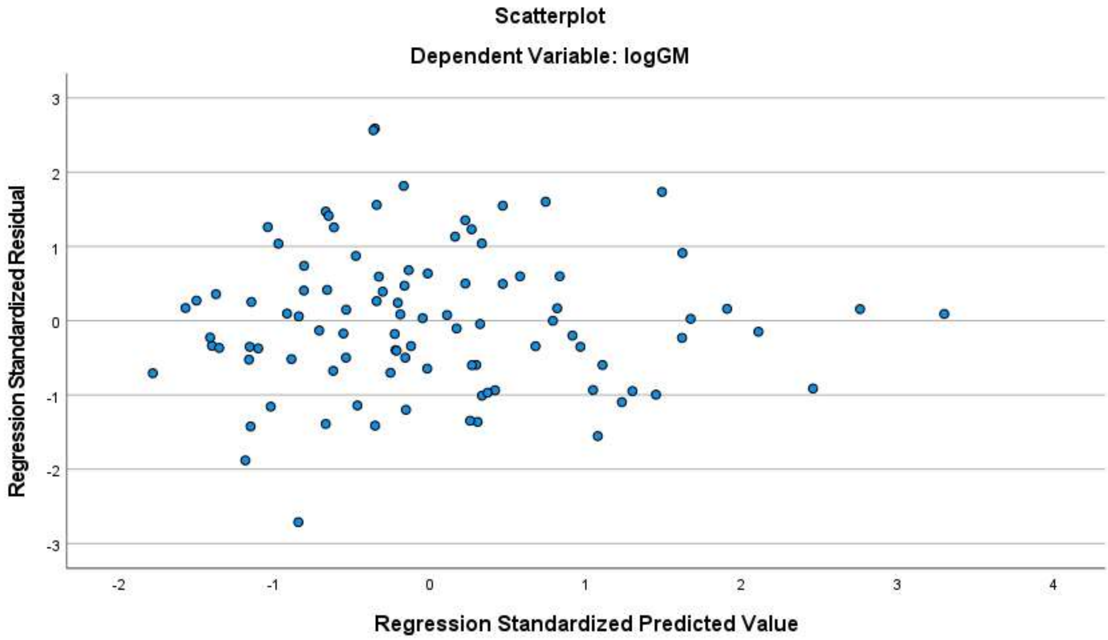
Testing Heteroscedasticity – Study 1- Model 6





