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Impact of Network Relational and Structural Embeddedness on Firm's Innovation: A Study at the Saudi Firm's Level

By

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ABSTRACT

Firms are facing great challenges in the rapidly changing economy of today's world. Therefore, firms have begun searching for new means and ways to innovate in order to stay alive, compete and grow. However, many firms have yet to discover that their embedded network of relations and structures can play a crucial role in their innovation outcomes. As a result, there is growing consensus among innovation scholars that networking and inter-firm collaboration are key strategies in stimulating innovation within firms. This has resulted in a growing body of literature focused on studying the link between innovation performance and firm participation and position in networks. However, there is still disagreement and fragmented results among scholars regarding the optimum firm's network embeddedness configuration for both product and process innovation. Moreover, firms should be aware of the type of network embeddedness configurations that could constrain their innovation performance. This remains unresolved academic and practitioner challenges that require detailed investigation. Furthermore, a limited number of studies have theoretically discussed and empirically tested this research area in the context of emerging economies.

This research study addresses the aforementioned challenges and aims to shed light on the relationship between firms' network embeddedness characteristics (i.e. relational embeddedness and structural embeddedness) and their innovation output (i.e. product and process innovation). This study draws primarily on three complimentary perspectives—social capital, social network and network embeddedness—in order to shed more light on the effect that network embeddedness characteristics have on firms' product and process innovation. Furthermore, the thesis aims to both conceptually and empirically reveal the influence that network embeddedness aspects have on innovation outcomes in the context of emerging economies, with particular reference to medium and high (M&H) technology sectors in Saudi Arabia.

The study draws on the significance of network embeddedness characteristics in influencing firms' innovation performance with the principle aim of unravelling key network relational and structural embeddedness characteristics at the firm's level. This research is primarily based on new empirical evidence from the primary source data of 121 firms in M&H technology sectors in Saudi Arabia, using social network analysis and logistic regression modelling to investigate the effect of various configurations of firms' network, relational and structural embeddedness characteristics on the types of innovation (i.e. product and process innovation). The results of this study indicate that firms' innovation outcomes largely depend on their various network relational and structural embeddedness configurations. As a result, in order to fully capture the impact of network embeddedness characteristics on firms' innovation outcomes, network relational and structural embeddedness characteristics should be jointly considered (i.e. the interaction effect among different network embeddedness settings).

The evidence reveals that, by analysing the combination of firms' relational and structural network embeddedness characteristics, firms can recognise the potential, associated effects in product and process innovation outputs. This is indicated by the interaction effect between network embeddedness relational aspects (i.e. strong/weak ties) and structural properties (i.e. dense/sparse network and peripheral/central position). For instance, the findings suggest that, for high-density and central network embeddedness, strong ties type of relations will have a positive impact on firms' product and process innovation. In contrast, the empirical analysis suggests that firms that are sparsely and peripherally embedded in a network will become better product and process innovators if they develop relationships with other organisations in terms of weak ties type of relations.

The outcome of this research has both theoretical and practical implications. These implications are theoretical in the sense that they provide new insights into innovation networks area from the social capital, social network and network embeddedness perspectives, jointly considering firms' network relational and

structural embeddedness characteristics, as well as the direct, and the interaction effect on firm's innovation outcome. Regarding managerial implications, this study highlights the primary network structural properties, specifically addressing their direct, interaction effect on firms' product and process innovation. This could guide professional managers aiming for high innovation performance to re-evaluate their firms' network embeddedness configurations. Furthermore, in light of this study's limitations, directions for future research are outlined.

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Chapter 1

Introduction

1.1: Background and motivation for research

A core area of research among innovation literature concerns firms' relationship network structures, i.e. a firm's embeddedness in a network of relations, and how it conceivably enables or constrains a firm's innovation performance and outcomes (Gilsing et al., 2008; Rowley et al., 2000; Ahuja, 2000). Increasingly, firms are relying on their networks of relations and external knowledge sources for their innovation activities (Laursen and Salter, 2006; Pittaway et al., 2004). Research on network embeddedness is found to matters for firms' performance, economics, and innovation (Gilsing et al., 2008; Ahuja, 2000; Owen-Smith and Powell, 2004; Borgatti and Foster, 2003). However, not all firms' network embeddedness characteristics are equally valuable. The wide array of firms' network embeddedness configurations and their diverse effects on firms' economic actions and outcomes have created different and contradictory views on how firms should be embedded in networks (Rowley et al., 2000). This remains unresolved in academic and practitioner challenges, and it requires detailed investigation.

This thesis explores the effect of firms' network relational and structural embeddedness characteristics on their innovation output (i.e. product and process innovation). It examines the network embeddedness factors that influence firms' innovation outcomes in the context of emerging economies with particular reference to the medium and high (M&H) technology sectors in Saudi Arabia. The study draws on the significance of network embeddedness characteristics in stimulating innovation performance with a principle aim to unravel the key network relational and structural embeddedness characteristics at the firm level in the M&H technology sectors. Primarily, this research, based on new empirical evidence from primary source data, social network analysis (SNA), and appropriate statistical methods, investigates the effect of various configurations of firms' network relational and structural embeddedness characteristics on their types of innovation (i.e. product and process innovation).

Innovation is widely regarded as a critical driving force in fostering firms' competitiveness, profitability (Freeman, 1991; Mol & Birkinshaw, 2009), long term survival, and growth (Faems, Van Looy, & Debackere, 2005; Gopalakrishnan & Damanpour, 1997; Rothwell, 1991). The current pace of the world economy and today's rapidly changing business environment have created both opportunities and challenges for different actors in the economy, which has led practitioners, academics, and politicians to react and take special steps towards understanding the different mechanism and strategies that help induce innovation (Nieto & Santamaria, 2007; Tsai, 2009). However, innovation is a difficult task and involves multidisciplinary efforts from various players in the economy (Faems et al., 2005; J. Frishammar & Horte, 2005). As such, a growing body of literature on issues relating to innovation has been carried out in wider contexts, such as business and management, economies, and engineering. Innovation is generally defined as the development and commercialization of new ideas or new ways of doing things (Porter, 1990). In this thesis, innovation is defined based on the Organisation for Economic Co-Operation & Development Oslo manual (OECD OSLO), which defines it as 'the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations' (OECD, 2005, p. 46).

Firms in both developed and emerging economies face great challenges and competitive pressures that drive them to develop higher quality products or processes to gain and sustain a competitive advantage. A firm's ability to innovate is widely considered a crucial task for achieving renewal, survival, and growth (Bradley, McMullen, Artz, & Simiyu, 2012; Johan Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012; Liao, Fei, & Liu, 2008). The degree of a firm's innovativeness and competitiveness, however, may not simply depend on a single firm’s internal capabilities and skills, as a growing number of evidence has shown. Rather, it depends on how firms can gain access to external sources of knowledge, information, and competencies through an effective innovation network (Laursen & Salter, 2006; Nieto & Santamaria, 2007). Typically, the innovation process involves the participation of several actors, such as firms and other organizations, particularly where more novel innovations are sought. Therefore, organizations start to recognise that innovation is not the product of an individual firm’s isolated efforts, but instead depends on inter-firm network relationships and links as external sources of innovation (Coombs, Harvey, & Tether, 2003; Freeman, 1991; Nieto & Santamaria, 2007; Perkmann & Walsh, 2007).

Innovation scholars have primarily focused on the role of firms’ endogenous factors in innovation performance. More recently, the focus of innovation inquiry has shifted from examining the role of internal characteristics to examining the role of exogenous characteristics, particularly the role of networks (Ahuja, 2000; V. Gilsing, Nooteboom, Vanhaverbeke, Duysters, & van den Oord, 2008; V. A. Gilsing & Duysters, 2008; Owen-Smith & Powell, 2004; Phelps, 2010; Powell, Koput, & SmithDoerr, 1996; Rowley, Behrens, & Krackhardt, 2000). This recent development has advanced our knowledge to recognize the significant role inter-firm relations and networking play in fostering innovation. This can be seen in the form of gaining strategic benefits, such as knowledge, information, and resources (Owen-Smith & Powell, 2004), enhancing learning and innovation (Phelps, 2010), and access to new knowledge and information (Soh, 2003). However, there is still lack of work in relation to network analytics in existing innovation literature (Ahuja, 2000).

Previous research examined the link between firms’ innovation and external sources of knowledge, such suppliers, customers, competitors, universities, and etc. Scholars used different metaphors to theorize their approaches to firms’ interactions with their external environments, such as alliance networks, network embeddedness, clustering, research and development (R&D) cooperation, inter-organizational collaboration, and others. Exerting new ideas and knowledge from firms' external relationships and networks has grown in importance over the past two decades. This has led to a growing body of literature examining various aspects of organization from a network perspective (Borgatti & Foster, 2003; Jones, Hesterly, & Borgatti, 1997; Zaheer & Bell, 2005). Yet, the nature of such network characteristics, despite its critical significant to firms' innovation performances and to types of innovation, has not been treated in much detail in innovation literature. Moreover, the effect of firms' network characteristics in terms of relational and structural aspects on their innovation remains an under-explored area of research (V. A. Gilsing & Duysters, 2008; Rowley et al., 2000).

This thesis is inspired by the emerging stream of research that investigates the relationships between network relational and structural characteristics and firms' innovation in the view of social capital, network embeddedness, and social network perspectives (Ahuja, 2000; V. Gilsing et al., 2008; V. A. Gilsing & Duysters, 2008; Owen-Smith & Powell, 2004; Phelps, 2010; Powell et al., 1996; Rowley et al., 2000). Network embeddedness refers to 'the fact that economic action and outcomes are affected by actors' dyadic (pairwise) relations and by the structure of the overall network of relations' (Granovetter, 1992, p. 33). A firm's embeddedness in a network of relations is critical for its performance, economics, and innovation (Ahuja, 2000; Borgatti & Foster, 2003; V. Gilsing et al., 2008; Owen-Smith & Powell, 2004). The social network perspective allows for the examination of many firms' network embeddedness in terms of structural and relational characteristics and their effects on innovation. Furthermore, the main advantage of a social network approach is that its focus on the relations and structural features of the actors in the network (Wasserman and Faust, 1994). It can also provide information on the configurations and positions of actors in a network (i.e. structural embeddedness characteristics). Additionally, a social network approach can detail the quality and depth of relationships among and between actors in a network (i.e. relational embeddedness characteristics) (Granovetter, 1992).

Moreover, firms' network relational and structural embeddedness characteristics play a significant role in innovation output. The effects of these aspects could have different impacts when considered jointly. For instance, previous work that considered the effects of network relational properties (e.g. strong/weak ties) on innovation in isolation of the network structural factors (e.g. network density) produced interesting insights. However, the joint consideration of both network relational and structural embeddedness characteristics enriches our understanding of this interactive effect on firms' innovations as recommended by scholars (V. Gilsing et al., 2008; Gulati, 1998; Rowley et al., 2000). This type of joint consideration could assist firms to better recognize the innovation opportunities or constraints that lie beneath their network embeddedness configurations. Therefore, this dissertation aims to investigate this potential interactive effect on firms' innovation outcomes.

Another motive that triggers this study is the dearth of literature on the emerging economies contexts. The fact that innovation is an important strategic element in firms' competitiveness and growth is nowadays broadly accepted and is well established in developed countries. In fact, innovation literature considerably advanced our knowledge regarding innovation networks and collaborative linkage in developed countries. In contrast, few scholars have theoretically discussed and empirically tested this area of research in the context of emerging economies (Chen, Guo, & Zhu, 2012; Zeng, Xie, & Tam, 2010). Moreover, recent studies of emerging economies suggest that firms rely mostly on accessing foreign knowledge and resources for their innovation activities (Kafouros & Forsans, 2012; Li, Chen, & Shapiro, 2010; Mahmood & Mitchell, 2004; Wang & Kafouros, 2009). Therefore, this research seeks to bring together the effects of firms' network of relations and structures on their innovation outputs in emerging economies.

Lastly, but not least, the inspiration for this research comes from the emerging industrial policy in the Kingdom of Saudi Arabia (KSA), which targets economic diversification and seeks to reduce KSA's modern dependence on exporting crude oil (Saudi vision 2030). Saudi Arabia considered one of the largest oil producers in the world and aims to extend its pool of product and process innovation through economic diversification. Saudi Arabia is a G20 country and has become Middle East-North Africa's (MENA) top destination for foreign investment, while in the period 2009-2014, Saudi Arabia attracted only about 111 billion dollars in foreign investments (Saudi Arabian General Investment). Furthermore, KSA plans to lay the foundations of a knowledge-based economy in which it will focus on fostering technological learning and exchanging knowledge with various players in the local and global economy to leverage industry innovation (Ministry of Economy and Planning). Nonetheless, the lack of well-documented work on innovation-related issues such as networking and openness, firms' internal and external characteristics, and firms' innovation capabilities, alliances, and partnerships make it an interesting case to instigate.

This study will build on the extant literature that examined and acknowledged the significance of network embeddedness on economics and innovation. This research distinguishes between two main types of network embeddedness, relational embeddedness and structural embeddedness. It develops a model to explain these network embeddedness characteristics and their association with firms' product and process innovations in the M&H technology sectors in emerging economies. The following section presents the objectives and research question of this thesis.

1.2: Aim, significance, and scope of the research

1.2.1: Research question and objectives

The overall aim of this thesis is to investigate and understand the potential impact of firms' network characteristics on their innovation outcomes in the context of medium and high (M&H) technology sectors in emerging economies. The following objectives have been developed to address this aim: first, to conceptualize and operationalize the notion of network embeddedness in M&H technology sectors in emerging economies; second, to develop and test the research conceptual model and derive the study hypothesis linking network embeddedness characteristics to firm innovation; third, to use social capital, network embeddedness, and social network perspectives to understand firms’ network characteristics and their potential effect on types of innovation (i.e. product and process innovation); fourth, to provide an empirical application of the effects of network embeddedness on firms’ innovation outcomes; and lastly, to provide theoretical and practical implications for the scientific community and business sectors as along with directions for future research.

Based on the discussed aims and objectives of this study, the specific guiding research question is as follows:

To what extent do firms’ network embeddedness characteristics (i.e. relational and structural embeddedness characteristics) impact their innovation outcomes (i.e. product and process innovation)?

The research question was developed to enhance the understanding of the relationship between network embeddedness characteristics and product and process innovation. Moreover, the research question addresses the two main aspects of network embeddedness (i.e. relational and structural embeddedness characteristics) and their direct and combined effects on innovation. Accordingly, this study argues that the characteristics of a firm’s network relational and structural embeddedness have important implications on its likelihood to generate product and process innovation. The developed conceptual framework in this research is shown in Figures 1.1 and 3.1 and depicts the relationship between a firm’s network embeddedness characteristics and its innovation outcome (i.e. product and process innovation).

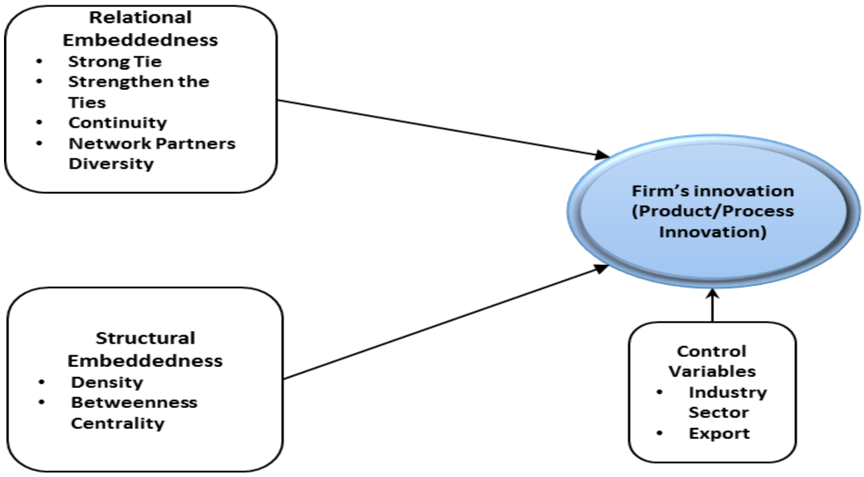

Figure 1.1: overview of the research conceptual model

1.2.2: Significance of the study

The significance of this study can be specified according to its theoretical contributions and managerial implications. The outcomes of this research are expected to shed light on the key role played by a focal-firm's network embeddedness in terms of structural and relational characteristics on its innovation types (i.e. product and process innovation). The uniqueness of this study resides in its ability to address many remaining black boxes in the emerging fields of innovation studies, social capital, network embeddedness, and social network in the context of emerging economies' medium and high technology sectors. Moreover, by examining focal-firms' key network embeddedness characteristics in terms of relations and structures, this research attempts to demonstrate that firms' economic actions and outcomes, such as innovation, are influenced by the networks of relations in which they are embedded. The study also provides a conceptually derived framework model that links innovation to network embeddedness characteristics. Empirical primary data were sought, analysed, and discussed to provide informed evidence towards our understanding of the effects of network embeddedness characteristics on a firm's product and process innovation. This research shed more light on which aspects of network embeddedness may stimulate or constrain a firm's innovation outcomes. Additionally, it brings several significant findings that have insightful implications for the research community in the fields of innovation studies, social capital, network embeddedness, and social networks, as well as for firms seeking the optimal network embeddedness configuration for their diverse innovation efforts.

1.3: Research methods

The primary source data to investigate the developed conceptual framework and test the proposed hypotheses was collected via a self-completion questionnaire. To ensure the reliability and validity of the research instruments' constructs, the questionnaire was sent to number of experts in both academia and industry for comments and improvements. The questionnaire was designed to capture data on firms' product and process innovation and focal-firms' network embeddedness in terms of structural and relational characteristics. The targeted respondents were top managers/directors in the medium and high technology sectors in Saudi Arabia. This was achieved based on a multiple sampling procedure to approach the targeted sample.

614 firms were identified as M&H technology sectors in Saudi Arabia. The final valid response rate was 121 firms representing 22% of the distributed questionnaires. Focal-firms' network embeddedness data were constructed and computed using UCINET 6.586 software, a social network analysis package (Borgatti et al., 2002). Subsequently, the full analysis was carried out using statistical testing by the means of logistic regression modelling (LR). The full explanation of the adopted research methodology can be found in Chapter 4.

1.4: Limitations

The insights this dissertation provides into innovation, social capital, network embeddedness, and social network domains are limited by its cross-sectional and survey-based design. It is unable to explore firms' network dynamics and its accumulative effect on innovation. To overcome this limitation, future research could employ a longitudinal approach and in-depth case studies to further investigate the nature and mechanisms of the long-term effects. Another limitation of this research is related to the relatively small sample size of 121 firms. Although sufficient for accomplishing the objective of this research, collecting more samples may be useful to strengthen the outcomes. Having a larger sample size could also help control other specific effects like the type of sector and the network collaboration partners. In addition, the study was restricted to the context of the medium and high technology sectors in Saudi Arabia. Future research could aim to build on this study by testing its conceptual model in other research contexts.

Furthermore, this study relies on the derived conceptual model, which has not been tested beyond the abovementioned survey. The self-reports used in this study might not be entirely accurate, as they rely mostly on a respondent's experience and memory of their firm's related innovation and networks data. However, the study tried to remedy this limitation by employing reliable innovation questions, such as OECD's community innovation survey, providing adequate definitions for network questions and consulting available firm's and public archival data, but it might not be sufficient to claim perfect reliability. Additionally, the current research was only focused on two types of innovation (product and process innovation), meaning the outcome of this study is only related to these types of innovation. Future research could be extended to other types on innovation, such as organization, marketing, incremental, and radical innovation. Moreover, the measures of product and process innovation were based on respondents' perceptions. Future research could use other objective measures, such as profit, return on sales, return on profits, and patents. The final limitation is related to the unit of analysis (the firm) and the adopted network level of analysis (i.e. ego-network). The study results suggest very insightful implications from the focal firm's perspective. However, it does not capture all network aspects, which might have an effect on a firm's ego-network and innovation. This reveals a great opportunity for future work to incorporate and examine various levels of analysis, such as the whole network and industry levels.

1.5: Thesis structure

This thesis is structured into the following seven chapters:

Chapter 1: Introduction. This chapter addresses the research background and motivation. It also discusses the aim, contributions, and scope of the research, research questions and objectives, and significance of the study. Additionally, it presents an overview of the research methods and analyses, and addresses some limitations of the study, suggesting research paths for future work.

Chapter 2: Literature review. This chapter introduces the research rationale and objectives, and establishes the theoretical foundation underpinning this thesis by reviewing extant literature in innovation, social capital, social networks, and network embeddedness. It explains the applied systematic literature review that identifies knowledge gaps in the current stream of research, what has motivated this research.

Chapter 3: Conceptual framework development. This chapter uses the concept and rationale provided in the previous chapters as a foundation to develop the conceptual model of the study. Based on this model, a number of hypotheses are developed and proposed in order to answer the study research question.

Chapter 4: Research design and methodology. This chapter describes the research design and methodological approach in this thesis. It begins by providing an overview of the adopted philosophy and its implications with the adopted research strategy and design. Additionally, various aspects of the research methodology are discussed in detail, such as analytical methods, research instrument construction and implementation, and methods of data analysis.

Chapter 5: Quantitative findings and data analysis. This chapter presents the quantitative findings and data analysis. It provides the research conceptual model that was tested using the data collected via the research instrument (questionnaire). Additionally, it explains the statistical method, data analysis, and results of hypotheses testing in terms of the direct and interaction effects of firms' relational and structural network embeddedness on their product and process innovations.

Chapter 6: Discussion. This chapter provides the main discussions and insights based on the research hypotheses. Additionally, it describes and explains in detail the key findings of the statistical analysis, as well as its connections and contradictions to current literature.

Chapter 7: Conclusion. The final chapter of the study reviews the research aim and objectives. It also discusses the theoretical contributions and practical implications that can be extracted from this study. In the final part, the research limitations are discussed and avenues for future research are offered.

Chapter 2

Literature Review

2.1: Introduction

This chapter seeks to establish the theoretical foundation underpinning this thesis by reviewing extant literature on innovation, social capital, network embeddedness, and social networks. The chapter starts by explaining the applied systematic literature review and identifies knowledge gaps in the current stream of research, which motivates this study.

An increasing number of studies have investigated and acknowledged the important role of inter-firm and collaborative networking on firms' innovation. However, the effects of network structural and relational characteristics on firms' innovation remain under-explored (Rowley et al., 2000; Gilsing and Duysters, 2008). This research is motivated to explore these network properties and their influence on innovation from the social capital, social network and network embeddedness perspectives, which will be discussed in detail in the second part of this chapter. The main social network and structural and relational characteristics will be identified and explained in relation to their degree of impact on innovation.

Therefore, the research objectives in the present study are motivated by two streams in innovation literature: first, the significant role innovation plays in a firm's survival, growth, and competitiveness, which depend heavily on the way firms interact and collaborate with other actors in the economy; and second, to enrich our understanding and investigate in-depth the effect of firms' network structural and relational characteristics on innovation.

In light of these motivations and objectives, a systematic literature review was conducted to map and assess the existing body of knowledge on innovation. Additionally, the systematic literature review summarizes research outcomes and highlights the identified knowledge gaps in the extant literature.

2.2: Systematic literature review (SLR)

This section presents the systematic literature review (SLR) to map and evaluate the relevant body of knowledge and to illuminate the key scientific contributions linking networking to innovation that have been published over the past 35 years. It outlines the present study's chosen methodology to find the current themes of research as well as knowledge gaps that are relevant to this study main topic. Moreover, the outcome of this approach has helped identify an under-explored avenue of research concerning emerging economies in the field of innovation management studies. It has also developed, specified, and established the legitimacy of the research question of the present study.

A systematic review of the literature provides a rigorous, replicable, scientific, and transparent process that improves the quality of the review process and outcomes (Tranfield et al., 2003). Moreover, SLR helps search the body of knowledge in the intended research area to identify current research themes as well as knowledge gaps that are relevant to the research topic (Tranfield et al., 2003; Crossan and Apaydin, 2010; Pittaway et al., 2004). Additionally, the SLR aims to map and evaluate relevant existing evidence-based studies (Thorpe et al., 2005).

In this thesis, the SLR follows the protocol outlined by Tranfield et al. (2003) and Crossan and Apaydin (2010), which consists of a three-stage procedure: planning, execution, and reporting. First, during the planning stage, the review protocol was defined and the initial inclusion and exclusion criteria were set, as illustrated in Table (2.1). Second, the execution stage of mapping the literature was achieved by accessing, retrieving, and evaluating the quality and relevance of publications. Finally, the reporting stage identified knowledge gaps in this domain and helped construct the research question.

2.2.1: Stage 1: Planning the review

The planning stage of the review consists of three main steps: setting the inclusion/exclusion criteria, locating and selecting potential studies, and grouping publications. This research elected to restrict the selection of studies to published peer-reviewed journals and to articles retrieved from the ISI Web of Knowledge's Social Sciences Citation Index (SSCI) database from 1980 to 2017. Table (2.1) shows the inclusion / exclusion criteria for this review.

Inclusion Criteria	Reason for inclusion	Reference
Published Peer-reviewed Journals articles	Considered validated knowledge and are likely to have the highest impact in the field.	Crossan and Apaydin, 2010; Thorpe et al., 2005.
Articles located at ISI Web of Knowledge's Social Sciences Citation Index (SSCI) database	It is one of the most comprehensive databases of peer-reviewed journals in the social sciences. Its unique feature of citation counts allows a rank of a large pool of articles based on this objective measure of influence.	Crossan and Apaydin, 2010.
Theoretical and empirical studies	To provide the working assumptions for the research.	Crossan and Apaydin, 2010; Pittaway et al., 2004.
Quantitative and qualitative studies	Identify all empirical analyses and different methodologies.	Crossan and Apaydin, 2010; Pittaway et al., 2004.
1980-to current	To narrow the reviewed articles in order to identify current knowledge gaps. With very few exceptions, contributions and studies to networking started to be published after 1980	Pittaway et al., 2004.
Exclusion Criteria	Reason for exclusion	
Pre-1980	To narrow the reviewed articles in order to identify current knowledge gaps. With very few exceptions, contributions and studies to networking started to be published after 1980	Pittaway et al., 2004.
Other than Published Peer-reviewed Journals articles (i.e. Books, Books reviews, conference papers, periodicals, magazines, doctoral dissertations, unpublished articles)	To focus only on published peer-reviewed journals.	Crossan and Apaydin, 2010.
IT networks related to systems and integrations	Not considered inter-organizational networks.	Pittaway et al., 2004.
Narrowly focused articles (e.g. on libraries, healthcare, agriculture, tourism, IT, environmental, etc.)	Not relevant to the research topic.	Pittaway et al., 2004.

Table 2.1: The inclusion / exclusion criteria of the systematic literature review

2.2.2: Stage 2: Execution

This stage of the SLR involved identifying initial search strings, search keywords, and research areas. In addition, articles were grouped into three main groups: reviews and meta-analyses, highly cited papers, and recent papers.

2.2.3: Initial search strings, search keywords, and research areas

A comprehensive structured search is what distinguishes a systematic review from a traditional narrative review. It is conducted by identifying keywords and search strings (Tranfield et al., 2003). For the purpose of this research, the initial keyword 'innovation' and its derivatives were used for the first group of publications (reviews and meta-analyses), as highlighted below. The results were analysed and used to identify further keywords and research areas for the link between networking and innovation research.

2.3: Grouping Publications

This study intends to map and assess current publications and develop a comprehensive understanding of innovation and networking literature in different disciplinary backgrounds. Researched scientific publications were grouped into three categories following the protocol outlined by Crossan and Apaydin (2010), but with some of the methods refined slightly. The first group (Group 1) consisted of Reviews and Meta-analyses, which allowed for an understanding of the broadness of the innovation field. The second group (Group 2) was made up of studies that have the most citations in the field, which were identified by applying citation-based selection criteria. The final group (Group 3) was considered to include recent scholar's publications to reduce possible citation bias in applying citation-based analysis to the recent publications. Additionally, the inclusion and exclusion criteria outlined in Table (2.1) were applied to all three groups. Each paper was subjected to two stages of evaluation: analysis of the title's relevance to the topic and abstract analysis. Furthermore, each group was restricted to specific additional criteria, such as citation-based analysis and journal rank for each individual group, which will be further elaborated on the following sections.

2.3.1: Group 1: Reviews and Meta-analyses

Reviews and meta-analyses were identified by restricting our search to papers using the basic search string 'innovation' and its derivatives (i.e. innovation*) in the title and 'review' and 'meta' in the topic (title, abstract, or keywords). Table (2.2) summarizes the search protocol for this group. A total of 644 studies were retrieved, and were then further subjected to inclusion/exclusion criteria through a two stage analysis: title analysis and abstract analysis. In the end, 44 studies were considered in this group.

Stage#	Group Name	Number of studies		
		included	excluded	duplicate
1	**Reviews and meta-analyses**	644	-	-
1.1	Title analysis	114	530	-
1.2	Abstract analysis	**44**	70	-
Search string (SSCI) database	TITLE: (innovation*) Refined by: RESEARCH AREAS: (BUSINESS ECONOMICS OR OPERATIONS RESEARCH MANAGEMENT SCIENCE OR PUBLIC ADMINISTRATION) AND DOCUMENT TYPES: (ARTICLE OR REVIEW) AND LANGUAGES: (ENGLISH) AND TOPIC: (meta or review) Timespan=1980-2017			

Table 2.2: Summary of the search for reviews and meta-analysis (Group 1)

2.3.2: Group 2: Highly Cited Papers

For highly cited papers, a citation-based analysis was employed to measure the paper quality, as it is considered a proper measure of a paper's contribution to knowledge accumulation and development (Crossan and Apaydin, 2010). Additional keywords were added to the search string to identify articles relevant to the area of innovation networks. The review initially identified 919 papers, and, using 2013 at the base year, the retrieved studies were sorted by the number of citations in order to identify the highest impact papers, which had at least five citations per year (Crossan and Apaydin, 2010). Following that, 134 papers were considered in this group in the SLR. Details for this group are found in Table (2.3).

Stage#	Group Name	Number of studies		
		included	excluded	duplicate
2	**Highly cited Papers (initial search)**	919	-	-
2.1	Citation-based analysis *Identified high impact papers, which had at least five citations per year (using 2013 as the base year) (Crossan & Apaydin, 2010)	326	593	-
2.2	Title analysis	171	152	3 (included in G1)
2.3	Abstract analysis	134	37	
Search string (SSCI) database	You searched for: TITLE: (innovat* and network*) OR TITLE: (innovat* and ties) OR TITLE: (innovat* and alliance) OR TITLE: (innovat* and Collaboration) OR TITLE: (innovat* and linkage) OR TITLE: (innovat* and Inter-organizational) OR TITLE: (Innovat* and cooperation) OR TITLE: (innovat* and Cluster) OR TITLE: (Innovat* and sources) Refined by: RESEARCH AREAS: (BUSINESS ECONOMICS OR OPERATIONS RESEARCH MANAGEMENT SCIENCE OR PUBLIC ADMINISTRATION) AND DOCUMENT TYPES: (ARTICLE) AND LANGUAGES: (ENGLISH) AND [excluding] DOCUMENT TYPES: (MEETING OR OTHER OR CLINICAL TRIAL OR BOOK) Timespan: 1980-2017.			

Table2.3: Summary of the search for highly cited papers (Group 2)

2.3.3: Group 3: Recent Papers

The recent publication group (2012-2017) was formed to reduce the bias of the citation-based analysis approach, which might discriminate against newly published papers that do not have time to accumulate citations (Crossan and Apaydin, 2010). Using the search strings highlighted in Table (2.4), 596 papers were retrieved during the initial search. Based on the premise that top journals normally publish top quality papers (Crossan and Apaydin, 2010), the review followed The Association of Business Schools' (ABS) academic journal quality guide (Harvey et al., 2010) to identify the highest grade journals (grades 3, 4, and 4*), which reduced the number of studies to 242 papers. In addition, 43 articles were identified as already belonging to Groups 1 and 2. This left 116 studies published in recent years (2012-2017) for further analysis by the inclusion/exclusion criteria. The total considered studies for the SLR are summarized in Table (2.5).

Stage#	Group Name	Number of studies		
		included	excluded	duplicate
3	**Recent papers (initial search)**	596	-	-
3.1	Grade 3,4, and 4* Journals	242	354	
3.2	Title analysis	184	15	43 (either G1 or G2)
3.3	Abstract analysis	**116**	68	
Search string (SSCI) database	You searched for: TITLE: (innovat* and network*) OR TITLE: (innovat* and ties) OR TITLE: (innovat* and alliance) OR TITLE: (innovat* and Collaboration) OR TITLE: (innovat* and linkage) OR TITLE: (innovat* and Inter-organizational) OR TITLE: (Innovat* and cooperation) OR TITLE: (innovat* and Cluster) OR TITLE: (Innovat* and sources) Refined by: RESEARCH AREAS: (BUSINESS ECONOMICS OR OPERATIONS RESEARCH MANAGEMENT SCIENCE OR PUBLIC ADMINISTRATION) AND DOCUMENT TYPES: (ARTICLE) AND LANGUAGES: (ENGLISH) AND [excluding] DOCUMENT TYPES: (MEETING OR OTHER OR CLINICAL TRIAL OR BOOK) AND PUBLICATION YEARS: (2012-2017			

Table2.4: Summary of the search for recent papers (Group 3)

Group Name	Initial search	included	excluded	duplicate	Considered studies for the review
1: Reviews and Meta-analysis	644	44	600	0	44
2: Highly Cited Papers	919	134	785	3	134
3: Recent Papers	596	116	480	43	116
Total					
	2159	294	1865	46	**294**

Table2.5: Considered studies in the systematic review

2.3.4: Other considered literature

Several key publications (i.e. books and articles) were also considered in this research. The considered references are among the major contributions to knowledge in innovation management, social capital, and social network and network embeddedness fields.

2.4: Background of innovation

This section provides a review of innovation literature. It begins by providing a definition and discussion of innovation and the dimensions of innovation (i.e.

innovation as a process and as an outcome). It continues by explaining how innovation concepts have evolved over time (i.e. models of innovation) and discusses the types of innovation. Lastly, this section outlines the different context of innovation in the reviewed literature.

2.4.1: Innovation defined

One of the challenges in innovation literature is the lack of consensus on defining innovation (Garcia and Calantone, 2002). This is might be because innovation studies include scholarly contributions from multidisciplinary fields such as management, marketing, engineering, economics, and others. Most definitions highlight the exploration and exploitation of new knowledge. One of the early definitions of innovation was introduced by Schumpeter (1934), who defined innovation to cover five main aspects: the introduction of new goods (product innovation); the introduction of new methods of production, including new ways of handling a commodity commercially (process innovation); the opening of new markets (market innovation); the conquest of new sources of supply (input innovation); and the carrying out of a new organisational practice in any industry (organisational innovation) (Schumpeter, 1934, p. 66; Drejer, 2004). Schumpeter's definition embraces two main elements of innovation, one element is the 'introduction/opening/carrying out' and other element is being 'new', which means that it is an essential feature of innovation that it is something new and carried into practice (Schumpeter, 1934; Drejer, 2004). Porter (1990) agrees, and he refers to innovation as a new way of doing things that is commercialised (Porter, 1990). These concepts and definitions of innovation serve as the basis of innovation in the context of this thesis. Innovation in this study is defined based on the OECD (2005) OSLO manual definition, which is 'the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations' (p. 46).

2.4.2: Dimensions of innovation

Researchers have classified innovation into two primary categories, namely innovation as a process and innovation as an outcome (Crossan and Apaydin, 2010; Gupta et al., 2007). Studies that looked into innovation as a process (how the new idea emerged) dealt with this approach by considering internal and external factors that could serve as drivers or sources of innovation (Crossan and Apaydin, 2010). For internal factors, innovation can be driven by a firm's available knowledge and resources, such as internal research and development (R&D), or can be sourced through idea generation. External drivers include market opportunities or imposed regulations, and they can be in the form of complementary resources acquired from elsewhere (Crossan and Apaydin, 2010; Laursen and Salter, 2006). However, the view of innovation as a process is still an under-developed area of research, findings are varied (Crossan and Apaydin, 2010; Gupta et al., 2007; Becheikh et al., 2006; Keupp et al., 2012; Tidd, 2001).

The other dimension deals with innovation as an outcome (what or what kind of new idea) (Crossan and Apaydin, 2010; Gupta et al., 2007). Innovation as an outcome takes different types and magnitudes. Innovation can take the form of commercialization a product, process, marketing, or organizational innovation. Additionally, the literature identifies innovation as either radical or incremental depending on the degree of change associated with it (Gopalakrishnan and Damanpour, 1997; Toedtling et al., 2009; OECD, 2005). Other scholars defined the degree of change or newness of innovation to be either radical or incremental based on its newness to the firm, to the market, or to the industry (Reichstein and Salter, 2006; Crossan and Apaydin, 2010). For example, the taxonomy of novelty of innovation is radical if it is associated with the market and industry, such as microchip, and is incremental when making smaller changes like changing the packaging on an existing product (Henderson and Clark, 1990; Laursen and Salter, 2006; Ettlie et al., 1984).

Innovation concepts have been conceptually and empirically examined across different levels and contexts. Studies at different levels of analysis and approaches to the field of innovation at various levels, such as regional, national (Watkins et al., 2015; Fu et al., 2011), industry, market, firm (Coriat and Weinstein, 2002, Tether, 2002, Ritter and Gemunden, 2004), team, or individual levels, have advanced our understanding and helped enhanced innovation literature. However, various research and theoretical perspectives have produced inconsistent and fragmented outcomes (Adams et al., 2006; Gupta et al., 2007). Therefore, specifying the context of innovation and a theoretical perspective are critical while reviewing literature.

The reviewed literature as illustrated in this section emphasizes the importance of specifying innovation dimensions and theoretical perspectives in any research. For that reason, and for the purpose of this thesis, the reviewed journal papers were categorized based on the form of innovation, the innovation models, and the innovation context. Table (2.6) provides further explanation of these categories.

Innovation dimensions	
Innovation models	Innovation evolved over time from a simple linear sequence process model (technology push, market pull model) into a model with a more interactive nature. Integration and networking with multiple players in the environment lead to further development in innovation processes and a more open innovation perspective.
Innovation form	The form of innovation comprises the type or magnitude of innovation. Product, process, marketing, or organizational innovations differentiate between the specific new administrative and technological natures of innovation. The magnitude of innovation indicates the innovation's degree of newness to the firm, market, or industry.
Innovation context	The context of innovation refers to the broad environment where innovation emerges. This addresses the effects of economics and social environments on innovation, such as the international context, national context, emerging or developing economies context, industry context, and firm context.

Table 2.6: Dimensions of innovation

2.4.3: Models of innovation

Many scholars have sought to understand the innovation process and failed to provide a comprehensive framework to guide innovation research or management practice (Tidd, 2001; Gupta et al., 2007). A review of the different innovation models that occurred over time might lead to a better understanding of how the concept evolved. According to Rothwell (1994) and Tidd et al. (2013), early models viewed innovation progress as sequential linear activities. For the first generation innovation process model (1950s to mid-1960s), innovation opportunities arose from scientific discovery or through technological development in industry to the marketplace, in what's called a technology-push model. Market-pull model (sometimes referred to 'Need-Pull') is the second generation model of innovation (mid-1960s to early-1970s). In this model, the innovation process began to shift towards a need for something new based on market demands. The market was the source of ideas triggering research and development (R&D) in manufacturing. The first two linear models suffered from a clear limitation because innovation in practice requires a complex process with multiple, cumulative interactions between different players and activities. The third generation model (early 1970s to mid-1980s) was introduced to overcome this shortfall and to integrate both technology push and market-pull models. This third model is considered a coupling model, where interaction and feedback loops between science, industry, and market are critical elements in the innovation process. Further advances to the complex and the interactive nature of innovation have led to the birth of the fourth generation model (early 1980s to early 1990s). It has been recognised in leading Japanese companies where integration with suppliers and customers in the early stages of innovation activities and parallel in-house development rather than sequential are essential features of the fourth innovation model.

One of the key aspects of innovation is that firms should recognise the complex, uncertain, and highly risky sets of phenomena inherited in managing innovation. There is a growing consensus in the literature that innovation is not simply a one actor task, but is instead a result of an interactive, multi-actor process that requires a high level of integration and networking. This has been the main driver for shifting towards the fifth generation model of innovation, a process of systems integration and networking facilitated by information and communication technology (ICT). Firms are connected to an extremely diversified set of actors through collaborative networks and the exchange of knowledge and information. In this model, innovation is seen as a result of on-going interaction and collaboration between many players, such as individuals, firms, and external environmental factors (Rothwell, 1994; Tidd et al., 2013). Furthermore, innovation management scholars started to explore the idea of organizations' openness, which suggests that innovation is no longer seen as a single organization's isolated efforts (Dahlander and Gann, 2010). Through his proposed open innovation model, Chesbrough (2003) points out that firms should start to look outside their own boundaries and be more open to shifting their strategies and using a wide range of external actors and sources to help them achieve and sustain innovation. Chesbrough (2006) also defined open innovation as 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively' (p. 2). This definition highlights with the importance of engaging with different players in the economy and building on existing networking and interaction to leverage their internal capabilities and innovation performances. Table (2.7) summarizes the innovation models over different generations.

Generation	Key features	References
First/Second	Simple linear models; technology push, need/market pull	Rothwell's five generation of innovation models (Tidd et al., 2013, p. 77).
Third	Coupling model; recognising interaction between different elements and feedback loops between them	
Fourth	Parallel model; integration within the company; upstream with key suppliers and downstream with demanding and active customers; emphasis on linkages and alliances.	
Fifth	Systems integration and extensive networking; flexible and customised response; continuous innovation	
Sixth	'A paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology'	Chesbrough's open innovation model (Chesbrough, 2006, p. 2).