Testing Heteroscedasticity – Study 2 – Model 1





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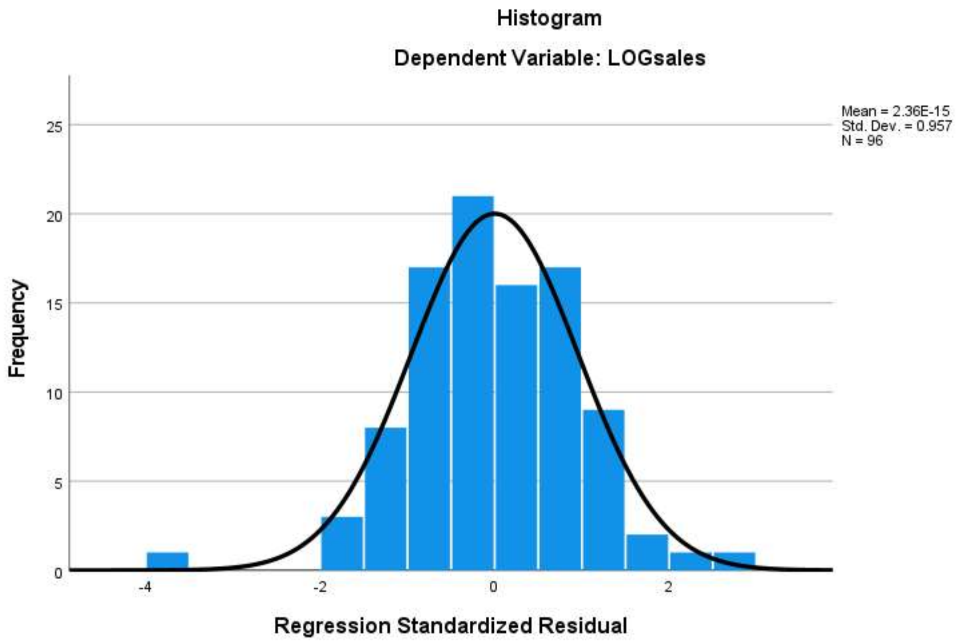