Table 2.7: Innovation models over different generations

2.4.4: Types of innovation

The notion that innovation takes several forms with different competitive effects is well established (Henderson and Clark, 1990; Ettlie et al., 1984; Garcia and Calantone, 2002; Reichstein and Salter, 2006). Therefore, a clear distinction between the various forms of innovation is necessary. In this thesis, the forms of innovation refer to innovation outcomes that can take several types and magnitudes according to scale, nature, and degree of novelty (Gupta et al., 2007). Many scholars have accepted OECD's definition of innovation and innovation types since it accommodates a range of different forms of innovation(see Tether and Tajar, 2008b; Tether, 2002; Weterings and Boschma, 2009; Mol and Birkinshaw, 2009; Laursen and Salter, 2006; Becheikh et al., 2006; Lasagni, 2012; Gunday et al., 2011; Leiponen and Helfat, 2010; OECD, 2005). The definition identifies four types of innovation: product, process, marketing, and organizational. Moreover, the minimum requirement for innovation is that it must be new, or at least significantly improved, to the firm (OECD, 2005). Product innovation can be defined as the introduction of a new or a significantly improved good or service with respect to its capabilities. The definition complements new technological products and services in both the manufacturing sector and the service sector. Process innovation is the implementation of new or significantly improved production processes, distribution methods, or supporting activities, but excludes purely organizational or managerial changes (OECD,2005; Reichstein and Salter, 2006).

One criticism to the earlier OECD's edition is that it favoured technological over other types of innovation, as it was initially designed to capture technological product and process (TPP) innovation in manufacturing (Tether and Tajar, 2008b). This was amended in the latest revision (OECD third edition) to include non-technological innovation. As a result, two new innovation types were introduced: marketing and organizational innovation. Marketing innovation is defined as the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion, or pricing

(OECD, 2005). The focus is on a firm's marketing concepts and strategies (Mol and Birkinshaw, 2009; Tether and Tajar, 2008b) to create superior value for the customer (Radas and Bozic, 2009). Organizational innovation is defined as a new organisational method in a firm’s business practices, workplace organisation, or external relations (OECD, 2005). It is distinguished from minor organizational changes by only considering the organizational method that has not been used before in a particular firm and it must be a result of strategic management decisions (OECD, 2005; Tether and Tajar, 2008b).

The literature has also categorised innovation based on the degree of its novelty (newness). The magnitude of innovation can be either incremental or radical. Incremental innovations refer to minor and continued improvement activities in which firms make on their existing products or practices, and they mainly reinforce the existing capabilities of firms (Gopalakrishnan and Damanpour, 1997; Reichstein and Salter, 2006). Scholars refer to incremental innovations as new to the firm but not new to the industry. In contrast, innovations that are new to the market or industry are considered radical (Crossan and Apaydin, 2010; Reichstein and Salter, 2006; Tether and Tajar, 2008a; Belderbos et al., 2004). Radical innovations are associated with fundamental changes in the activities of a firm and represent a clear departure from existing products and practices (Gopalakrishnan and Damanpour, 1997; Ettlie et al., 1984; Tidd, 2001; Faems et al., 2005; Coombs et al., 2003; Crossan and Apaydin, 2010). Table (2.8) summarizes the different forms and magnitudes of innovation.

	Product innovation		
Definition	Market introduction of a new or a significantly improved good or service with respect to its capabilities.	New products or services introduced to meet an external user or market need.	New product/service innovation that is new to the firm, new to the market, or new to the industry, and something that is introduced for the benefit of customers outside of your firm.
References	OECD, 2005.	Damanpour, 1991.	Frishammar and Horte, 2005.
	Process Innovation		
Definition	The implementation of a new or significantly improved production process, distribution method, or supporting activity.	New elements introduced into an organization's production or service operations.	New elements, equipment, or methods introduced into the firm's production system to develop a product or service.
References	OECD, 2005; Reichstein and Salter, 2006.	Damanpour, 1991.	Camison-Zornoza et al., 2004.
	Marketing innovation		
Definition	The implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion, or pricing		
References	OECD, 2005.	Authors Adopting OECD,2005 definition: Gunday et al., 2011; Castellacci, 2008.	
	Organizational/Administrative innovation		
Definition	A new organisational method in the firm's business practices, workplace organisation, or external relations.	A new organizational structure or administrative processes.	New approaches and practices to motivate and reward organizational members, devise strategies, and structures of tasks and units, and modify the organization's management processes.
References	OECD, 2005.	Damanpour, 1991.	Damanpour et al., 2009; Birkinshaw et al., 2008.
	Radical innovation		
Definition	Associated with fundamental changes in the activities of a firm and represents a clear departure from existing products and practices.	Innovations associated with newness to the market and/or industry.	Innovations that embody a new technology that results in a new market infrastructure.
References	Gopalakrishnan and Damanpour, 1997.	Crossan and Apaydin, 2010.	O'Conner, 1998; Song and Montoya-Weiss, 1998.
	Incremental innovations		
Definition	Minor and continuous improvement activities to existing products or practices reinforcing the existing capabilities of firms. It is new to the firm but not new to the industry.	Continuous improvement initiatives that may be new to the firm.	Products that provide new features, benefits, or improvements to the existing technology in the existing market.
References	Gopalakrishnan and Damanpour, 1997; Reichstein and Salter, 2006.	Crossan and Apaydin, 2010.	Song and Montoya-Weiss, 1998.

Table 2.8: Different forms and magnitudes of innovation

2.4.5: Innovation context

Scholars have addressed various contexts in which to innovation. Innovation context refers to the broad environment were innovations emerge. A spectrum of approaches has emerged from the reviewed literature where different views and outcomes were produced. For instance, studies on the international context are concerned with global views of innovation and how cross-borders factors influence innovation activities. In the national context, all actors in the economy and market are considered, such as firms, industries, research and development institutes, and universities. The elements that constitute and affect national innovation systems and innovation creation, development, and diffusion in different countries were examined and investigated. Research on firms and industry contexts were more focused on the different markets, economy structures, and innovation activities within these settings. Research into cross-industry and different technology sectors to determine innovation fostered more understanding of generation, diffusion of innovation, and forms of innovation at the industry and firm levels. Table (2.9) maps the reviewed papers and offers an outline of the main themes of innovation research.

International context		**References**
Main themes of research	Internationalization of innovation systems Global collaboration on R&D, cross-border integration, networking of knowledge Innovation generation and diffusion Inter -regional technology transfers, knowledge spill overs Innovation policy Developed and emerging economies Multinational corporations (MNC), foreign direct investment (FDI)Economic geography, proximity, and innovation	Alnuaimi et al., 2012; Boschma, 2005; Love and Roper, 2001; Mohnen and Roller, 2005; Carlsson, 2006; Simmie, 2003; Keupp et al., 2012; Frost, 2001; Zhou and Xin, 2003; Narula and Hagedoorn, 1999; Zander, 1999.
National context		**References**
Main themes of research	National Innovation Systems (NIS), creation, diffusion, and use of knowledge Innovation policy at the national level Interactions, collaboration, networking between and among national different actors, i.e. science/industry Emergence and diffusion of new innovations Sectoral patterns of innovation (manufacturing & services) Innovation and Economy growth	Teixeira, 2014 ;Watkins et al., 2015; Castellacci, 2008; Mohnen and Roller, 2005; Carlsson et al., 2002; Simmie, 2005; Keupp et al., 2012 ; Simmie, 2003; Love and Roper, 1999; Motohashi, 2005; Fritsch and Franke, 2004.

	Developed and emerging economies Industrial geographies/proximity, local economic and social networks	
Industry context		**References**
Main themes of research	Industry, market structures Technology intensity and innovation types and magnitude (low, medium, high technology industries) Collaboration, networking, joint R&D, clusters Determinants, measurements of innovation Generation, diffusion of innovation Innovation types (product, process, etc.) and magnitude (radical, incremental)	Keupp et al., 2012; Crossan and Apaydin, 2010; Love and Roper, 1999; Pouder and StJohn, 1996; Bell, 2005; Baptista and Swann, 1998; Robertson and Langlois, 1995; Gay and Dousset, 2005; Ahuja, 2000.
Firm context		**References**
Main themes of research **Intra-firm level**	level of analysis Determinants, measurements of innovation Generation, diffusion of innovation Intra-firm collaboration, networks, external knowledge sources, social network Large firms, SME's Size and innovation Innovation types (product, process, etc.) and magnitude (radical, incremental) Inter-unit knowledge transfer Managerial performance, entrepreneurship, entrepreneurial teams Organizational learning, capabilities, absorptive capacity Innovative and non-innovative firms	Keupp et al., 2012; Crossan and Apaydin, 2010; Gopalakrishnan and Damanpour, 1997; Tsai, 2001; Aalbers et al., 2013; Hoang and Antoncic, 2003; Ruef, 2002.
Inter-firm level	level of analysis Inter-firm collaboration, networks, external knowledge sources, social network Strategic alliances Industry clusters Innovation types (product, process, etc.) and magnitude (radical, incremental) Organizational learning, capabilities Innovative and non-innovative firms	Keupp et al., 2012; Crossan and Apaydin, 2010; Rothwell and Dodgson, 1991; Gopalakrishnan and Damanpour, 1997; Powell et al., 1996; Schilling and Phelps, 2007; Love and Roper, 1999; Bell, 2005; Hagedoorn and Duysters, 2002; Quintana-Garcia and Benavides-Velasco, 2004; Teece, 1986; Rothwell, 1991; Freeman, 1991; Ahuja, 2000; Landry et al., 2002; Soh and Roberts, 2003.

Table 2.9: A summary of the main themes of innovation research

The next section discusses innovation from the perspective of firms. In line with this project's aim and objectives, literature on innovation at the firm level is reviewed, which provides a better understanding of the central aspects and approaches that stimulate and reinforce firms' innovation outcomes.

2.5: Innovation from the firm perspective

This section focuses on innovation from a firm’s perspective. Studies on innovation in firms get much attention from industrialists, policy makers, and academics (Rothwell and Dodgson, 1991). Ample studies have addressed the different aspects in which a firm’s innovation is characterised. For instance, Utterback (1971) indicated the main characteristics that contribute to firms’ innovation in terms of originating, developing, and implementation are the characteristics of the firm's environment, internal factors of the firm itself, and flows between the firm and its environment. Furthermore, there are two approaches to innovation from a firm’s perspective that have been identified in the literature. In their review of innovation research, Gopalakrishnan and Damanpour (1997) noted that innovation literature on firms take two approaches, the outcome approach or the process approach. Scholars who take the process approach seek to describe a broad class of events and the critical stages in the innovation process. On the other hand, researches on innovation as an outcome seek to identify a range of elements that differentiate innovative from non-innovative firms in terms of internal and external environmental settings such as the contextual, structural, and behavioural characteristics of firms (Gopalakrishnan and Damanpour, 1997; Kimberly and Evanisko, 1981; Capon et al., 1992; Ritter and Gemunden, 2004).

The reviewed literature employed varied approaches to innovation as an outcome at the firm level. It is well established that innovation is one of the fundamental instruments of firms’ growth, survival, and competitive advantages (Frishammar et al., 2012; Bowen et al., 2010; de Vries, 2006; Teece, 1986). In their review published between 1993 and 2003, Becheikh et al. (2006) identified several factors pertaining to a firm’s innovation. They grouped them into internal factors (i.e. specific to the internal environment of the firm) and contextual/ external factors (i.e. related to the firm’s external environment) (Becheikh et al., 2006). Several firms’ internal characteristics related to innovation were considered, such as size (Greve, 2003; Camison-Zornoza et al., 2004), culture (Bueschgens et al., 2013), strategy (Ritter and

Gemunden, 2004; Ahuja, 2000; Ahuja et al., 2008), research and development (R&D) intensity and collaboration (Becker and Dietz, 2004; Belderbos et al., 2004), and intra-firm collaboration (Lukas and Ferrell, 2000; Keller, 2001).

According to Becheikh et al. (2006), a firm's innovation and outcome could be impacted by its surrounding environment. In their review, they grouped these factors into the following six categories: (1) the industry to which the firm belongs, such as industry and market structures (Whitley, 2000; Amara and Landry, 2005; Castellacci, 2008); (2) the region where it is located and developed (Love and Roper, 2001), and emerging economies (Radas and Bozic, 2009; Fu et al., 2011; Wang and Kafouros, 2009); (3) networking relations with various actors within its environment (Laursen and Salter, 2006; Frishammar and Horte, 2005; Boschma, 2005); (4) the acquisition of knowledge and technologies (Vega-Jurado et al., 2009; Leiponen and Helfat, 2010; Loof and Heshmati, 2002); (5) government and public sector policies (Mohnen and Roller, 2005); and (6) the surrounding culture (Frishammar et al., 2012).

Studies on innovation at the firm level have advanced our theoretical and practical understanding of the phenomena at hand. However, more studies and scholarly work are necessary in this area of research.

2.6: Innovation and networking in the context of emerging economies

Emerging economies have become a central part of the global economy and critically important in today's international markets (Hitt et al., 2000). The reviewed literature on emerging economies highlighted the role of collaborative networking and knowledge sharing among different players on firm's innovation performance (Fu et al., 2011; Wang and Kafouros, 2009; Kafouros and Forsans, 2012; Li et al., 2010; Hadjimanolis, 2000; Berry, 2014). Firms collaborate and network with other actors in the economy to seek learning about new ideas, sharing knowledge and enhance firm's resources for better returns (Berry, 2014; Chen et al., 2012). In the context of emerging economies, ample studies have addressed the different aspects and challenges in which transferring knowledge and resources across firms' boundaries might face due to the nature of knowledge required for innovation (Alnuaimi et al., 2012). For instance, firms embedded networks, such as foreign partnerships, R&D collaboration, linkage with customers and suppliers, can be critical to firm's innovation performance (Almeida and Fernandes, 2008). Furthermore, firms embedded networks of collaboration with national and international players enable firms to access external knowledge and resources that are unavailable internally which in turn lead to better firm's innovation outcome (Kafouros and Forsans, 2012; Bradley et al., 2012; Simmie, 2003).

literature on emerging economies focused on certain topics in relation to networks, external sources of knowledge and innovation, such as determinants of technological change, the role of foreign direct investment (FDI), multinational corporations (MNC) (Fu et al., 2011; Wang and Kafouros, 2009; Kafouros and Forsans, 2012; Li et al., 2010; Hadjimanolis, 2000; Berry, 2014), entrepreneurship (Chaston and Scott, 2012; Liu et al., 2010), business groups and their effect (Mahmood and Mitchell, 2004), trade orientation (export/import) (Seker, 2012), in-house R&D and technology transfer (Hu et al., 2005), innovation culture, ideation, diffusion, and adaptation (Pothukuchi et al., 2002; Chen et al., 2012), and the internationalization of innovation (Patel et al., 2014). However, research shows the advantages and disadvantages of diverse aspects of networking, knowledge sources and collaboration on innovation, but the nature of firm's embedded networks is still a developing area in the literature. Therefore, in depth investigation is required to the characteristics of firm's networks embeddedness and its potential effect on accessing new knowledge sources and enhancing innovation performances in emerging economies (Chen et al., 2012). Incorporating network embeddedness measures could shed more light on the possible influences of network embedded ties among firms and different actors in the economy (Patel et al., 2014).

2.7: Gaps in the existing body of knowledge and directions for future research

This section summarizes the analysis of the systematic review of the literature in order to identify major gaps in the existing body of knowledge and to identify paths for future research. Literature on the field of innovation has acknowledged that innovation is now unavoidable for firms that seek to develop and maintain a competitive advantage (Becheikh et al., 2006). Nowadays, however, a firm's innovation success faces greater challenges and difficulties related to increasing costs, decreasing innovation times, and increasing technology complexities (Ritter and Gemunden, 2004; Tether, 2002; Ritter and Gemunden, 2003). Therefore, revisiting the literature and identifying those evolving issues is a necessary step towards understanding firms' innovation.

2.7.1: Networking characteristics and firms' innovation outcomes

Prior research suggests that over the past two decades, there has been a systematic and fundamental change in the way firms undertake innovation activities (Pittaway et al., 2004). Moreover, there is growing evidence that innovation is becoming less and less the outcome of a single actor's isolated efforts (Nieto and Santamaria, 2007; Toedtling et al., 2009). Accordingly, firms are continuously seeking collaborative arrangements, networking, strategic alliances, and interaction with other actors to identify and exploit external knowledge, to create windows of new opportunities, and to overcome internal constraints (Soh, 2003, Anand and Khanna, 2000; Baum et al., 2000; Freeman, 1991).

Recent studies have emphasized the importance of networking for firms' innovation (Ahuja, 2000; Toedtling et al., 2009; Nieto and Santamaria, 2007; Phelps, 2010). They have focused on different types of organization networking, such as alliance networks, clustering, joint venture, R&D cooperation, and inter-organizational collaboration. However, insights into the dynamics of the type of networking relationships have been fragmented with inconsistent results (Pittaway et al., 2004). In their systematic review of networking and innovation, Pittaway et al. (2004)

provided evidence on the important role network relationships with different actors, such as suppliers, customers, and professional and trade associations, play on innovation performance and productivity. Firms could benefit from business networking and relationships with other actors by acquiring key resources and complementary skills such as risk sharing, access to new markets and technologies, lead time to market, and access to external knowledge. The review, however, acknowledged that firms that do not cooperate with others limit their knowledge base and ultimately reduce their abilities to enter into exchange relationships. Additionally, the authors stressed the need for further investigations into the relationships between networking and different types of innovation (Pittaway et al., 2004). Similarly, Nieto and Santamaria (2007) underlined the central role that collaborative networks play in constructing types and magnitudes of innovation. They emphasized the importance of diverse collaborative networks and continuity of collaboration for novelty product innovation, and encouraged future research on the topic to include both product innovation and process innovation.

Previous studies reported that firms are increasingly relying on external knowledge sources for their innovation activities. In their analysis of the innovation activities in U.K. manufacturing firms, Laursen and Salter (2006) suggest that firms seeking to achieve and sustain innovation should search widely and deeply across a broad range of external knowledge sources. They also suggest that openness for search has two-folds. On one hand, they agree with Chesbrough's open innovation model that points to the importance of external ideas and knowledge sources for innovation (Chesbrough, 2003). They confirmed in their analysis that intensive probing of external search channels can provide ideas and resources that enable firms to gain and exploit innovation opportunities. On the other hand, they stressed that innovation searches involve some costs and need careful attention not to get into over-search. They emphasized that innovation searches need to be carefully managed in terms of time, resources, and money. The authors concluded that firms need to be highly involved in the early stages of product life cycles with key sources of innovation outside firms' boundary. This type of external search depth will help firms develop innovation. In the later stages, where technology and markets mature, access to different sources of knowledge is essential to find new combinations of existing technologies to enable further improvements in product innovation (Laursen and Salter, 2006).

A major dearth of scholarship exists still on network analytic approaches in existing innovation literature, as Ahuja (2000) indicated. In his study, he examined the relationship between a firm's position (direct ties, indirect ties, and structural holes) in the industry network of inter-firm collaborative linkage and its innovation output from the firm's ego network perspective. Ahuja's longitudinal study of firms in the international chemicals industry showed that firms' network relations (i.e. direct and indirect ties) have a positive impact on their innovation, and the optimal structure of inter-firm networks depends on the objectives of the network member (Ahuja, 2000). In another longitudinal study, Phelps (2010) examines the influence of alliance network structures and compositions on firms' exploratory innovation. The author pointed out that, although there is research that examines the influence of alliance network structure (the pattern of relationships that exist among a set of actors) on firm innovation, there is still a lack of studies concerning the composition of firms in these networks (i.e. network composition; the types of actors in a network) (Phelps, 2010).

Previous research examined the link between firms' innovation and external sources of knowledge, such suppliers, customers, competitors, universities, and etc. Scholars used different metaphors when theorizing their approaches to firms' interactions with their external environments, such as networks, clustering, R&D cooperation, inter-organizational collaboration, and others. Exerting new ideas and knowledge from firms' external relationships and networking has grown in importance in the past three decades. Even still, despite their critical significant to firms' innovation and innovation types, the nature of such relationships has not been treated in much detail in innovation literature. This revelation leads to the first research gap identified in this study.

Research Gap 1

Research on innovation should investigate and explain the relationship between firms' innovation outcomes and network characteristics.

2.7.2: The effect of network embeddedness on firms' innovation outcomes

As discussed in the previous section, research on the effect of inter-firm network characteristics on firms' outcomes needs more scholarly attention. However, strategic alliances and organizational scholars recognize the significant role that inter-firm networks of relations play in a firm's performance (Borgatti and Foster, 2003). An increasing number of studies explore the influence of network characteristics on firms' performances and innovations through the lens of network embeddedness (Rowley et al., 2000; Uzzi, 1997; Gulati, 1998; Moran, 2005; Mazzola et al., 2015). The notion of network embeddedness, which will be discussed more fully later in this chapter, has gained publicity among innovation literature scholars in the past two decades (Gilsing et al., 2008). In his seminal work, Granovetter (1992) defined the concept of embeddedness as 'the fact that economic action and outcomes are affected by actors' dyadic (pairwise) relations and by the structure of the overall network of relations' (Granovetter, 1992, p. 33). Granovetter (1985) suggests that actors' relations and structures (i.e. embeddedness) determine in part the interdependency and patterns among network members, which accounts for subsequent actions and outcomes.