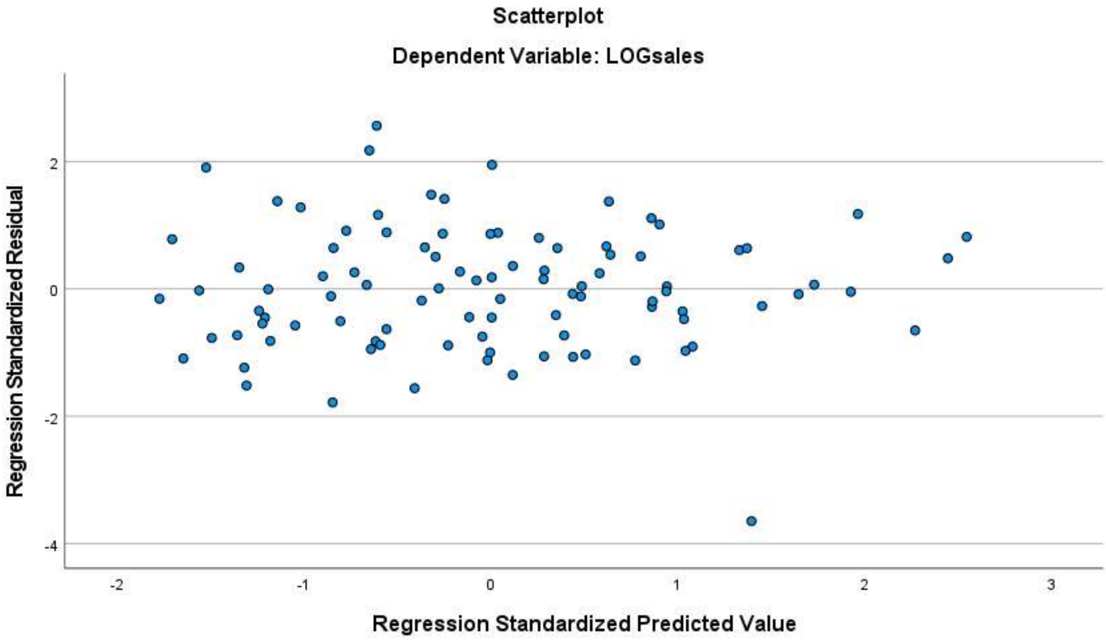
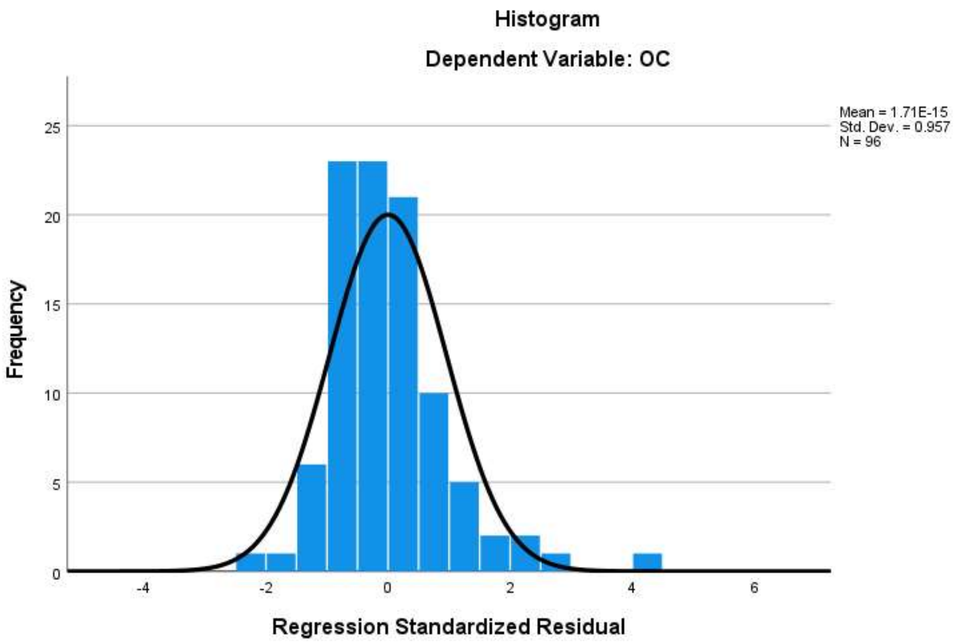
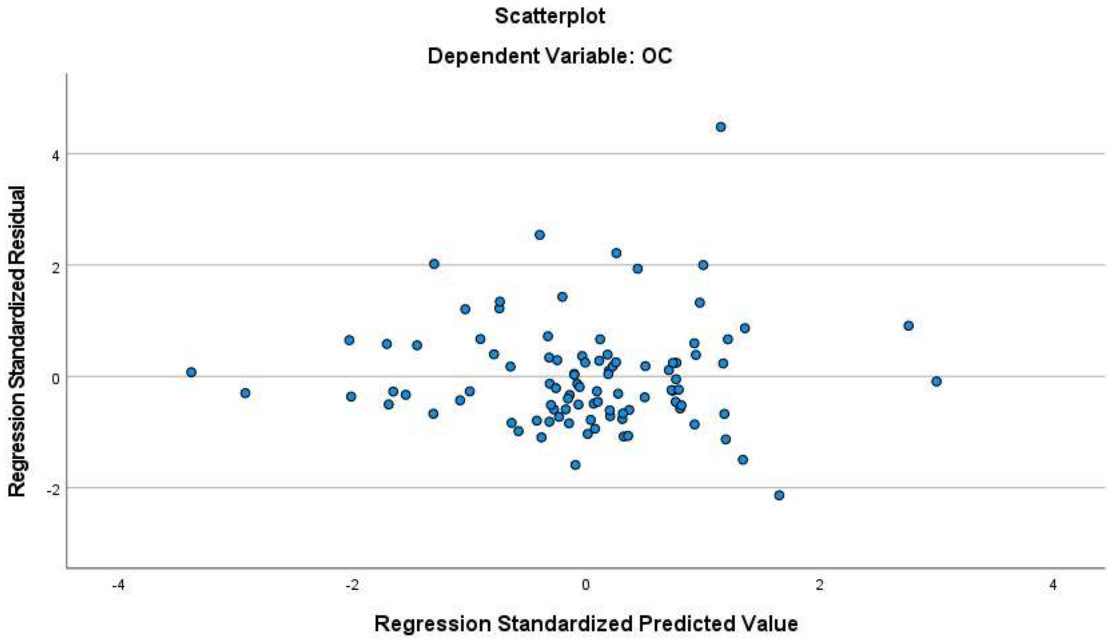