Granovetter's (1985, 1992) discussion of embeddedness has initiated interesting debates among scholars in relation to the positive and negative effects of embeddedness and network structures on actors' performances (Uzzi, 1996; Uzzi, 1997). While the original focus of studies was on how individual embeddedness in networks influences behaviour, a similar approach has been extended to organizations (Gulati, 2002; Burt, 1982). However, at the firm level, little is known about what types of network embeddedness characteristics influence actors' subsequent economic outcomes (Uzzi, 1996). Uzzi (1996, 1997) argued that it is an important initial step to specify actors' network embeddedness aspects to account for their effects on economic action. Different network embeddedness and patterns could lead to an early actor's learning and an early opportunities recognition, or could potentially cause constraints for actors embedded in the network (Burt, 1992; Ahuja et al., 2012). Understanding an actor's network embeddedness dimensions is essential to foresee the effectiveness of its economics of exchange and outcomes (Burt, 1992; Granovetter, 1985).

The reviewed literature identified two types of network embeddedness (network relational and structural embeddedness) that have the potential to influence firms' behaviours and performances (Rowley et al., 2000; Gulati, 1998; Granovetter, 1992). Network relational embeddedness is said to be related to the quality and depth of relationships and ties among actors in a network. Structural embeddedness is concerned with the patterns of relationships between actors in a network (Granovetter, 1992). Research into network embeddedness and its effects on innovation outcomes at the firm level has focused mainly on a single form of embeddedness, i.e. either relational or structural aspects. There are few studies that consider the joint effect of network relational embeddedness and network structural embeddedness. Furthermore, the optimal inter-firm network embeddedness configuration and its influence on a firm's outcomes cannot be fully understood without considering both forms of network embeddedness, along with the types of their direct effects and their possible interaction effects. Looking into different structural embeddedness characteristics of an actor, for instance, in isolation of its relational embeddedness aspects, or vice versa, might lead to incomplete consideration of its effects on a firm's performance and outcomes (Rowley et al., 2000). Therefore, further work is needed to account for the network embeddedness concepts of a firm, its nature, and to the joint consideration of the types of network embeddedness characteristics. This revelation leads to the second identified research gap.

Research Gap 2

Research on firms' network embeddedness should seek to advance the concept of embeddedness at the firm level and should address the potential diverse and joint effects of both relational and structural embeddedness characteristics on firms' innovation outcomes.

2.7.3: Emerging economies context

The fact that innovation is an important strategic element in firms' competitiveness and productivity is broadly accepted and well established in developed countries. In fact, innovation management literature is rich in diverse studies and approaches on innovation networks and collaborative linkage in relation to developed countries, as illustrated in the previous section. In contrast, little attention has been devoted to this area of research in the context of emerging economies (Zeng et al., 2010; Chen et al., 2012). For example, recent literature on emerging economies focused on certain topics in relation to external sources of knowledge and innovation, such as determinants of technological change, the role of foreign direct investment (FDI), multinational corporations (MNC) (Fu et al., 2011; Wang and Kafouros, 2009; Kafouros and Forsans, 2012; Li et al., 2010; Hadjimanolis, 2000; Berry, 2014), entrepreneurship (Chaston and Scott, 2012; Liu et al., 2010), business groups and their effect (Mahmood and Mitchell, 2004), trade orientation (export/import) (Seker, 2012), in-house R&D and technology transfer (Hu et al., 2005), innovation culture, ideation, diffusion, and adaptation (Pothukuchi et al., 2002; Chen et al., 2012), and the internationalization of innovation (Patel et al., 2014). However, research shows the advantages and disadvantages of diverse aspects of knowledge sources and collaboration on innovation, but in depth investigations to the structure of such firms' external sources have been limited.

There is a knowledge gap in relation to firms' innovation sources and innovation performances in emerging economies (Chen et al., 2012). Incorporating network-centric measures could bridge this gap by investigating the possible influences of connections among firms and different actors in the industry (Patel et al., 2014). Therefore, this study attempts to advance the literature with an in-depth analysis of the network structural and relational dimensions and their influence on firms' innovation and innovation types in an emerging economy. This leads to the third and final research gap identified herein.

Research Gap 3

Research on innovation should explore and understand the relationship between firms' innovation, innovation types, and network characteristics in the context of emerging economies.

The aim of this section was to summarize the analysis of the SLR. Several gaps were identified in the existing body of knowledge in innovation literature. Prior studies on innovation have indicated that little attention has been paid to the types and effects of network characteristics on firms' innovation outcomes. Additionally, there were many research studies that looked into network characteristics' influences on firms' innovation from the lens of network embeddedness. Investigations into the network embeddedness concept could contribute to our knowledge by addressing the potential direct and joint effects of network embeddedness characteristics on firms' innovation outcomes. Finally, the review of the extant literature indicated far too little attention has been paid to the relationship between innovation and network characteristics in the context of emerging economies. In the following section, the main theoretical perspectives used in the reviewed innovation literature are discussed.

2.8: Theoretical perspectives in the reviewed literature

This section provides a discussion of the theoretical perspectives used in most of the reviewed studies. Innovation literature theories and empirical work draw from a variety of disciplinary backgrounds, such as management, economics, engineering, science, marketing, social science, and so forth (Kimberly and Evanisko, 1981; Crossan and Apaydin, 2010). The reviewed literature can be roughly divided into two streams: one looking into firms' internal aspects that shape their innovation, and another focusing on the factors found on the boundary of the firm, as well as in its network, by considering firms' external relationships and interactions with other players in the economy (Ritter and Gemunden, 2004; Zaheer and Bell, 2005). Recently, management scholars have started to extend their theoretical approaches to firms' innovation to include internal as well as external elements (Zaheer and Bell, 2005; Vega-Jurado et al., 2008). In the reviewed innovation literature, there are four views that are primarily employed to conceptualize innovation studies: Resource Based View (RBV), Transaction Cost Economics (TCE), Organizational Learning, and Resource Dependency. These four theoretical perspectives are the focus of the following sections.

2.8.1: Resource Based View (RBV)

An RBV focuses on the firm's internal resources and capabilities in establishing and sustaining a competitive advantage. From the RBV perspective, firms can achieve a competitive advantage by owning resources that are rare, valuable, non-imitable, and non-substitutable (Barney, 1991). Therefore, according to RBV, a firm's essential task is to exploit its existing resources and capabilities in order to sustain a competitive advantage (Barney, 1991; Barney, 2001) and innovation (Stieglitz and Heine, 2007; Grant, 1991). Firms' resources are defined as those tangible and intangible assets that firms possess. Tangible assets refer to resources that are visible, such as plants, machinery, finances, and people. On the other hand, intangible resources refer to invisible assets like a firm's knowledge, values, routines, reputation, and skills (Grant, 1991; Eisenhardt and Schoonhoven, 1996).

Scholars have extended the original idea of RBV beyond its traditional approach that only focuses on internal resources and capabilities to incorporate the external resources outside a firm's boundaries (Lavie, 2006, Das and Teng, 2000). In today's high-paced and competitive environment, resources are both expensive and difficult to develop and maintain (Stanko and Calantone, 2011). Therefore, firms started to explore complementary resources that networks bring in order to share risks, reduce time and costs, and maximize their strategic opportunities and competencies (Eisenhardt and Schoonhoven, 1996, Lavie, 2006, Das and Teng, 2000). Therefore, firms started to explore complementary resources that networks bring in order to share risks, reduce time and costs, and maximize their strategic opportunities and competencies (Eisenhardt and Schoonhoven, 1996; Lavie, 2006). The notion of firm network resources refers to resources embedded in the inter-firm networks (Gulati, 1999). Thus, the integration between firms' internal assets and the external resources that are embedded in their networks can be critical to firms' performances and innovation (Zaheer and Bell, 2005; Terziovski, 2010; Eisenhardt and Schoonhoven, 1996).

2.8.2: Transaction Cost Economics (TCE)

Transaction Costs Economics (TCE) focuses on the individual firm and its use of alliances and networks to minimize production and transaction costs (Barringer and Harrison, 2000; Osborn and Hagedoorn, 1997). Different factors influence both production and transaction costs: learning and experience effects, location, and expenses associated with arranging, managing, and monitoring transactions across markets (Kogut, 1988). A typical example of TCE is a make or buy decision by a firm, when the firm has to decide between buying a product from another firm or making it internally. Accordingly, it is better for a firm to buy a product from another firm that is an expert at making it if it is more cost effective than producing the product within the firm. However, the firm might decide to internalize the production of a product due to other transaction reasons. An alternative way to avoid such transaction or production cost is by involving in inter-organizational relationships with other actors in the market (Barringer and Harrison, 2000). For instance, joint ventures as a form of inter-organizational relationships could help firms avoid the cost of opportunism and increase the likelihood of mutual commitment of resources to maintain the partnership (Kogut, 1988). Moreover, strategic network as another form of inter-organizational relationships, as conceptualized by Jarillo (1988), could benefit firms in the networks by lowering the overall cost through focusing on core competencies and subcontracting other activities to specializing firms, and could minimize opportunism through mutual trust and the desire to remain in the network for further collaboration after successful completed transactions (Jarillo, 1988). Although TCE has its advantages in addressing inter-organizational relationships among firms, scholars have highlighted some of its limitations. One criticism is its primary focus on the efficiency and cost-minimizing rationales for firm alliances (Barringer and Harrison, 2000), and another is that is focuses only on a single actor, which neglects the interdependence between involved partners (Zajac and Olsen, 1993).

2.8.3: Resource Dependency Theory (RDT)

The Resource Dependence Theory is rooted in the open system framework, which assumes that in order for firms to gain the required assets, they must engage in exchanges with other actors in their environments (Barringer and Harrison, 2000). It focuses on obtaining resources that are critical to a firm's survival and growth that can be found outside the boundary of the firm. (Barringer and Harrison, 2000; Castanias and Helfat, 1991; Simonin, 1997). From a resource dependency perspective, firms tend to form inter-organizational relationships with other organizations for different reasons. One reason is to obtain access to critical resources, such as a large firm's partnership with small firms to access their cutting edge research. Another reason is acquire power over other organizations; for example, one firm chooses to partner with another organization to gain enough market power to limit some of the competition. However, firms could simply form partnership with other organizations just to fulfil some of their needs, such as knowledge and human resources (Barringer and Harrison, 2000; Oliver, 1990).

One of the common strategies for firms to seek ties with other organizations is to take advantage of the complementary assets residing outside their boundaries (Barringer and Harrison, 2000). For example, in the pharmaceutical industry, it is a common strategy for large firms to tie with smaller firms in order to access their novel knowledge base and cutting edge research. Likewise, smaller firms are eager to form linkages with larger organizations to benefit from their financial resources and logistics channels (Fisher, 1996). According to Barringer and Harrison (2000), RDT finds its strength in explaining the need for critical resources among firms and the necessity for social exchange. However, it is limited in explaining the formation of strategic alliances and why organizations choose some other strategies to obtain the needed resources, such as mergers and acquisitions and recruitment of key human capital from competitors (Barringer and Harrison, 2000).

2.8.4: Organizational Learning Theory

Firms seek to gain knowledge and access information to capitalize on opportunities for organizational learning through establishing partnerships with other organizations (Barringer and Harrison, 2000; Hitt et al., 2000). Another rationale for firms to form relationship with other organizations, such as strategic alliances, collaborative networks, and know-how, is to enhance their competitive position through superior knowledge (Barringer and Harrison, 2000; Simonin, 1997) and though knowledge being transferred in embedded relations among organizations (Kogut, 1988).

Knowledge-base and learning are forms of intangible benefits that firms' collaborative partnerships and inter-firm alliances can utilize to capture specific skills and competencies from their partners (Kogut, 1988, Simonin, 1997). When it comes to tacit knowledge or novel ideas, for instance, firms tend to form relationships with others who have knowledge to fully benefit from and exploit it and learn a new skill (Barringer and Harrison, 2000). Powell et al. (1996) extended this idea to inter-organizational networks in support of the key role that networks play in organizations' learning and innovation. They argue that the locus of innovation is no longer an individual firm's isolated efforts, but is rather found in networks of learning. Powell et al (1996) stressed that 'Knowledge creation occurs in the context of a community, one that is fluid and evolving rather than rightly bound or static. The canonical formal organization with its bureaucratic rigidities is a poor vehicle for learning. Sources of innovation do not reside exclusively inside firms; instead they are commonly found in the interstices between firms, universities, research laboratories, suppliers and customers' (pp. 116-118).

According to March (1991), organizational learning that takes place in the context of inter-organizational relationships can be divided into two broad concepts: exploration and exploitation. Exploration involves a firm desire to discover new opportunities (Faems et al., 2005), and includes activities , such as basic research, risk taking, flexibility, invention, and innovation (Barringer and Harrison, 2000; March, 1991). This can be in a form of search for solutions to new problems in which firms reuse or exploit available knowledge (Katila and Ahuja, 2002). Exploitation, on the other hand, is about activities that lead to an improvement in a firm's productivity and efficiency by leveraging existing assets and capabilities (Faems et al., 2005; March, 1991; Barringer and Harrison, 2000), and combining current knowledge to generate new solutions (Katila and Ahuja, 2002). However, both exploration and exploitation depend on the strategic objectives of a firm and involve high cost implications (March, 1991). Thus, firms enter into partnerships with other organizations to learn from them, obtain necessary resources, and as a means of sharing risks and costs (Powell et al., 1996; Barringer and Harrison, 2000; March, 1991).

A firm's learning and knowledge-base enhancements are particularly important in inter-organizational relationships. However, such relationship's benefits need to be accompanied by a firm's internal competences and accumulative experience, such as absorptive capacity, in order to determine how much a firm can capture and learn from the network of relations (Barringer and Harrison, 2000; Powell et al., 1996; Hitt et al., 2000). Absorptive capacity is defined as 'the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends' (Cohen and Levinthal, 1990: p.128). The absorptive capacity differs among firms, and depends on several characteristics, such as cumulative knowledge, prior experience, culture, and the level of employee's skills, among others (Cohen and Levinthal, 1990; Powell et al., 1996; Fabrizio, 2009). Therefore, firms with greater internal capabilities are in better shape to capture and learn from their participation in networks of relations and alliances (Barringer and Harrison, 2000). In addition, they might find difficulties in their learning opportunities due to an inadequate firm's absorptive capacity (Hitt et al., 2000).

Although there is strong evidence that learning is a rationale for firms to form partnerships and inter-organizational relationships with other organizations, there are some limitations. According to Barringer and Harrison (2000), there are two main limitations that need to be accounted for in inter-organizational relations: first, not anticipating the involved cost that comes with the firm's desire to increase their internal competencies and skills, such as training and education for the firm's personal; and second, the increase of non-added value spill overs (i.e. unwanted knowledge) that is not within the intended scope of the alliance, which could lead to a loss of valuable information (Barringer and Harrison, 2000).

A summary of the reviewed theoretical perspectives are provided in Table (2.10). The table provides a brief explanation for each theory and the rationale behind establishing business or inter-organizational relationships according to the different views. In addition, some limitations for each perspective have been summarized.

Theoretical perspective	Description	Rational for establishing external/ Inter-organizational relationships	Limitation	References
Resource Based View (RBV)	Focuses on the firm's internal resources and capabilities in establishing and sustaining a competitive advantage. It emphasizes achieving a competitive advantage by owning resources that are rare, valuable, non-imitable, and non-substitutable.	Recently, there was a shift to integrate internal as well as external resources outside the firm's boundaries. Firms started to explore complementary resources that networks bring in order to share risk, reduce time and cost, and maximize their strategic opportunities and competencies.	Solely focuses on a firm's internal environment. Focusing only on a single actor neglects the interdependence between involved partners.	Barney, 1991; Barney, 2001; Stieglitz and Heine, 2007; Grant, 1991; Eisenhardt and Schoonhoven, 1996; Lavie, 2006; Stanko and Calantone, 2011; Zaheer and Bell, 2005.
Transaction Cost Economics (TCE)	Mainly focuses on the individual firm and its use of alliances and networks to keep production and transaction costs to a minimum.	Minimization of the sum of production and transaction costs. Inter-organizational relationships can reduce uncertainty caused by market failure and reduce costs associated with establishing a hierarchy.	Its primary focus is on the efficiency and cost-minimizing rationales for firm alliances, and focuses only on a single actor, which neglects the interdependence between involved partners.	Barringer and Harrison, 2000; Osborn and Hagedoorn, 1997; Kogut, 1988; Jarillo, 1988; Zajac and Olsen, 1993.
Resource Dependency Theory	This theory is rooted in the open system framework, which assumes that, in order for firms to gain the required assets, they must engage in exchanges with other actors in their environments. It focuses on obtaining resources that are critical to a firm's survival and growth and can be found outside the boundary of the firm.	Firms form inter-organizational relationships to exert power or control over organizations that possess scarce resources. Alternatively, an organization may enter an inter-organizational relationship in an effort to take advantage of the complementary resources residing outside its boundaries.	It is limited in explaining the formation of strategic alliances and why organizations choose some other strategies to obtain the needed resources, such as mergers and acquisitions and recruitment of key human capital from competitors.	Barringer and Harrison, 2000; Castanias and Helfat, 1991; Simonin, 1997; Oliver, 1990; Fisher, 1996.
Organizational Learning theory	A theory that is concerned with the processes that lead to organizational learning. Firms seek to gain knowledge and access information in order to capitalize on opportunities of organizational learning through establishing partnerships with other organizations.	Absorbing as much knowledge as possible from Inter-organizational relationships partners increases organizational competencies and ultimately adds value to the organization.	It does not anticipate the involved cost that comes with a firm's desire to increase their knowledge. It does not account for non-added value spill overs (i.e. unwanted knowledge) that are not within the intended scope of the partnership, which could lead to loss of valuable information.	Barringer and Harrison, 2000, Hitt et al., 2000, Simonin, 1997, Kogut, 1988, Powell et al., 1996, March, 1991.

Table 2.10: Summary of the reviewed theoretical perspectives

2.9: Adapted theoretical approach in the study

Several gaps have been identified from the reviewed theoretical perspectives. For example, most studies have focused on explaining the crucial role that inter-firm networks can play in sustainable competitive advantages and innovations. Despite the apparent importance of acquiring valuable knowledge and resources embedded in networks of relations, their nature and configuration and their associated effects have been much less discussed. Furthermore, a network analytic approach to study innovation remains underutilized (Ahuja, 2000).

Traditionally, studies on firms' networks and innovation have focused on a single firm and have not devoted much attention to the interdependence between involved actors. Recent studies have taken a broader view by also considering network characteristics to include the focal firm and its network's alters (i.e. partners). However, research on the roles and the patterns of inter-firm network characteristics among and between actors is still underdeveloped (Gilsing and Duysters, 2008). Moreover, the combined effect of both structural and relational aspects of networks on firms' outcomes is still a developing area of research in the innovation field. Therefore, this thesis was motivated to turn to social capital, social network, and network embeddedness literature to develop a comprehensive understanding of firms' network relations and patterns. Social capital, social networks, and network embeddedness perspectives lay more emphasis on the strategic importance of the relational (Amara and Landry, 2005) and structural properties of networks in shaping firms' outcomes (Gulati, 1998). In addition, social networks provide a set of methods and tools that enable measuring, visualizing, and describing firms' network relations and patterns in great detail (Gilsing and Duysters, 2008).

Researchers have argued that sources of innovation can be embedded in a firm's inter-organizational networks and relationships. In the past two decades, studies on external sources in the form of network embeddedness have gained popularity in explaining how firms' interactions and collaborations with their external environments stimulate innovation (Rowley et al., 2000; Capaldo, 2007; Gulati, 1998; Owen-Smith and Powell, 2004; Ahuja, 2000; Phelps, 2010; Bellamy et al., 2014; Kilduff and Brass, 2010; Uzzi, 1997). Therefore, building on the social capital theory and the social network and network embeddedness views, this thesis aims to further explore this stream of research and to provide an in-depth investigation on the effect of network characteristics in terms of both relational and structural embeddedness on innovation.

2.10: Social capital and social network contexts

At present, it is widely accepted that innovation is no longer considered a specific result of one actor's actions (Hidalgo and Albors, 2008). According to the reviewed literature, firms adopting a type of networking strategy are more successful than firms that do not adopt networking strategies. Moreover, a firm's propensity to innovate is highly associated with its engagement in diverse forms of networking, such as inter-organizational collaboration, strategic alliances, partnerships, collaboration agreements, and so forth. Firms are characterized by different network structures that can lead firms to achieve different outcomes. Recently, extant literature introduced the notions of social capital, social network and network embeddedness perspectives into firms' networks, strategic alliances, and inter-organizational research in an attempt to investigate organization networks and their effects on innovation performance. In innovation management research, for instance, networks have been viewed as an essential aspect for organizations to gain strategic benefits such as knowledge, information, and resources (Owen-Smith and Powell, 2004). Organizations' positions, relations and linkages to other actors in the network, and the diversity of these actors could enhance learning, innovation (Phelps, 2010), and access to new knowledge and information (Soh, 2003). Therefore, this study aims to understand the shape and nature of firms' networks and to investigate firms' network characteristics and their impact on innovation in the context of social capital, social networks, and network embeddedness perspectives.