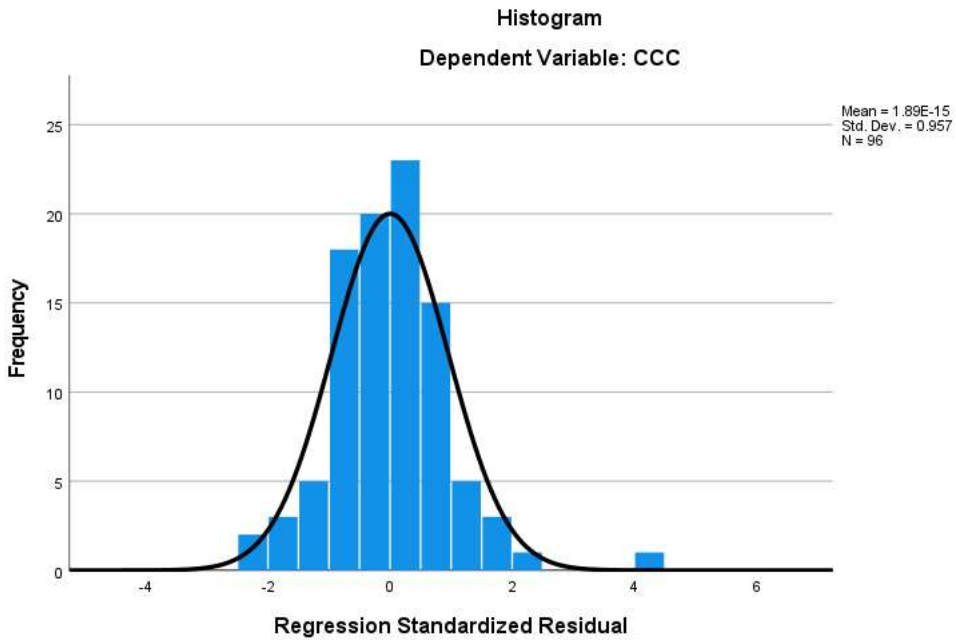


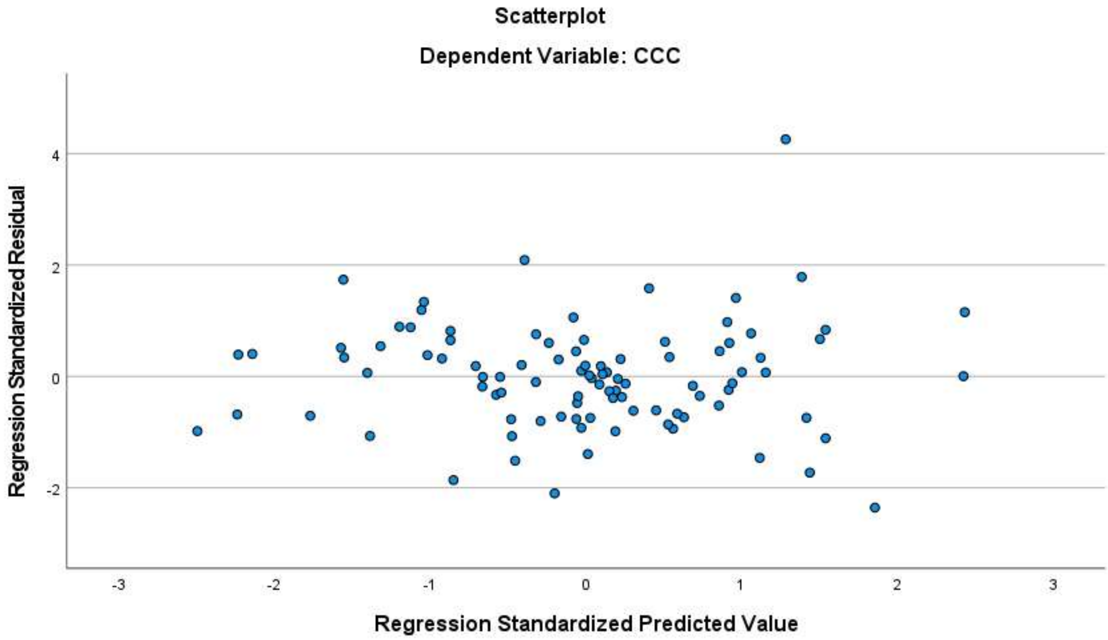
Testing Heteroscedasticity – Study 2 – Model 3