2.10.1: Social capital

The network structural and relational characteristics of a firm are more than just the structure of a set of actors connected with a set of linkages. The notion of social capital provides a useful perspective for focusing on the value of network connections (Borgatti and Foster, 2003). Firms' network relationships can influence their behaviours and performances (Rowley et al., 2000; Adler and Kwon, 2002), and could be a source of resources, knowledge, and competitive advantages (Bellamy et al., 2014; Capaldo, 2007) and may enhance learning and innovation (Phelps, 2010; Gilsing et al., 2008; Ahuja, 2000; Mazzola et al., 2015; Rost, 2011). Social capital is seen in the value of certain positions in the structure of relationships that is created through exchange or interaction between actors and among actors in a network, which can create a competitive advantage and lead to better returns (Burt, 2000; Coleman, 1988)

According to Lin (2001), social capital has two key elements: (1) resources embedded in a social structure, and (2) actors' access and use of such resources for actions. Similarly, Coleman (1990) viewed social capital as an aspect of a social structure that facilitates certain actions within the structure. Coleman (1988) stressed that,

'Social capital is defined by its function. It is not a single entity but a variety of different entities having two characteristics in common. They all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure. Like other forms of capital, social capital is productive, making possible the achievement of certain ends that would not be attainable in its absence' (p. S98).

The key premise of social capital is the investment in social relations with expected returns in the marketplace (Lin, 2001). It is all those resources that an actor can access, mobilize, and/or profit from because of the actor's embeddedness in a social network of relations with other actors (Esser, 2008). Social capital provides a way to enable firm's access to information, resources, and knowledge. It is important to understand the nature of social capital available to firm through its alliances in order to assess and explain it effect on firm's performance (Koka and Prescott, 2002; Koka and Prescott, 2008).

In the social network perspective of social capital, an actor's (i.e. individual, firm) embedded resource can enhance outcomes by facilitating the flow of information and carrying out valuable resources (Lin, 2001). According to Flap (1994), social capital has three key ingredients: (1) the number of actors in the social network, (2) the strength of the relationships among actors, and (3) the availability and accessibility of an actor's resources. In this perspective, Burt (1992) argues, not only the actor's relationships in the social network, but also an actor's network positions should be taken into consideration in which it represent and create competitive advantages in a way that links actors and their network alters to information and resources (Burt, 1992). In Burt's view, social capital is the actor's advantages that are created by the actor's structure of relationships (Burt, 2005). Therefore, considering both relational and structural aspects of social networks between ego and alters seems conceptually essential to the objective of this research.

2.10.2: Social Network

The social network field of research has attracted considerable scholarly attention in recent years (Wasserman and Faust, 1994; Borgatti and Foster, 2003). Presently, there is an increasing interest in the idea that a firm's characteristics in a network matter for their economics and innovation. The concept of social networks has been used to examine many structural and relational aspects of organizations and their effects on innovation in various industries, such as the biotechnology (Owen-Smith and Powell, 2004; Powell et al., 1996; Gilsing and Duysters, 2008), biopharmaceutical (Mazzola et al., 2015), chemical (Ahuja, 2000; Gilsing et al., 2008), multimedia (Gilsing and Duysters, 2008), telecommunications (Phelps, 2010), semiconductor, and steel industries (Rowley et al., 2000). Moreover, researchers have adopted a social network approach to investigate various firms' phenomena, such as knowledge transfer (Levin and Cross, 2004), employee motivation (Aalbers et al., 2013), supply network (Bellamy et al., 2014), entrepreneur and entrepreneurship (Hoang and Antoncic, 2003; Ruef, 2002), managerial performance (Rodan and Galunic, 2004), market entry (Lee, 2007), project teams (Edmondson and Nembhard, 2009), and intra-organizational knowledge sharing (Tsai, 2002).

Networks and relations are at the heart of social network analysis where the focus is on the relationships among actors (i.e. individuals, groups, organizations) (Gilsing and Duysters, 2008). Borgatti et al. (2013) defined networks as ‘a way of thinking about social systems that focus our attention on the relationships among the entities that make up the system, which we call actors or nodes’ (p. 1). Social networks are formally defined as a set of actors (individuals, departments, organizations, etc.) that are connected by one or more types of relations, which are a collection of ties among actors (Marin and Wellman, 2011; Wasserman and Faust, 1994).

Social networks are concerned with actors and the relationships among them. Accordingly, Social Network Analysis (SNA) is based on the assumed importance of relationships between interacting actors. Hence, SNA aims to study and analyse these relationships (Wasserman and Faust, 1994). According to the social network perspective, actors and the relations among them are the two fundamental concepts in any network (Marin and Wellman, 2011; Wasserman and Faust, 1994). Furthermore, networks play an important part in actors’ access to and benefits from the flow of information, knowledge, and resources (Borgatti and Lopez-Kidwell, 2011; Goyal, 2011; Wasserman and Faust, 1994; Ibarra, 1993; Owen-Smith and Powell, 2004). The type of access and benefits depends heavily on how well an actor is connected to other actors in the network. Additionally, the network approach captures the positions and interactions of any actor within the larger field of activities to which the actor belongs (Kilduff and Tsai, 2003). Therefore, by focusing on actors and the relationships among them, SNA enables us to gather and investigate network characteristics in terms of actors' relational and structural properties in great detail (Gilsing and Duysters, 2008).

There are two fundamental approaches to social network designs: socio-centric (whole) network and ego network designs (Borgatti et al., 2013). The socio-centric network type of research is concerned with the social structure and relations among all actors in a given set of networks (Marin and Wellman, 2011; Wasserman and Faust, 1994). Conversely, an ego-centred network (or ego network), by definition, is a network that consists of a particular actor (ego), where the actor's ego is connected to ego's alters (i.e. other network members, partners), and the measurement of the ties from ego to its alters and on the ties between alters (Borgatti et al., 2013; Wasserman and Faust, 1994). At the firm level, the ego network approach is more appropriate because it allows for an in-depth analysis of the organizations at hand (actors) and uncovers their network characteristics with which the focal firm transacts. In social network analysis, the ego network approach allows for gathering and examining the firm's relational data, constructing and defining the structural network, and the composition of the ego's alters, the firm's partners (Wasserman and Faust, 1994). Moreover, investigating a firm's ego-network characteristics could help to explain its performance (Rowley et al., 2000) and the subsequent firm's innovation outcomes (Ahuja, 2000).

There are two broad network characteristics that have been identified in the literature that could influence firms' innovation: relational network characteristics and structural network characteristics. First, relational network properties address the relationships among actors in the network. Such relations take the form of a collection of ties among actors (i.e. strong ties and weak ties), the strength and composition of these ties, the length or continuity of the relations, and the diversity among actors and alters. Second, structural network properties, such as network density and centrality, are concerned with the pattern of ties and interactions that exist among a set of actors (Powell et al., 1996; Wasserman and Faust, 1994). The two social network dimensions have been further conceptualized by management scholars. Firms’ network embeddedness and social capitals have gotten the most attention among organizational scholars (Borgatti and Foster, 2003; Adler and Kwon, 2002; Gilsing et al., 2008; Burt, 2000). In the following sections, the concepts of network embeddedness and social networks are reviewed. In addition, the two network’s characteristics, properties, and variables will be discussed in detail.

2.10.3: Network embeddedness

The trend towards more inter-firm collaborations and networks with other organizations has important economic values for firms. In recent years, there has been an increasing consensus in that a firm’s embeddedness in a network of inter-firm relations affects its performance, economics, and innovation (Gilsing et al., 2008; Ahuja, 2000; Owen-Smith and Powell, 2004; Borgatti and Foster, 2003). According to Granovetter (1992), embeddedness refers to ‘the fact that economic action and outcomes are affected by actors' dyadic (pairwise) relations and by the structure of the overall network of relations’ (p. 33). According to Gulati (1998), there are two types of network embeddedness that affect and shape a firm’s optimal network configuration in its industry: relational and structural embeddedness. Gulati (1998) explains that ‘Relational embeddedness or cohesion perspectives on networks stress the role of direct cohesive ties as a mechanism for gaining fine-grained information … Structural embeddedness or positional perspectives on networks go beyond the immediate ties of firms and emphasize the informational value of the structural position these partners occupy in the network’ (p. 296). According to Granovetter (1992), relational embeddedness addresses the quality of pairwise exchange in which actors involved in a relationship consider each other’s needs and goals. Ultimately, relational embeddedness is related to the quality and depth of relationships and ties among and between actors in a network (Granovetter, 1992; Jones et al., 1997). Whereas, structural embeddedness can be defined as the extent to which a "dyad's mutual contacts are connected to one another" (Granovetter, 1992: 35). The structural aspect of embeddedness is concerned with the configuration and position of actors in a network (Granovetter, 1992). In this sense, economic exchanges of actors are embedded in social networks (Granovetter, 1973, 1985), and embeddedness is seen as a function of the number of actors in a network, their frequency of interaction, the likelihood of future interaction, and contacts among them (Granovetter, 1973, 1985; Jones et al., 1997). The original focus of studies was on how individual embeddedness in networks influences behaviour. A similar approach has been extended to organizations (Gulati, 2002). Firms can be embedded in a network with other organizations through various types of social and economic relationships, which constitute their social networks (Gulati, 1998). The value of all the resources and benefits in which an actor (e.g. a person or a firm) can obtain and enjoy is through embeddedness in relationships with other actors. Firms opt to form relationships with other organizations for various reasons and objectives. However, not all firms' network structures and relation aspects are equally valuable. The wide array of relationships and their diverse effects on firms' outcomes and competitive advantages have created different and contradictory views on how firms should be embedded in networks (Rowley et al., 2000). Actors' relational and structural network embeddedness properties, for instance, determine in part constraints and opportunities that an actor might encounter. Therefore, identifying such network dimensions is fundamental for predicting actors' outcomes (Borgatti et al., 2013; Kilduff and Tsai, 2003; Owen-Smith and Powell, 2004; Phelps, 2010). These different views and arguments in relation to firms' network relational and structural embeddedness and their influences on innovation are discussed in the following sections.

2.11: Network relational embeddedness characteristics

In the social network perspective, network relational aspects are concerned with the collection of ties and linkages among actors in a network. Moreover, it is the property of the relationships between a pair of actors and not inherently a characteristic of a single actor in the network (Wasserman and Faust, 1994). Network relational concepts are central constituents of any network research.

network research requires not only identifying network structure dimensions, such as an actor's network density and centrality, but should also be complemented with an investigation of the relations between network actors (Hanneman and Riddle, 2011), where these types of relations and ties are the key components of social network concepts (Wasserman and Faust, 1994). Relations can take the form of a collection of ties among actors, and includes the strength and composition of these ties (Powell et al., 1996; Wasserman and Faust, 1994). These could include collaborations, trade ties, resource flows, information flows, or any other possible linkages between particular actors (Wasserman and Faust, 1994; Goyal, 2011).

For the purpose of this research, it is highly relevant to investigate the relational aspects of the focal firm with its ties (i.e. partners) in terms of inter-firm relationships, and to analyse and understand the types of these relational variables and their effects on innovation. In the following section, the key network relational embeddedness characteristics in terms of strength of ties (i.e. strong/weak ties, strengthen the ties), repeated collaboration (continuity) and network diversity of actors (partners) will be discussed.

2.11.1: Strength of ties

A tie is a social relation that links actors and/or establishes a linkage between a pair of actors (Wasserman and Faust, 1994). It represents the presence or absence of a relation between the actors in a network (Scott, 2013). The concept of strength of ties was introduced at the interpersonal level for the first time by Granovetter (1973) in his 'strength of weak ties (SWT)' theory. According to SWT theory, the strength of ties is characterized by time, emotional intensity, intimacy (mutual confiding), and reciprocal services. He discussed the two types of ties, strong and weak ties. In the personal level, for instance, strong ties represent an individual friendship and a family's linkages, which require more time and intimacy. In contrast, weak ties are formed by relations with persons one is loosely connected to, such as acquaintances (Granovetter, 1973, 1983). Granovetter argued that strong ties are unlikely to be a source of novel information. Overreliance on strong ties will cause an information overlap with what an individual has already because close friendships type of relations will generate strong ties between people who are already similar (part of the same social circle) and provide redundant information. Weak ties, on the other hand, tend to be ties with disconnected people (i.e. acquaintances), who, in most cases, are not well known; thus, actors receive information outside their own social worlds. According to SWT theory, weak ties act as bridging ties that become sources of novel information. A bridging tie, as illustrated in Figure (2.1), is a tie that links an ego to other actors who are not directly connected to the ego network and who can be a potential source of more useful, non-redundant information circulating outside the ego's immediate network (Granovetter, 1973, 1983, 1985, 2005; Borgatti and Lopez-Kidwell, 2011).

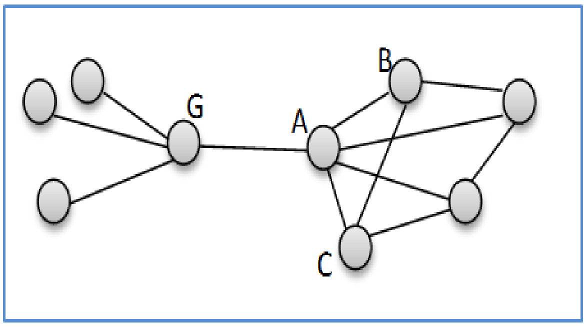

Figure 2.1: Weak ties (Bridging ties) from A to G; removing the tie disconnects the network

Adopted from: (Borgatti and Lopez-Kidwell, 2011)

Tie strength is a concept that can be characterized by the closeness of the relationship between two actors and the frequency of their interaction, ranging from weak ties at one extreme to strong ties at the other (Levin and Cross, 2004). In innovation studies, strong and weak ties have been investigated by researchers with the objective of analysing inter-firm networks, strategic alliances, R&D cooperation, and so forth, and its influence on firm-level innovation (Capaldo, 2007; Ahuja, 2000; Obstfeld, 2005). Rowley et al. (2000) defined tie strength by adapting working relationships among firms in terms of frequency of interaction between partners and their level of resource commitment to the relationship. In their study, they relied on the ranking criteria rating of the strategic linkage adapted from Contractor and Lornnge (1988) (Rowley et al., 2000). According to this approach, strong ties can be categorised to indicate the type of relationship which firms had with partners. For example, equity alliances, joint ventures, and cooperative (R&D) ventures are categorized as strong ties, and weak ties are categorised as marketing agreements, and licensing and patent agreements. In addition, firms frequency of interaction with partners such as daily, weekly and several times a month contacts are considered strong ties, while once a month and yearly contacts are considered weak ties.

In the same study, Rowley et al. (2000) discussed the advantages each type of tie might bring to organizations. For instance, strong ties are associated with the exchange of high-quality information and tacit knowledge. They provide organizations with access to external resources, share risks and costs, or pool complementary skills. In contrast, weak ties can act as channels to access novel information from which actors in the network can benefit. Weak ties are more likely than strong ties to be links between distant actors, providing access to heterogeneous sources of knowledge and information (Rowley et al., 2000). In addition, network ties are important sources of referrals that enable prospective partners to identify and learn about each other's capabilities (Gulati et al., 2000). In a study of the semiconductor and steel industries, Rowley et al. (2000) found that strong ties in a highly dense strategic alliance network negatively affect firm performance in the semiconductor industry. Conversely, steel and semiconductor firms that have a mix of ties, both strong and weak ties, perform better (Rowley et al., 2000).

In a longitudinal study of the inter-firm relational network properties of three design-intensive furnishing manufacturers, Capaldo (2007) investigated the different impacts of an ego's (lead-firm) strong ties on its innovative capabilities. He argued that, even though strong ties bring great benefits to the lead-firm from its network, the firm might end up locked-in in a closed circle network, which is a type of small social world as indicated by SWT theory. Instead, adopting a dual network strategy in which the lead firm integrates core strong ties with heterogeneous weak ties. Strong ties allow the lead firm to have trust and reciprocal relationships with partners that facilitate the exchange of valuable and thick information. At the same time, novel ideas, different organizational practices, and new markets can be explored through a mix of weak ties with diverse partners. The study's findings suggest that strong ties accumulated over time yield mutual understanding among lead-firms and partners about each other's resources, capabilities, and know-how. This in turn helps firms select the right partner for the right project, joint-design effectiveness, new products, and time to market. Another advantage is that both parties are willing to pool resources, assets, and share knowledge and know-how stimulated by strong relationships that inhabit trust based-relationships, reputation, and mutual commitment. Moreover, strong relations reduce opportunistic behaviours, which prevent the unwanted transfer of knowledge or information to competitors. However, Capaldo's study pointed to some weaknesses of strong ties. For instance, strong ties limit firms to a narrow network of members, which constrain firms' access to new ideas and information. This isolates firms from their industry and from market trends, which negatively affects their knowledge base and innovation outcomes. Nonetheless, Capaldo (2007) argues that having a network that enjoys both types of relationships (i.e. strong ties and heterogeneous weak ties) has advantages over the strong ties network for four main reasons: (1) firms avoid being locked-in in a closed network, which fosters new learning and innovation.; (2) mixed relationships increase partner's diversity within the network, which enlarges the firm knowledge base; (3) they encourage repeated interactions among diverse network members, which will enhance the lead-firm's internal capabilities and approaches; and (4) firms can leverage openness towards new market trends to both the leading firm as well as its partners (Capaldo, 2007).

The reviewed literature reveals that firms' network relationships in the form of linkages and ties (i.e. strong, weak, or a mix of both) have a significant impact on innovation. Actors' ties within a network also have a significant influence on organizations' access to new knowledge and information. Depending on the type of ties, therefore, firms can use tied relationships to search for new opportunities and to realize valuable information to their innovation outcomes (Nieto and Santamaria, 2007).

2.11.2: Repeated collaboration (continuity)

Repeated collaboration (continuity) can be defined as a firm's decision to form a means of collaboration with other organizations and to continue these collaboration efforts over time with the same or different organizations (Soh, 2003). It is also defined as the number of partners with repeated alliances based on a cumulated number of alliances (Soh, 2003).

Collaboration between organizations has become an important strategic approach for acquiring resources and skills firms cannot produce internally (Nieto and Santamaria, 2007; Powell et al., 1996). Firms that tend to be involved in repeated collaborations with other organizations are considered to have accumulated experience and knowledge, which in turn could strengthen their innovation competences (Nieto and Santamaria, 2007; Soh, 2003). In a longitudinal study, Nieto and Santamaria (2007) studied the effect of continuity of collaboration with diverse partners on the degree of novelty of product innovation. They found that the aspect of continuity in technological collaborations and the diversity of partners is highly significance with product innovation novelty among Spanish firms. Furthermore, firms were able to pool complimentary resources and capabilities from their counter parties, which led to the successful generation of new products (Nieto and Santamaria, 2007). Similarly, using the social network approach, Soh (2003), in an investigation of 48 firms in the computer networking market, confirmed the importance of increasing the number of repeated partners when it comes to new product performance. In technology collaboration networks, firms were able to enhance their new product performances by increasing their central network positions and acquiring new ideas and information through their repeated collaborations. However, not every firm is capable of forming alliances or establishing cooperation agreements with their network members. Continued collaboration with other actors in the network entails additional costs and opportunistic behaviours that need to be accounted for in order to allow firms to benefits from their relationships (Soh, 2003).

2.11.3: Network diversity of actors (partners)

Network member's composition could reveal various aspects of ego networks. It refers to the various characteristics of actors in a network, such as an actor's traits and features (Powell et al., 1996; Wasserman and Faust, 1994). One of the main dimensions of a network is the diversity of organization alliances within it (Faems et al., 2005). Partners' diversity refers to firms' access to more diverse sources of resources, information and knowledge through their networks relationships. It has the potential of accessing diverse sources of knowledge, information, and resources which allow firms to create new combinations of capabilities and knowledge (Gilsing et al., 2008). Whereas, structural embeddedness or positional perspectives on networks is concerned with the configuration and position of actors in a network (Granovetter, 1992). Therefore, partners' diversity as a new concept introduced here, has more features and closer properties to relational embeddedness characteristics that is related to the quality and depth of relationships and ties among and between actors in a network (Granovetter, 1992; Jones et al., 1997).

Firms are increasingly seeking new ideas and knowledge to better perform and compete in the market. Having different sources of information and ideas through collaboration with diverse partners has been found to enhance firm's innovation due to the amount and the variety of knowledge that is shared between these partners (Nieto and Santamaria, 2007). Phelps (2010) emphasizes the importance of increasing network diversity, which in turn increases the firm's access to diverse and novel knowledge. Additionally, in a study of telecommunications equipment manufacturers, Phelps (2010) suggests that a firm's network with diverse knowledge base alters can provide the firm with access to a pool of information and ideas independent of the ego-network structure. He also suggests that a firm can stimulate its exploratory innovation if it has a combination of both network closure (dense network) and access to a diverse knowledge base through ego-alters in the network (Phelps, 2010).

In their study of 221 Belgian manufacturing firms, Faems et al. (2005) empirically examined the effects of inter-firm collaboration with diverse partners on innovation effectiveness. The authors argued that firms that engage in a heterogeneous network inter-organizational collaboration are better able to produce innovative products. Their study findings suggested that partners diversity of firm's collaborative network is highly related to the firm's achievement in terms of new or improved products (Faems et al., 2005).

2.12: Network structural embeddedness characteristics

Examining network effects on innovation from a structural perspective has received great scholarly attention in the past two decades. Network structural embeddedness is generally concerned with the position that an actor occupies in a network (Zaheer and Bell, 2005; Rowley et al., 2000). At the ego network level, a structural pattern can posit both opportunities and constraints for actors, which shape and influence their performance, and outcomes (Granovetter, 1985; Burt, 1982; Gulati, 1999). For example, as opportunities for firms, structural patterns can be an inimitable resource and capability (Gulati et al., 2000), can provide brokerage advantages (i.e. access to and control of information) (Burt, 2000), can be a source of competitive advantages, and are more likely to increase a firm's innovation (Salman and Saives, 2005; Rowley et al., 2000; Gilsing et al., 2008; Bellamy et al., 2014; Phelps, 2010; Gay and Dousset, 2005; Obstfeld, 2005). However, a firm could be limited by its structural configuration in a network. For instance, actors might end up in strategic locked-in situations in their network structures, preventing them from exploring potential opportunities (Gulati et al., 2000; Lee, 2007).

Network structural variables are considered the cornerstone of social network data. Measurements of these variables can be carried out on pairs of actors (Wasserman and Faust, 1994). Measuring these variables enables the exploration of the impact of the structure of relations around actors on their propensity to cooperate with one another (Gulati and Gargiulo, 1999; Granovetter 1992). Moreover, a firm's network structural embeddedness could positively or negatively affect its economic actions and outcomes (Uzzi, 1997). Therefore, understanding network structural embeddedness is critical for actors in the network in order to be able to assess their subsequent actions and recognize the potential of various networks (Gulati et al., 2000; Granovetter, 1985). Types of network structural embeddedness characteristics, including actors' positions in terms of network density and centrality and their importance to firms' innovation, will be the main focus of the following section.

2.12.1: Network density

Network density is one of the main measures of network structure. In general, network density is a measure of connectedness between members in a network. According to Lee (2007), network density is defined as the degree to which a firm's contacts are connected between each other (Lee, 2007). It is the actual number of ties in the network expressed as a proportion of the hypothetical maximum number possible (Scott, 2013; Borgatti, 2013; Ahuja et al., 2012).There are two types of network densities: global and local. Global network density considers both types of ties—direct and indirect—as a property of the total network (Gilsing et al., 2008). Conversely, local density examines the interconnectedness of relationships among a focal firm's direct partners (Rowley et al., 2000).

Based on the reviewed literature, there are two views concerning the effect of network density on a firm's innovation. On the one hand, scholars tend to conceptualize and discuss network structure properties based on Burt's 'structural holes' social capital theory (Burt, 1992). Structural holes theory is concerned with the actor's type of connection in a network, and structural holes are the weaker connections between actors in a network. They act as buffers between different groups of actors and can be a source of competitive advantages for an ego-firm whose relationships span the holes (Burt, 1992, 2000, 2004). According to Burt, an efficient network structure is characterized by non-redundant contacts and brokerage opportunities. Moreover, structural holes can provide actors with opportunities for information access, timing, referrals, and control (Burt, 1992, 2000,2004), relating an actor's weak ties to positive outcomes in the SWT theory (Borgatti and Foster, 2003). Moreover, Burt (1992, 2000) argues that sparse network structure (i.e. structural holes) is more beneficial for ego since it is a source of non-redundant information, and an ego-firm embedded in a less dense network will enjoy efficiency and brokerage advantages over the flow of information (Burt, 1992, 2000; Rowley et al., 2000; Phelps, 2010; Rodan and Galunic, 2004; Ahuja, 2000; Zaheer and Bell, 2005). Figure (2.2) illustrates the graphical representation of structural holes. Figure (2.2.a) represents an ego with a sparse network (i.e. many structural holes), which means, in theory, it has less redundant contacts providing an opportunity to access new and diverse information and knowledge sources. In contrast, in Figure (2.2.b), all actors in the network are well connected to each other and can all potentially receive overlapping information (Burt, 1992, 2000; Borgatti et al., 2009; Gilsing and Duysters, 2008; Soh, 2003).

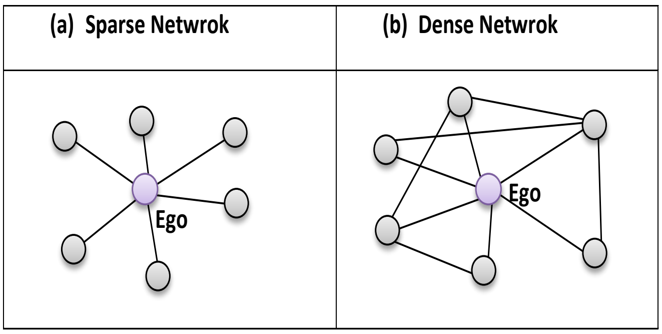

Figure 2.2, (a & b): Graphical representation of network density/structural holes

adopted from: (Borgatti et al., 2009)

In contrast to Burt's view, Coleman's (1988, 1990) closure argument on social capital calls for a dense ego network structure. A dense network promotes trust, reciprocity norms, and a shared identity, which can increase cooperation and knowledge sharing among members (Phelps, 2010; Schilling and Phelps, 2007; Ahuja et al., 2012; Kilduff and Brass, 2010; Borgatti and Foster, 2003). Moreover, firms embedded in a dense network might enjoy competitive advantages that arise from increased trustworthiness and cooperation among actors, which helps manage risk and can enhance communication and the flow of information across contacts in the network (Coleman, 1988, 1990; Zaheer and Bell, 2005; Ahuja, 2000; Walker et al., 1997; Rowley et al., 2000; Zaheer and Venkatraman, 1995). In fact, there is still argument and disagreement among scholars regarding the optimum structural embeddedness leading to better performance and innovation. Nevertheless, both views (dense and sparse networks) provide different benefits, which are useful for different strategic purposes (Rowley et al., 2000; Ahuja, 2000). Moreover, Burt (2000) argued that both closure and structural holes perspectives should be seen as complimentary rather than contradictory. He emphasized that, although brokerage across structural holes enables access to sources of potential added value, network closure is critical to capturing this value (Burt, 2000).

Previous studies have shed light on the effects of a firm's network density on innovation performance. Gilsing et al. (2008) explored the density effect on novelty creation from the global density perspective (considering both direct and indirect ties). The authors suggest a curvilinear relation between the network density of a firm and its innovation activities. Their findings support the theory that a firm's innovation can be influenced by its network structure, and firms should discover their network's optimum density configuration for higher value creation (Gilsing et al., 2008). Similarly, a recent study by Tan et al. (2015) suggests that different network structural embeddedness, in terms of high and low density, can have different implications on a firm's innovation. For instance, they argue that at high network density, a firm's network configuration in terms of central position will be less beneficial for their innovation performance. However, central position and structural holes complement each other by enriching a firm's innovation in a low-density network (Tan et al., 2015).

A longitudinal study of 77 telecommunications equipment manufacturers by Phelps (2010) examined the influence of network density on a firm's exploratory innovation performance. He adopted the ego network analysis approach to identify all possible undirected pairwise combinations of his sample firms. In his study, Phelps (2010) supported the network closure view and suggested that firms that enjoy a dense network among their partners benefit from the strong influence of partner diversity, which in turn increases exploratory innovation (Phelps, 2010). In another major study, Ahuja (2000) showed that the lack of ties among a firm's partners (i.e. the presence of structural holes) in inter-firm collaboration networks negatively affects the patenting rates of firms, and hence negatively affects a firm's innovation (Ahuja, 2000). On the other hand, some empirical research found a negative impact of network density on a firm's economic outcomes. For example, drawing on a study of network alliance structures and firm profitability in U.S telecommunication companies, Bae and Gargiulo (2004) reported a significant negative effect of network density on firm profitability.

Reviewing the literature and the empirical work on the effect of network density on ego-firm innovation performance indicates support to Burt's argument. Burt (2000) suggested that both sparse and dense networks are important structural configurations and are valuable in different contexts (Rowley et al., 2000). The literature suggests that where coordination and trust among ego-firm network is more important, a dense network is more effective, whereas a sparse network structure is more effective for firms seeking to access scarce resources and/or novel information.

2.12.2Cliques:

A Clique is one of the network structural characteristics that describe the maximal sub-graph of three or more nodes (actors) (Wasserman and Faust, 1994; Hanneman and Riddle, 2011; Gulati, 1999). It is a subset of actors in a network in which every actor is directly connected to all others (Borgatti, 2013; Hanneman and Riddle, 2011; Scott, 2013; Kilduff and Brass, 2010). Provan and Sebastian (1998) suggested that different cliques aspects, such as strongly connceted ones or overlapping cliques, could have different effect on firm's outcomes. For instance, cliques within a network could exert an opportunity for firms within a clique to learn about each other establishing a working relationships built on trust and cooperation (Uzzi, 1997; Provan and Sebastian, 1998; Brass et al., 2004). Moreover, firms working together in a form of cliques can integrate their resources and commonly solve problems effectively (Provan et al., 2007) and are exposed to new knowledge and opportunities (McEvily and Zaheer, 1999; Inkpen and Tsang, 2005; van der Valk et al., 2011; Hoang and Antoncic, 2003). However, thick cliques might hinder firms from interacting outside their immediate contacts and potentially end up relatively isolated from external sources of information (McEvily and Zaheer, 1999; Borgatti and Cross, 2003). Cliques are concerned with subgroups in a network that required a whole network consideration (Borgatti, 2013). Therefore, cliques are not going to be considered in this research since the focus is on the ego-network approach.

2.12.3: Centrality

In social network analysis, the concept of centrality is considered one of the most important constructs and it is concerned with an actor's position in a network (Borgatti, 2013). A central actor is one that is at the centre of a number of connections in a network (Scott, 2013). The actor could be an individual or organization, where the strategically centred actor can enjoy wider access to knowledge and flow of information, as well as control over valued resources (Ibarra, 1993; Freeman, 1979; Ahuja et al., 2012; Gulati, 2002). Significantly, an actor who is centrally embedded in a network can benefit by being at the passage point of transmitted knowledge and information in the network (Owen-Smith and Powell, 2004), where an actor's position is a possible source of opportunities and advantages (Borgatti, 2013). The main constructs to measure different aspects of centrality in a network are: degree centrality, betweenness centrality (Freeman, 1979), eigenvector centrality and closeness centrality (Borgatti, 2013; Wasserman and Faust, 1994). These are the focus of the following sections.

Figure (2.3) illustrates three different types of network positions. For example, from the line network, all the actors in the middle of this network, including the ego-firm, have the potential to control some of the information and resources transmitted through the network, while those at the edge of the graph might not. For the circle network, all the actors in the graph are interchangeable and equally central; hence there is no actor in a favourable position over others. Lastly, the star network shows that the ego-firm is the most central actor, as it falls between other actors in the network, which give the ego-firm potential control over the paths in the graph (Freeman, 1979; Freeman et al., 1991; Wasserman and Faust, 1994). In addition, it implies that the ego-firm might act as a gatekeeper or broker over the information and resources within the network (Borgatti, 2013), which also improves the possibilities to benefit more from their network than less central firms (Gulati, 1999).

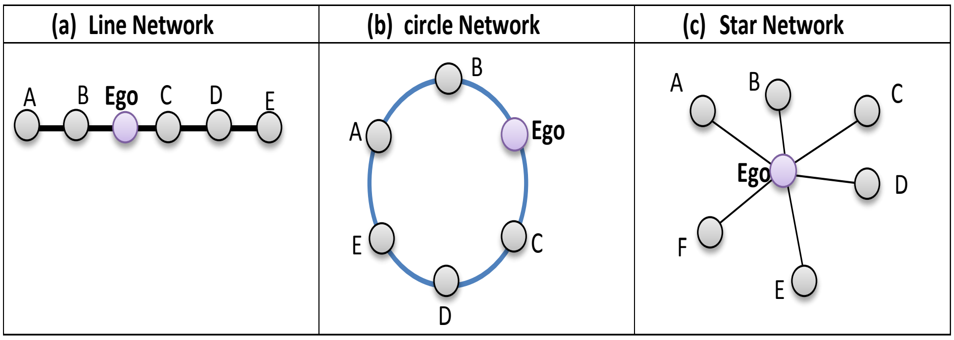

Figure 2.3 (a, b & c): Different types of networks

Adopted from: (Wasserman and Faust, 1994, p. 171)

2.12.4: Degree centrality

Degree centrality can be defined as the degree to which an actor is involved with other actors in a network. Central actors can be considered the most active in the sense that they have the most ties to other actors in the network (Wasserman and Faust, 1994; Hanneman and Riddle, 2011). Degree centrality can be measured by the number of other actors to which the focal actor is adjacent (Scott, 2013). According to Powell et al. (1996), a firm's centrality is the number of other firms connected to it, regardless of how well those partners are connected (Powell et al., 1996). A firm's central position in a network can increase its early access to resources, knowledge, and information flow (Lee, 2007). Moreover, a central position can offer returns to an organization in terms of competitive advantages (Owen-Smith and Powell, 2004). Furthermore, an actor with a high degree of centrality is considered highly visible and tends to be seen as important (Borgatti, 2013) and as a major channel for receiving and transmitting information (Wasserman and Faust, 1994). This has the implication of increasing the ego-firm experience and gaining from its network relationship (Gulati, 1999).

2.12.5: Betweenness centrality

Betweenness explores the concept of centrality and is the most-researched centrality measure in innovation literature. It is concerned with the position of an actor that lies between other actors in s network (Owen-Smith and Powell, 2004; Borgatti, 2013). In addition, betweenness centrality measures the centrality of a focal actor in a network (Gilsing et al., 2008). Many scholarly works build on Freeman's (1979) argument that an actor that lies between two other actors that are not directly connected to each other has control over the information and resource flows (Borgatti, 2013). It is suggested that being structurally embedded is a favoured position where an actor falls in the geodesic paths between other pairs of actors in the network (Hanneman and Riddle, 2011). High ego-firm betweenness centrality indicates a firm's ability to absorb information flows through the network (Owen-Smith and Powell, 2004). Additionally, betweenness centrality can be a measure of the influence an ego-firm has over the information and resources through its network (Gilsing et al., 2008). Betweenness centrality is measured by the extent to which a firm is located on the shortest path (i.e., geodesic) between any two actors in its network (Schilling and Phelps, 2007; Borgatti, 2013; Scott, 2013).

Betweenness centrality is one of the centrality measures that have been used primarily in intra-firm network, inter-firm network, and innovation literature. For instance, one of the earliest works on the impact of network centrality on a firm's innovation was carried out by Ibarra (1993). On the intra-firm level, she investigated the effect of being in a central position among workers on innovation, and concluded that centrality was one of the main influential aspects for the creation and diffusion of a firm's innovation (Ibarra, 1993). Similarly, Tsai (2001) investigated 24 business units in a petrochemical company and 36 business units in a food-manufacturing company. He found that being in a central position is beneficial for organizational units in order to access new knowledge in a timely manner. Moreover, occupying a central position has a positive influence on innovation performance (Tsai, 2001). At the inter-firm level, Shan et al. (1994) investigated 114 start-up firms in the biotechnology industry and found that a firm's position in inter-organizational relations is positively related to innovation output.

Soh (2003) carried out a study on 201 observations for 48 firms in the computer networking market, and found that central positions in the technology collaboration networks of a firm improve new product performance (Soh, 2003). Another study conducted by Gilsing et al. (2008) investigated the relationship between the explorative innovation performance of companies and network centrality (betweenness centrality). Acquiring a panel data on the alliance and patenting activities of 116 companies in chemicals, automotive, and pharmaceutical industries, they concluded that highly central firms enjoy the strongest improvements in their explorative innovation performance networks (Gilsing et al., 2008). However, Schilling and Phelps (2007) did not find statistically significant evidence concerning the effect of betweenness centrality on subsequent firm patenting and new product generation in their longitudinal study of 1,106 firms. On the contrary, they concluded that efficiency had a significant negative effect on firm patenting, which suggests that the presence of structural holes in a firm's ego network of alliance relationships has negative consequences on its innovative output (Schilling and Phelps, 2007).

Therefore, according to the literature, network position in terms of centrality can play a crucial role in determining a firm's innovation performance. However, most of the mapped literature considers only the direct effects of network structural embeddedness on innovation. This necessitates further work on the combined effects of network relational and structural characteristics, and calls for joint consideration of their effects on a firm's innovation.

2.12.6: Eigenvector centrality

Eigenvector centrality is another centrality concepts that accounts for both direct and indirect ties of an actor in a network (Bonacich, 1987; Carpenter et al., 2012). It refers to the number of actors adjacent to a given actor in a network weighted by each adjacent actor by its centrality (Borgatti, 2013; Koka and Prescott, 2002). In general, eigenvector centrality captures the connectivity of an actor alters in a network in which it accounts for the number of alters an actor have in a network (direct ties) as well as the number of actors those alters know (indirect ties) (Borgatti, 2005). Therefore, the most central actor (firm) in a network is the one that linked to several other actors, which are in turn associated with several other actors (Gulati and Gargiulo, 1999). Scholars use eigenvector centrality to indicate access to resources and flow of information (Koka and Prescott, 2002; Mazzola et al., 2015) which provide actors with high eigenvector centrality an early recognition of novel knowledge opportunities (Salman and Saives, 2005). However, eigenvector centrality is a measure of centrality to the whole network since it is about the links from an actor to all other actors in a network (direct and indirect ties) and it is not applicable to ego-network approach (Everett and Borgatti, 2005).

2.12.7: Closeness centrality:

Closeness centrality refers to the focal actor's distance for other actors in the network and account for both direct and indirect linkage (Borgatti, 2013; Wasserman and Faust, 1994; Hanneman and Riddle, 2011; Freeman, 1979; Salman and Saives, 2005). Actor's closeness centrality measure reflects how close and actor is to other network members (Wasserman and Faust, 1994). It can be measured as the shortest path distance of each actor from other members in the network (Freeman, 1979; Gulati et al. 2002). actor with high closeness centrality has an advantage of quickly interacting with network members allowing for faster information flow and more likely to integrate with other actors and share resources (Wasserman and Faust; 1994; Gulati, 1999). Additionally, closeness centrality can be an indication of an actor's ability to independently access to knowledge and information that other possessed (Freeman, 1979; Rowley, 1997). High closeness centrality can help the focal actor to be more accessible to other network members and have a higher chance of being referred by other members when there is a rewarding opportunity (Gulati et al. 2002). However, as in eigenvector centrality concept, closeness centrality cannot be applied to ego-network approach since it is concerned with direct and indirect links in a network (Everett and Borgatti, 2005).

2.12: Conclusion

This chapter provided an overview of developments in the current literature on innovation and networks. A systematic literature review was adapted to define the notion of innovation and to identify existing gaps in the body of knowledge, as well as to highlight paths for research. Moreover, different models of innovation were studied, and different types of innovation, their definitions, aspects, and differences were identified and discussed. Taxonomy for different types of innovation was introduced, which will be employed to categorize different types of innovation in this thesis. Moreover, reviewing literature in the field of innovation revealed a number of knowledge gaps that need further attention. The identified research gaps lead to the development of the main research question of this thesis:

To what extent do firms' network embeddedness characteristics (i.e. relational and structural embeddedness characteristics) impact their innovation outcomes (i.e. product and process innovation)?

This chapter also shed light on different theoretical perspectives on networks and innovation. It discussed the main theoretical views underpinning innovation research, namely Resource Based View (RBV), Transaction Cost Economics (TCE), Organizational Learning, and Resource Dependency. It highlighted the need for firms to build on external knowledge and resources found outside their boundaries. It was found that current theories have not fully addressed firms' network characteristics that might explain their innovation outcomes. Thus, in order to fill the current knowledge gaps, social capital theory, social networks, and network embeddedness views were introduced and discussed to foster a better understanding of firms' networks implications on innovation.

In the last part of the chapter, the concepts of social capital, social networks, and network embeddedness were reviewed in detail. An explanation of the social network and network embeddedness perspectives was given illustrating its key constitutes (network relational and structural embeddedness aspects), properties, and concepts. Furthermore, the constructs that were used for developing the conceptual framework of the study were theoretically and empirical introduced and discussed.

In the next chapter, the conceptual framework underpinning this research is developed based on the concepts reviewed in this chapter. In addition, to address the identified knowledge gaps, a number of hypotheses were developed and the theoretical model of the study is tested.