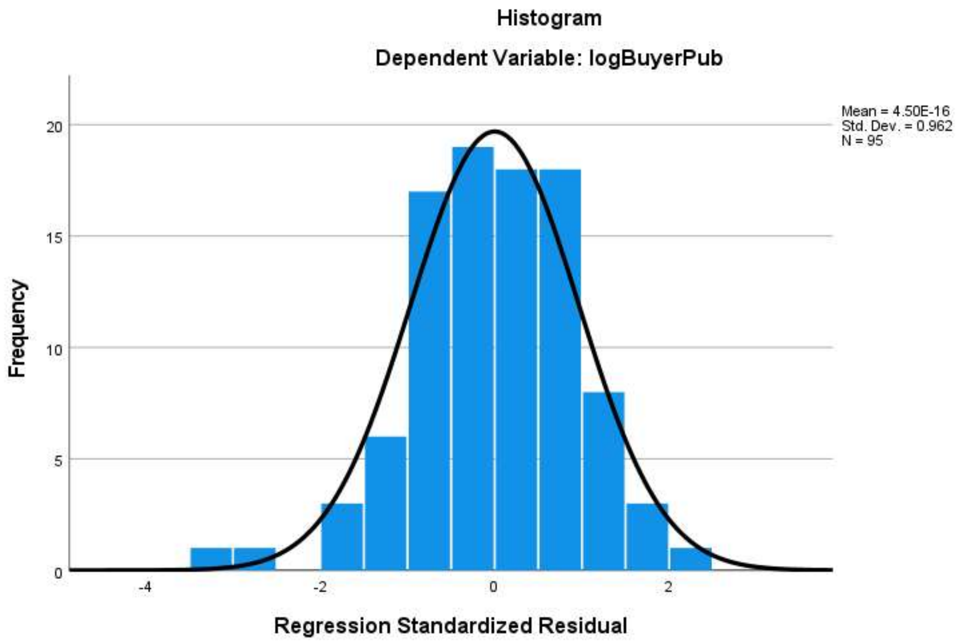


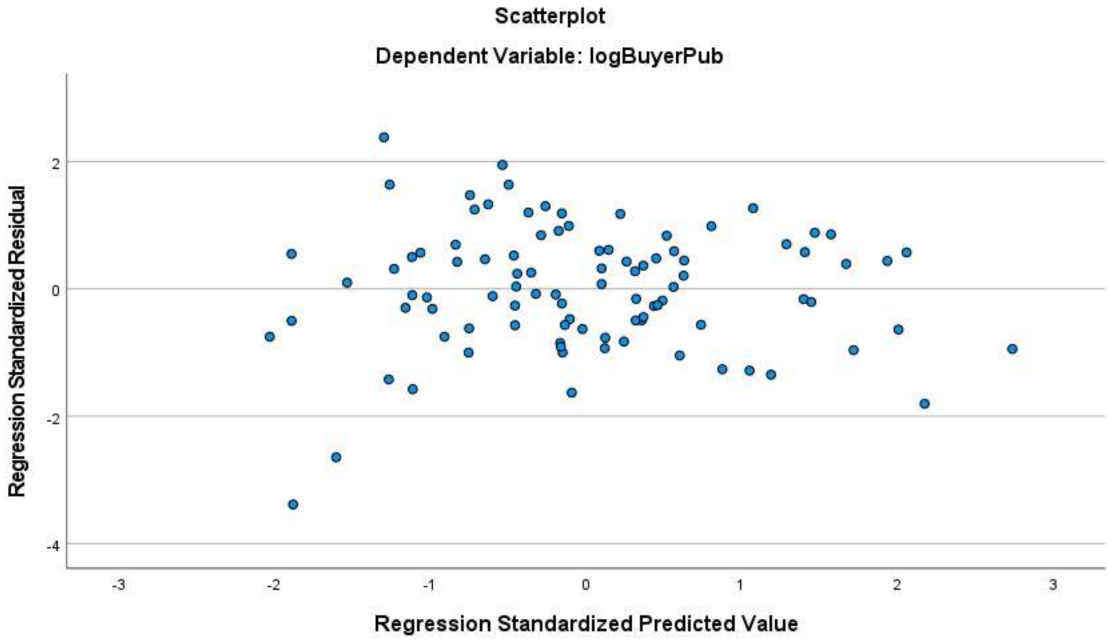
Testing Heteroscedasticity – Study 2 – Model 4





Testing Heteroscedasticity – Study 3




Scatterplot
Dependent Variable: logBuyerPub
Regression Standardized Residual
2
0
-2
-4
-3
-2
-1
0
1
2
3
Regression Standardized Predicted Value

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