Network construct	The discussed Literature			
	Authors	**Innovation performance measures**	**Operationalization of Network construct**	**Key findings**
Strength of ties (Strong/Weak Ties)	(Rowley et al., 2000)	Firms performance (net income and return on assets)	Ties strength (Strong/weak ties)	Strong ties in a highly interconnected strategic alliance network negatively impact firm performance
	(Capaldo, 2007)	Product innovation performance	Strong/weak Ties	• Strong ties benefit lead firms in sustaining innovation to a certain limits. Lead firms need to integrate these ties with a large number of weak ties to avoid being locked in a limited number of relationships (diversity of ties) • A combination of weak and strong ties (diversity of Ties) provide the lead firms with the capability to innovate
	(Ruef, 2002)	Innovation output (patent and trademark applications, and Innovation index according to the perspective of entrepreneurs)	Strong/weak ties	actors (entrepreneurs) whose relying on strong ties as a source of new ideas are less likely to innovate than actors relaying on weak ties
	(Gilsing and Nooteboom, 2005)	technological exploration/ exploitation networks	(Strong/weak ties)	In technological exploration network environment, density and strong ties are more favourable. However, content in terms of types of knowledge and technology should be taken into account.
Repeated Collaboration (Continuity)	(Nieto and Santamaria, 2007),	degree of novelty of product innovation	The number of years a company had participated in business/inter-organizational relationship networks.	• Continuity of collaboration of the collaborative network is highly significant dimensions in product innovation degree of novelty. • Collaboration with suppliers, clients and research organizations has a positive impact on the novelty of innovation, while collaboration with competitors has a negative impact.
	(Soh, 2003).	new product performance	the number of different partners with repeated alliances	Repeated collaboration improves firm's new product performance
Network diversity of partners	(Nieto and Santamaria, 2007),	degree of novelty of product innovation	Diversity of partners	Diversity of partners has a highly positive impact on the degree of innovation novelty
	(Faems et al., 2005).	technologically improved product	the type of partners	Positive relationship between inter-organizational collaboration and innovative performance, and this performance depend on the type of partners involved.

	(Phelps, 2010).	Exploratory innovation using patent citations.	Network technological diversity	Firm's exploratory innovation Increases as its technological diversity of alliance partners increase
	(Tsai, 2009)	Product innovation performance, which is measured by innovative sales productivity.	types of collaboration with different partners	more diverse partners allow access to broad knowledge networks, which increase firms' product innovation
	(Laursen and Salter, 2006)	Product innovation (radical/incremental/ significantly improved) As a fraction of the firm's turnover for each type	Breadth which is constructed as a combination of the 16 sources of knowledge or information for innovation	Firms that use a higher number of knowledge sources have access to a greater breadth of information for product innovation. however, too much diversity has a negative implication on firms' product innovation
	(Sampson, 2007)	New product using Post-alliance patents	diversity of partner technological capabilities	Diversity between partners leads to better innovation performance. Nevertheless, when partners are highly diverse, firms' learning and knowledge sharing is less valuable and might hinder their innovation

Table 2.11: Summary of reviewed literature on social capital, social network, and network embeddedness (Relational characteristics)

Network construct	The discussed Literature			
	Authors	Innovation performance measures	Operationalization of Network construct	Key findings
Network density	(Rowley et al., 2000).	Firms performance (net income and return on assets)	Network Density	In an exploitation context, dense network ties could be a source of competitive advantage
	(Phelps, 2010).	Exploratory innovation (patents count)	Network Density	Network density positively influence technological diversity, hence increases firms exploratory innovation
	(Soh, 2003).	New product performance	Network Density (as a control variable)	Density is positively associated with new product performance
	(Karamanos, 2016)	Exploratory/exploitative innovation (patents count)	Network density	Network density is positive and statistically significant for Exploratory/exploitative innovation. Furthermore, whole network density is consistently important for exploitative and exploratory innovation
	(Zaheer and Bell, 2005)	Firm's performance (firm's market share)	Network closure/ structural-holes	Innovative firms that bridge structural holes have better performance
	(Ahuja, 2000)	Innovation output (patents count)	structural-holes	Structural holes have both positive and negative (inverse-U shaped) influences on innovation (increasing structural holes has a negative effect on innovation). network closure increased the likelihood of firm innovation
	(Gilsing et al., 2008),	Explorative innovation performance (patents count)	Network Density	Density has an inverse-U shaped impact on Exploration (innovation performance)
	(Bae and Gargiulo, 2004)	Organizational profitability (return on investment and return on assets)	Network Density	negative effect of network density on organizational profitability
Centrality	(Powell et al., 1996).	Firms performance (net income and return on assets)	degree centrality	central connectedness (degree centrality) positively influence firms exploration activities
	(Soh, 2003).	New product performance	Closeness centrality	Firm's central position improves its new product performance
	(Gilsing et al., 2008)	Explorative innovation performance (patents count)	betweenness centrality	explorative innovation performance is highly improved for firms occupying a highly central position

	(Ibarra, 1993)	Administrative and technical innovation	Network centrality	centrality is one of the main influncial aspects for the creation and difussion of firm's innovation
	(Tsai, 2001)	number of new products introduced	Network Centrality	occupying central position shows a positive impact on units innovation performance
	(Liu, 2011)	Innovation performance (patents count)	betweenness centrality	betweenness centrality of a firm puts it in a place where it can access the network's flow of information, which is likely to positively contribute towards firms' innovation performance in networks
	(Karamanos, 2016)	Exploratory/exploitative innovation (patents count)	betweenness centrality	alliance ego–network centrality supports exploitative innovation
	(Gay and Dousset, 2005)	firm innovation capability (number of patent)	betweenness centrality/degree centrality	Central position is likely to positively contribute towards firms' innovation performance in networks

Table 2.12: Summary of reviewed literature on social capital, social network, and network embeddedness (Structural characteristics)

Chapter 3

Conceptual Framework Development

3.1: Introduction

This chapter provides a discussion of the overall conceptual research model. In addition, based on the literature reviewed in chapter 2, a number of hypotheses are developed and proposed in order to answer the questions posed in this study.

3.2: Overview of the conceptual framework underpinning the research

Literature reviewed in the previous chapter indicates that, although there is scholarly acknowledgement of the significance of a firms' network of relations on innovation, in-depth investigation to the characteristics of these network relationships, types, and structures at the firm level is not well addressed. Furthermore, the combined effects of structural and relational aspects of networking on firms' outcomes and the correct setting for inter-firm network configuration is still a developing area of research in the innovation domain. Far too little attention has been paid to the joint effects of firms' relational and structural embeddedness within a network. The impact of a firm's network relationships on its innovation cannot be fully understood without looking into how the firm is situated in that network (Rowley et al., 2000; Gilsing and Duysters, 2008; Gulati, 1998).

Innovation literature says little about the effect of the relational and structural embeddedness network characteristics on a firm's innovation. Firms' innovation performance can be affected by its embedded inter-firm relationships and structural configurations (Rogers, 2004; Ahuja, 2000b; Powell et al., 1996; Rowley et al., 2000; Gulati et al., 2000; Gilsing et al., 2008). Additionally, it is argued that innovation performance is no longer solely dependent upon a single firm's isolated efforts, instead it is increasingly enriched or constrained by the firm's surrounding environment. The environment a firm is embedded within is important, as is the search to establish relationships with other organizations to both identify and exploit knowledge and resources; this enables the creation of the proper setting and conditions for innovation. Therefore, this study devoted its central premise to contributing to this stream of research, using Gulati's (1998) concepts of network relational and structural embeddedness. Network relational embeddedness can be seen as how an actor benefits from its network of relationships through gaining valuable knowledge and fine grained information. Network structural embeddedness stresses the key role that an actor's network position plays in accessing and possessing resources and information (Gulati, 1998, Rowley et al., 2000; Gulati, 2002).

To understand the effect that network relational and structural embeddedness have on firms' innovation, this study draws on three complimentary perspectives; social capital, social network and network embeddedness. The social capital view suggests that firms' network relationships can influence their behaviour and performance (Rowley et al., 2000; Adler and Kwon, 2002; Moran, 2005), can be a source of resources, knowledge and competitive advantage (Bellamy et al., 2014; Capaldo, 2007; Koka and Prescott, 2002), and enhance firms' learning and innovation (Phelps, 2010; Gilsing et al., 2008; Ahuja, 2000a; Mazzola et al., 2015; Adler and Kwon, 2002; Koka and Prescott, 2008). Social capital theory highlights the value of certain positions in the structure of relationships, created through exchange or interaction between and among actors in a network, which can create a competitive advantage and lead to better returns (Burt, 2000; Coleman, 1988). All resources that an actor can access, mobilize and/or profit from because of their embeddedness in a social network of relations with other actors is the primary focus of the social capital view (Adler and Kwon, 2002; Castiglione et al., 2008; Koka and Prescott, 2008).

The social network and firms' network embeddedness perspectives are rooted in the social capital concept. The theory of social capital focuses on the resources embedded in an actor's (e.g. firms) social network, and how access to and use of such resources shape and benefit actor's actions (Lin, 2001). In the view of the social network and network embeddedness perspectives, economic actions and outcomes of firms are influenced by firms' pairwise relations and the effect of the structure of the overall network of relations (i.e. embeddedness) on the outcome (Granovetter, 1992; Gulati, 1998; Granovetter, 2005). This embedded resource can enhance the outcomes of actions by facilitating the flow of information and providing access to valuable resources (Lin, 2001). Moreover, as seen in the literature, network relational embeddedness characteristics reflect the quality and depth of linkage among actors (Jones et al., 1997; Gulati and Gargiulo, 1999; Gulati, 1998). Network structural embeddedness characteristics relate to the value of firms' structural positions in terms of flow of information and resources (Gulati, 1998; Granovetter, 1992; Gulati and Gargiulo, 1999).

Therefore, addressing such direct or combined effect of firms' network embeddedness characteristics could provide valuable insights into their innovation. Investigating innovation performance at the firm level could also shed light on different network embeddedness characteristics for each type of innovation. Moreover, this could uncover if there are any potential convergent or divergent effects in the optimal network embeddedness configurations in the M&H technology sectors for better innovation performance. For this study, Figure (3.1) provides an overview of the proposed conceptual model, describing the key aspects of ego-firm network relational and structural embeddedness and how they relate to the ego-firm's innovation output. Focusing on the ego-network involves investigating the network aspects of the focal actor (i.e. focal-firm); this is in line with the research objective, addressing the impact of network embeddedness characteristics on firms' innovation. Moreover, this is also consistent with measuring innovation output at the firm level.

3.3: Network relational embeddedness characteristics

The following section relates to the discussion of the main characteristics of network relational embeddedness and their relation to firms' innovation. It is also concerned with the network relational aspects, central to social network concepts. Network relational embeddedness is a property of the relationships between a pair of actors and not inherently a characteristic of a single actor in the network. Relational embeddedness characteristics can appear in the form of a collection of ties among actors, and the strength and composition of these ties (strong/weak ties, strengthen the ties) (Powell et al., 1996; Wasserman and Faust, 1994; Marin and Wellman, 2011), and can be extended to investigate collaboration in terms of repeated collaboration (continuity) (Nieto and Santamaria, 2007; Soh, 2003) and partner diversity (Faems et al., 2005; Phelps, 2010).

3.3.1: Strength of ties and innovation

In the fast pace of today's market, firms seek to improve their innovation performance by establishing relationships with other organizations. The nature of these relational ties can be strong, weak, or mix of both. At an interpersonal level, tie-strength is a combination of the amount of time, emotional intensity, intimacy, and reciprocal services associated with the tie (Granovetter, 1973). Gilsing and Nooteboom (2005) suggested three dimensions that represent tie-strength in innovation networks, derived from Granovetter's SWT argument. For instance, they proposed that frequency of interaction and duration of relationship represent intimacy. For emotional intensity, trust and openness in terms of firms' willingness to share knowledge, mutual learning, and reduce the chance of relational risks of spill-over and hold-up are indicators. In regards to reciprocal services, they proposed that the scope of activities that the firm and its partners are willing to share through their linkage was a good measure. Finally, the extent of formal, contractual control is another dimension that can indicate tie-strength competency and governance in the inter-firm networks (Gilsing and Nooteboom, 2005). Therefore, strong ties are characterized by a long duration of collaboration, high frequency of interaction between partners, and high resource commitments to the relationship, particularly when compared to weak ties (Capaldo, 2007; Rowley et al., 2000). Previous studies have reported that strong ties are important to firms because they can be conduits to useful knowledge, valuable resources and an increase in trust and mutual benefits between network actors (Uzzi, 1996; Uzzi, 1997; Gilsing and Nooteboom, 2005; Levin and Cross, 2004).

Strong ties enable actor-to-actor exchange of detailed information and effective communication of tacit knowledge (Hansen, 1999; Kilduff and Brass, 2010; Rowley et al., 2000). However, if strong ties dominate a firm's network, this might hinder their ability to access the new information and ideas needed to capture innovation opportunities. Besides, networks with strong ties among partners might force networks into a locked-in situation, isolating the ego-firm from the market (Gulati et al., 2002). This view was supported by Capaldo (2007), who argued that although strong ties could bring benefits to the ego-firm, it might isolate the firm from its market and industry in a confined set of closed networks, negatively affecting the knowledge base and innovation outcomes of the ego-firm (Capaldo, 2007). Furthermore, Ruef (2002) carried out an empirical study on over 700 organizational start-ups to examine their propensity to innovate. That study categorizes measurements of innovation into nine different categories, including the introduction of new product/service, process innovations, and development of new supplier linkages. Ruef demonstrated that actors (entrepreneurs) relying on strong ties as a source of new ideas are less likely to innovate than actors relying on weak ties (2002). Overreliance on strong ties in an ego-firm network is a source of overlapping information, blocking firms from novel ideas and learning. Moreover, this might lead to 'over-embeddedness', as proposed by Uzzi (1997), which suggests that strategic networks composed mostly of strong ties may threaten product innovation, rather than enhancing it.

Weak ties, on the other hand, are a type of relational ties that connect distant actors in the network. They entail little investment of time and intimacy. According Granovetter's (1973) weak ties argument, actors with this type of relations will enjoy better network structure since weak ties tend to act as bridges that connect distant actors operating in different networks. They provide focal actors with access to diverse sources of knowledge and novel information (Gilsing and Duysters, 2008; Gulati et al. 2002). Furthermore, from an inter-firm relationships perspective, firms with weak ties have the potential to have a beneficial search position for new products (Hansen, 1999), learn about and are able to exploit new opportunities available in the market earlier than others (Salman and Saives, 2005; Gulati et al. 2002), take advantage by stimulating and speeding up innovation (Capaldo, 2007), and help identify appropriate resources and capabilities found outside their immediate network circle (Soh, 2003). According to these arguments, the following hypothesis is proposed:

Hypothesis 1(H1): Strong ties in an ego-firm network are negatively related to firm's innovation.

The above arguments of strong and weak ties predict different impacts on a focal firm's innovation. For instance, Granovetter's SWT argument stressed the significance of certain relational linkages between actors in the network affecting their economic outcomes (Granovetter, 1973). This could facilitate benefits to the ego-firm and advantages from its network in terms of access to information and resources. In addition, as illustrated above, different network relational properties have the potential to improve or worsen a firm's innovation outcomes. Increasing frequency of interaction among an ego-firm and its partners could create new knowledge (Dyer and Nobeoka, 2000), lead to resource commitment, and exert a positive effect on the network value creation (Capaldo, 2007). Thus, it seems useful to explore the conditions under which an ego-firm strengthens its network ties with partners in order to perform better at innovation. Therefore, this thesis proposes the flowing hypothesis:

Hypothesis 2 (H2): Strengthen the ties in an ego-firm network is positively related to firm's innovation.

3.3.2: Repeated collaboration (continuity) and innovation

The interactive nature of innovation stresses the key role that continuous collaboration and knowledge exchange with other organization brings to the focal firm (Liefner et al., 2006; Dyer and Nobeoka, 2000). Firms' collaboration through their network of relationships becomes an important strategic path in order to access the knowledge, resources, and skills required for innovation (Hoecht and Trott, 2006; Freel, 2003). In order for firms to advance their local capabilities and learning, they rely heavily on their accumulated experience and knowledge base in terms of technological learning (Nieto and Santamaria, 2007), and on the management of collaborative ties (Powell et al., 1996). As Hagedoorn and Duysters (2002) suggested, firms with repeated interaction have higher learning potential from their networks, which will eventually enhance their innovation performance (Hagedoorn and Duysters, 2002).

In their empirical analysis of manufacturing firms in Austria, Toedtling et al. (2009) investigated the outcome of firms' collaboration with different types of partners, such as other firms, universities, and research organizations. They suggested that different types of knowledge sources and different types of ties linking different actors lead to different innovation outcomes. For instance, more advanced product innovation is linked to continued cooperation with universities and research organizations, whereas reliance on business sector interaction leads to the development of incremental product innovation. Moreover, their study claimed that innovation does not occur in the less binding form of cooperation among actors (Toedtling et al., 2009). Similarly, process innovation can be enhanced by collaborative activities with other actors in the industry (Reichstein and Salter, 2006). Additionally, Nieto and Santamaria (2010) demonstrated that the effects of technological collaboration depend on the type of innovation output of a firm. In their study, they found that the impact of collaboration on product and process innovation is positive and more significant in product innovation than process innovation (Nieto and Santamaria, 2010).

Nieto and Santamaria (2007) demonstrated that continuous collaboration could enrich firms' experience in managing network alliances, which in turn leads to better product innovation outcomes. In addition, as firms' learning experience accumulates due to repeated interaction with other organizations, they develop their capabilities and enhance resource endowments. In their analysis, they found that the aspect of continuity of collaboration among Spanish firms is highly related to better innovation performance, and encourage testing such impact on other types of innovation, such as process innovation (Nieto and Santamaria, 2007). Furthermore, Soh (2003) used a social network analysis approach to empirically investigate the role of networking alliances in obtaining novel information and enhancing innovation performance. This study showed the positive and significant effects of repeated cooperation among partners towards enhancing firms' innovation performance (Soh, 2003). Thus, in order address this potential effect, the following hypothesis is proposed:

Hypothesis 3 (H3): An ego-firm's repeated collaboration (continuity) is positively related to firm's innovation.

3.3.3: Network diversity of actors (partners) and innovation

Network diversity refers to firms' access to more diverse sources of resources, information and knowledge through their networks partnerships. Numerous studies argue that the value of a network of relationships that influences firms' innovation performance resides in the diversity of firm's alliance network rather than the number of partnership agreements (Baum et al., 2000; Faems et al., 2005; Laursen and Salter, 2006; Kim and Lui, 2015). A large number of benefits can be pooled from being embedded in a diverse network, such as access to a heterogeneous knowledge, resources, and know-how (Kim and Lui, 2015; Phelps, 2010; Beckman and Haunschild, 2002; Kaufmann and Todtling, 2001). In addition, this has the potential to increase a firm's chances of early recognition of business opportunities and novel ideas (Rodan and Galunic, 2004; Capaldo, 2007).

In their study of 221 Belgian manufacturing firms, Faems et al. (2005) empirically examined the effect of inter-firm collaboration with diverse partners on the effectiveness of improved or new product innovations. The authors argued that firms that engage in a heterogeneous network with inter-organizational collaboration are more able to produce innovative products. Furthermore, the study suggested that different types of partners have a different effect on innovation. For instance, partnership with universities and research institutes could lead to a high level of product innovation, and collaborations with suppliers and customers can be associated with improved product innovation. The study findings highly relate the partner diversity of a firm's collaborative network to their return on innovation investments achieved by the means of new or improved products (Faems et al., 2005). Collaboration with diverse types of partners entails accessing a larger pool of resources, while firms enjoy more opportunities and receive timely information about improvement and development in innovation (Amara and Landry, 2005; Leiponen and Helfat, 2010).

In their analysis of Canadian biotech start-ups, Baum et al. (2000) found that firms who engage with heterogeneous partners in the network enjoy superior early innovation performance because the same types of partner offer access to a less diverse pool of knowledge and resources (Baum et al., 2000). Similarly, Phelps (2010) emphasised the importance of increasing network diversity, which in turn increases firms' access to diverse and novel knowledge. In his study of telecommunications equipment manufacturers, Phelps (2010) suggests that firms engaged with a network with a diverse knowledge base will provide the firm with access to pool of information and ideas independent of the ego-network structure. Further, a firm can more readily stimulate its exploratory innovation if it has a combination of both network closure (dense network) and access to a diverse knowledge base through ego-partners in the network (Phelps, 2010). Therefore, this study proposes that:

Hypothesis 4 (H4): An ego-firm's network diversity is positively related to firm's innovation.

3.4: Network structural embeddedness characteristics

Structural embeddedness characteristics and their relationship to types of innovation are the primary focus of the following section. Structural embeddedness characteristics are generally concerned with the position that an actor occupies in a network (Zaheer and Bell, 2005; Rowley et al., 2000). They can be evaluated in terms of connectedness between members in a network (i.e. sparse or dense network), and can be examined according to the focal-actor's central position or connections in the network (Scott, 2013; Wasserman and Faust, 1994; Borgatti, 2013; Freeman, 1979; Freeman et al., 1991).

3.4.1: Network density and innovation

Network density refers to the strength of connection between an ego-firm's contacts in the network (Borgatti, 2013), represented by the actual number of ties in the network divided by the maximum number of ties that are possible (Scott, 2013; Borgatti, 2013; Ahuja et al., 2012). Scholars have attempted to explain the impact of network density on firms' innovation, yet there is still disagreement regarding the effects of dense networks (Coleman, 1988; Coleman, 1998; Coleman, 1990) and sparse networks (structural holes) (Burt, 1992; Burt, 2000; Burt, 2004) on firms' innovation.

This thesis, informed by Bae and Gargiulo's (2004) approach, examines the opposite effects of network density on an ego-firm's innovation. Until now, empirical research has produced some interesting findings regarding how firms should be embedded in networks, yet none have been conclusive (Bae and Gargiulo, 2004; Rowley et al., 2000). For instance, research carried out by Phelps (2010) points out the benifts of network closure (i.e. high density) to firms' innovation (Phelps, 2010). This is consistent with the findings of Ahuja's (2000) study, which provided a longitudinal assessment of the effects of a firm's network of relationships on innovation. In his research, Ahuja concluded that the presence of structural holes among firms' partners negatively affects the patenting rate of firms, hence negatively affecting firm's innovation (Ahuja, 2000a). Other researchers, however, have looked into the impact of sparse networks on firms' outcomes. For example, McEvily and Zaheer (1999) have reported a positive relationship between sparse networks and firm's ability to acquire competitive capabilities. Likewise, Gao et al. (2015), in their work regarding the effect of technological diversity in suplier networks on a focal buyer firm's innovation, suggested low density had a positive influence on firms' innovation. Therefore, this thesis will examine the impact of the two types of network embeddedness, dense and sparse networks, on an ego-firm's innovation.

According to the first stream of research, Coleman (1998, 1990), the network closure view, where a firm's contacts are connected between each other, stresses the positive effects of dense networks on the build-up of social norms accompanied by sanctions that facilitate effective coordination among actors (Coleman, 1988; 1998; 1990). Moreover, firms embedded in relatively dense networks can trust each other, lower the risk of opportunistic behaviour, and create a better environment for cooperation (Bae and Gargiulo, 2004). In such dense networks, firms are more likely to transfer valuable knowledge and resources with confidence (Lee, 2007; Phelps, 2010), and information necessary for innovation flows more easily through the network (Walker et al., 1997; Obstfeld, 2005; Hansen, 1999; Ahuja, 2000a). Thus, network closure view lead to the following hypothesis:

Hypothesis 5.1 (H5.1): The increase of an ego-firm's network density is positively related to firm's innovation.

The second stream of research on network density takes Burt's structural holes perspective, where the absence of connections (sparse network) among network partners brings more advantages to the ego-firm. According to Burt (1992, 2000, 2004), actors who are structurally embedded in a disconnected network will span the structural holes of the network and enjoy non-redundant contacts and brokerage opportunities (Burt, 1992; 2000; 2004). Non-redundant contact provides ego-firms with early opportunities to access fresh and diverse information and knowledge. Moreover, actors who broker between loosely connected network partners enhance their access to resources and control over the flow of information (Bae and Gargiulo, 2004; Rowley et al., 2000; Burt, 2000). Having different, less connected contacts provide a non-overlapping source of information, benefitting the focal firm by enabling access to more unique and valuable knowledge and resources (Lee, 2007). This type of disconnected network structure could stimulate knowledge creation (McEvily and Zaheer, 1999), creativity, and innovation (Phelps, 2010; Hargadon and Sutton, 1997; Rowley et al., 2000). Therefore, based on the structural holes perspective, the following hypothesis is proposed:

Hypothesis 5.2 (H5.2): The increase of ego-firm network density is negatively related to firm's innovation.

3.4.2: Betweenness centrality and innovation

Betweenness centrality refers to the frequency with which a firm lies between two other firms in their shortest path within a network (Freeman, 1979; Hanneman and Riddle, 2011). To examine this, this thesis built on Freeman's (1979) argument that an actor that lies between two other actors who are indirectly connected to each other has a favourable position; they can control the flow of information and resources (Freeman, 1979; Brass et al., 2004; Borgatti, 2013). A high ego-firm betweenness centrality indicates a firm's ability to absorb information flows through the network (Owen-Smith and Powell, 2004), it enables firms to extract important opportunities and valuable resources from the network because of their strategic network positions (Zheng, 2010; Gulati et al., 2002).

Firms are looking to expand their knowledge base and access to strategic resources in order to capture innovation opportunities. Occupying central position in a network allows early access to key ingredients, such as new knowledge, skills, and assets (Powell et al., 1996; Rowley et al., 2000), which promotes a competitive advantage (Tsai, 2001) and enhances innovation performance (Ibarra, 1993; Bell, 2005). For instance, Gilsing et al. (2008) showed that there is a strong association between the betweenness centrality of a firm and its innovation performance (Gilsing et al., 2008). Furthermore, central firms enjoy the possibility to improve timely access to important information and new ideas (Burt, 2004; Wasserman and Faust, 1994) increasing benefits from the network relationships and putting it in a stronger position than less central firms (Gilsing et al., 2008; Leenders and Dolfsman, 2016). Similarly, in his recent study, Karamanos (2016) found that an ego-firm which is structurally embedded in a central position will have better innovation performance (Karamanos, 2016). Based on the above argument, the following hypothesis is proposed:

Hypothesis 6 (H6): The ego-firm network betweenness centrality is positively related to firm's innovation.

3.5: Combined effects of network relational and structural embeddedness on innovation (interaction effect on innovation)

The previous sections outlined the key aspects of firms' network embeddedness properties and discussed their main effects on innovation. However, the arguments so far considered only the direct effects of such network embeddedness characteristics on innovation. For instance, Rowley et al. (2000) argue that network relational embeddedness, such as strong ties, has specific implications for a firm's performance and could act as a governance mechanism for ego-firm networks. Strong ties can facilitate inter-firm interaction and effective communication of detailed knowledge (Hansen, 1999; Kilduff and Brass, 2010; Rowley et al., 2000). Nevertheless, structural embeddedness characteristics can also play critical roles in ego-firms' network implications (Rowley et al., 2000), such as dense networks, which have the potential to provide a positive build-up of social norms accompanied by sanctions that facilitate effective coordination among network actors (Coleman, 1988; 1998; 1990). Therefore, looking into different structural embeddedness characteristics of an ego-firm in isolation of its relational embeddedness aspects might lead to an incomplete consideration of its effects on firms' innovation. So far, however, there has been little attention devoted to this combination effect in the innovation literature. Therefore, this study seeks to determine if, when an ego-firm is embedded in a structure of dense network and is characterized as having strong or weak ties of network relations, it has any impact on its innovation. Furthermore, does an ego-firm occupying a central position in the network and enjoying a diverse number of partners have any impact on the ego-firm's innovation? Thus, this study proposes to incorporate both relational and structural network embeddedness, and to investigate its joint effects on ego-firms' innovation.

3.5.1: 2-way interaction between relational embeddedness characteristics and structural embeddedness characteristics in terms of betweenness centrality

Although there is still disagreement among scholars on the optimal inter-firm network embeddedness configuration (Rowley et al., 2000), the literature review clearly indicated the significant role that different network embeddedness aspects can play on the firms' innovation outcomes. For example, Gilsing et al. (2008), in their investigation of different network embeddedness properties in firms' alliance networks and the exploration of novel technologies, confirmed the presence of a positive interaction effect between betweenness centrality and density on firm's exploration of novel technologies. Moreover, the authors urge further investigation into the complementary effects of diverse combinations of network embeddedness structures on novelty creation (Gilsing et al., 2008).

From both relational and structural embeddedness perspective, an ego-firm's specific network characteristics and its relative location in that network are likely to be important (Gulati et al., 2000). According to Gulati et al. (2000), firms should pay much attention to their network relationships, which could configure the ego-firm's network location and allow the occupation of a central position, which in turn benefits the ego-firm by enabling better access to information and opportunities compared to those that are peripheral (Gulati et al., 2000). Moreover, centrality, when combined with strength of linkage among network actors will determine the efficiency and accessibility of information within the network (Soh, 2003). Thus, this study proposes the following hypothesis:

Hypothesis 7 (H7): The 2-way interaction of Relational Embeddedness characteristics and Structural Embeddedness characteristics in terms of Betweenness Centrality has a positive effect on firm's innovation.

3.5.2: 2-way interaction between relational embeddedness characteristics and structural embeddedness characteristics in terms of the increase in network density

Network density, according to (Coleman, 1988; 1998; 1990), brings norms and sanctions to network's actors, which help to protect against opportunism, and thereby tacit knowledge and important information sharing is encouraged amongst the network members. However, an increase of network density was claimed to provide redundant information by multiple actors affecting the quality of the acquired data on firms' innovation and competitive advantage (Burt, 1992; 2000). Likewise, Uzzi (1997) discussed the notion of 'over-embeddedness' and suggested that strategic networks, composed mostly of strong ties might negatively impact innovation (Uzzi, 1997).

On the contrary, sparse networks seem to complement the strong linkage effects between an ego-firm and its partners. Rowley et al. (2000) provided an empirical investigation of the joint effect between network denisty and strong ties on firms' performance in the steel and semiconductor industries. The authors suggested a positive relationship with the interaction between strong ties and sparse networks on firms' performance, and their findings supported this proposition (Rowley et al., 2000). In a different study, Rodan and Galunic (2004) examined the effect of access on diverse knowledge and inhabiting a sparse network structure on managerial innovation performance. Their research is among the few studies in the literature that deals with the combined effect of network relational aspects (i.e. the heterogeneity of ego-network contacts) and network structure, such as sparse networks. The study concluded that, while network structure (sparseness) matters, access to heterogeneous knowledge through network contacts is of equal importance for innovation performance (Rodan and Galunic, 2004).

These findings suggest the need for further investigation of network structure in terms of ego-network density in order to account for its possible effects when combined with network relational characteristics. Thus, this thesis proposes the following hypothesis:

Hypothesis 8 (H8): The 2-way interaction of relational embeddedness characteristics and structural embeddedness characteristics in terms of the increase of network density has a negative effect on firm's innovation.

3.5.3: 2-way interaction effects among relational embeddedness characteristics in terms of strengthen the ties and weak ties

Granovetter (1973) introduced the theory of 'strength of weak ties (SWT)'; at the interpersonal level, it is characterized by the amount of time, intimacy and reciprocal service invested in a connection. An actor in a network has different properties if characterized with weak or strong relationships. For instance, according to SWT, strong ties are unlikely to be a source of novel information because overreliance on strong ties will cause information overlap with what the individual already knows, since close friendship relationships will generate strong ties with people who are part of the same social circle, providing redundant information. Weak ties, on the other hand, tend to be ties with disconnected, previously unrelated actors, thus prompting information gathering outside our social worlds.

At the firm level, strong ties are associated with the exchange of high-quality information and tacit knowledge that could stimulate innovation, providing firms with access to external resources, sharing risks and cost, or pooling complementary skills (Rowley et al., 2000). On the other hand, weak ties can act as channels to access novel, beneficial information. Weak ties are more likely than strong ties to be links between distantly connected actors, providing access to heterogeneous sources of knowledge and information (Rowley et al., 2000; Capaldo, 2007). Moreover, it has been argued that firms who have a mix of weak and strong ties perform better than others (Rowley et al., 2000). Therefore, weak ties as a source of novel information and valuable resources need to be integrated with strong ties in order to facilitate the exchange of valuable information and resources for innovation (Capaldo, 2007). Therefore, the following hypothesis is proposed to examine the 2-way interaction effect between strengthen the ties and weak ties:

Hypothesis 9 (H9): The 2-way interaction of relational embeddedness characteristics in terms of weak ties and strengthen the ties has a positive effect on firm's innovation.

3.5.4: 3-way interaction

The argument for considering the joint effect of network relational embeddedness characteristics and structural embeddedness characteristics can be extended to include 3-way interaction between different constructs. For instance, looking into a single network relational embeddedness property in isolation of other aspects will not provide the full picture of the nature of the effects of firms' network characteristics. Examining the interaction effect among different firms' network settings can shed more light on the optimum network characteristics configuration for better innovation performance. For instance, firms are characterised in their network as having both relational and structural embeddedness aspects (e.g. have strong relationships and dense and central position network structure), which could lead to different innovation outcomes. This thesis argued a positive innovation return for firms' central position in a network. Moreover, it argued contradicting perspectives for network density (i.e. network closure and sparse network). In his work on investigating the interacting effect between network denisty and strong ties on firms' performance in the steel and semiconductor industries, Rowley et al. (2000) suggested that the interaction of structural and relational embeddedness characteristics should be taken into consideration when investigating the networks effect on firm performance. Furthermore, the structural position of a firm could configure its ability to early access a new knowledge when it has a central network location accompanied with strong ties with its networks members (Soh, 2003).

Hence, looking into these aspects alongside relational embeddedness characteristics will enrich our understanding of their impact on firms' innovation. Therefore, the following hypothesis is proposed to examine the effect of the 3-way interaction between network relational embeddedness characteristics and structural embeddedness characteristics:

Hypothesis 10 (H10): The 3-way interaction of relational embeddedness characteristics and structural embeddedness characteristics has a positive effect on firm's innovation.

3.6: Conclusion

In summary, this chapter introduced and discussed the proposed conceptual model for this study, in the conceptual framework model in figure (3.1), the ego-firm network relational embeddedness characteristics and the structural embeddedness characteristics are displayed, along with their relationship with firms' innovation (RS main effect model). Figure (3.1) is also an illustration of the joint effects of both relational and structural embeddedness characteristics on firm's innovation (i.e. product and process innovation). This proposed conceptual model allows for the examination of different views and arguments in relation to firms' network relational and structural embeddedness and their impact on firms' innovation. In addition, it addresses the possible combinations of relational and structural elements of the ego-firm's network. In turn, it provides the foundation of the development of the research hypotheses discussed in this chapter.

Moreover, the proposed conceptual model can be illustrated as shown in Figure (3.2) for relational and structural characteristics (RS model), and in Figure (3.3) for the interaction terms of these characteristics (interaction effects model). The model highlights the main constructs of the ego-firm network's relational and structural characteristics and its expected impact on firms' innovation. In addition, a number of ten hypotheses were formulated and discussed based on the conceptual model framework designed for this research; these hypotheses are outlined in Table (3.1) below.

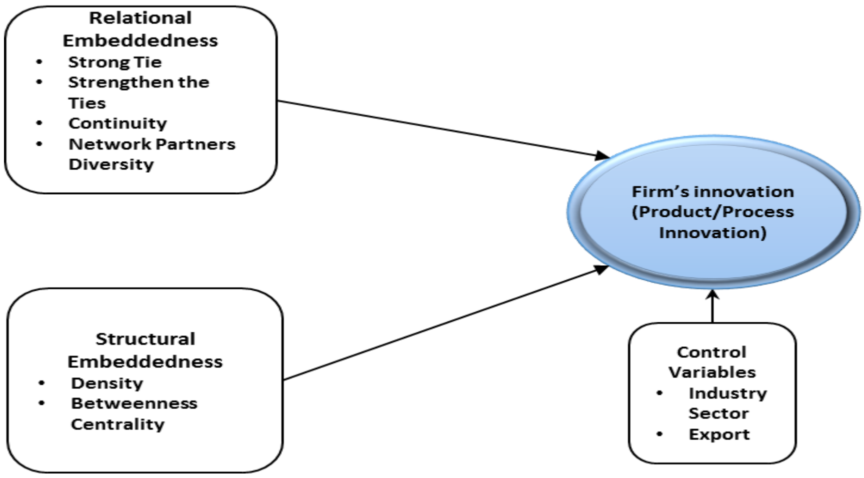

Figure 3.1 Overview of the research conceptual model

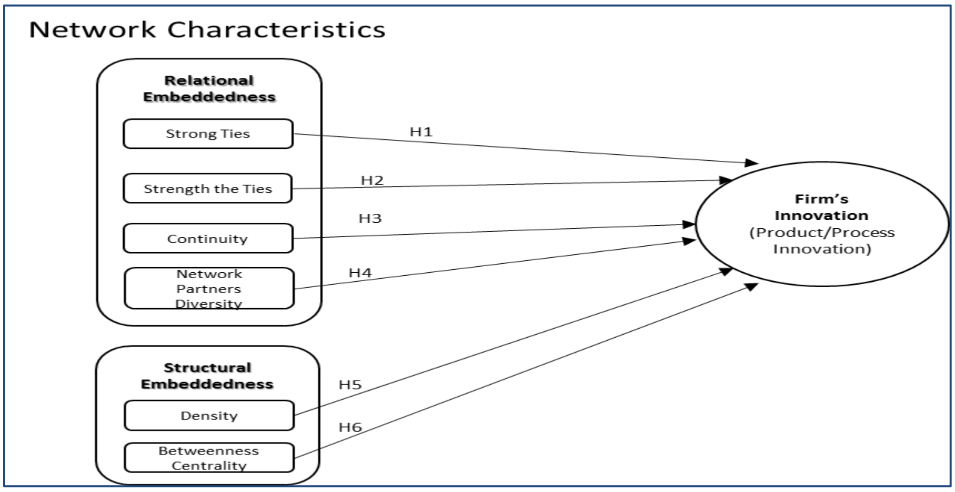

Figure 3.2: Research conceptual model (RS main effect model)

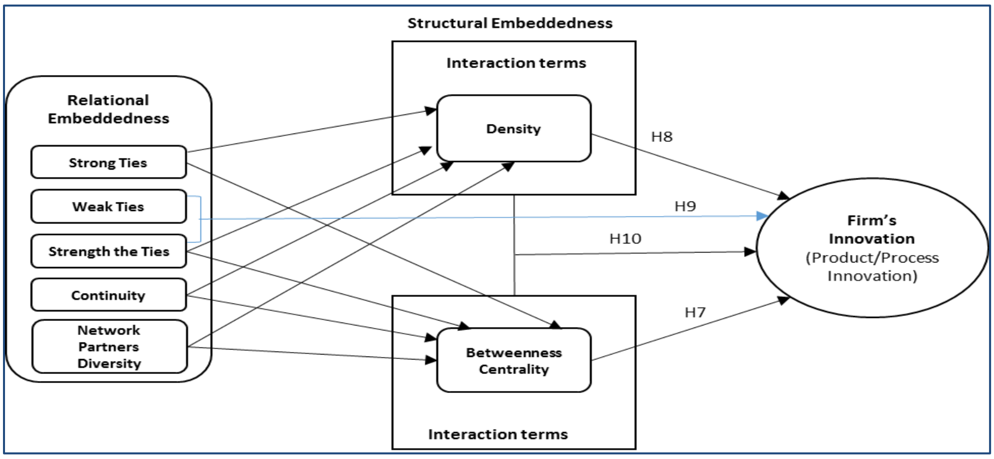

Figure 3.3: Research conceptual model (interaction effects model)

No.	Research Hypothesis	Effect sign
H1	Strong ties in an ego-firm network are negatively related to firm's innovation	-
H2	Strengthen the ties in an ego-firm network is positively related to firm's innovation	+
H3	An ego-firm's repeated collaboration (continuity) is positively related to firm's innovation	+
H4	An ego-firm network partners diversity is positively related to firm's innovation	+
H5.1	The increase of an ego-firm's network density is positively related to firm's innovation	+
H5.2	The increase of an ego-firm's network density is negatively related to firm's innovation	-
H6	The ego-firm network betweenness centrality is positively related to firm's innovation	+
H7	The 2-way interaction of Relational Embeddedness characteristics and Structural Embeddedness characteristics in terms of Betweenness Centrality has a positive effect on firm's innovation	+
H8	The 2-way interaction of relational embeddedness characteristics and structural embeddedness characteristics in terms of the increase of network density has a negative effect on firm's innovation	-
H9	The 2-way interaction of relational embeddedness characteristics in terms of weak ties and strength the ties has a positive effect on firm's innovation	+
H10	The 3-way interaction of relational embeddedness characteristics and structural embeddedness characteristics has a positive effect on firm's innovation	+

Table 3.1: Research hypotheses

Chapter 4

Research Design and Methodology

4.1: Introduction

The aim of this chapter is to describe the research design and methodological approach used in this thesis. It begins by providing an overview of the adopted philosophy and its implications within the adopted research strategy. Additionally, various aspects of the research methodology are discussed in detail, such as analytical methods, research instrument construction and implementation, and methods of data analysis.

4.2: Philosophical perspective

This section discusses the philosophical perspective of this thesis. The research philosophy is in the heart of any research project; it underlines the system of beliefs, assumptions about and rationale around the development of knowledge in a particular field (Saunders et al., 2016). Therefore, business and management researchers need to be aware of the philosophical assumptions they make in their chosen topic. Saunders et al. (2016) highlights the importance of such philosophical commitment:

- The researcher's philosophical position and the way they undertake the research.
- The nature of the research undertaken, which helps the researcher shape all aspects of the study.
- The choice of methodology, research strategy, data collection techniques and analysis procedures, allowing the designing of a coherent research project.

Adopting an adequate philosophical stance is central to any scientific research. Philosophy is "a set or system of beliefs stemming from the study of the fundamental nature of knowledge, reality, and existence" (Waite and Hawker, 2009, p.685). To examine the phenomena of interest, this thesis has adopted the realist ontological perspective and the positivist epistemological perspective. The following section addresses the ontological and epistemological assumptions and alternatives positions and the rationale for choosing these philosophies in this research.

4.2.1: Ontology and epistemology

Ontology is defined as the nature of reality and existence (Easterby-Smith et al., 2012). It is derived from two Greek words: 'ontos' (being) and 'logos' (theory of knowledge) (Johnson and Duberley, 2000). Thus, ontological beliefs are concerned with the nature of reality (Saunders et al., 2016). According to Collis and Hussey (2009, p59), "positivists believe social reality is objective and external to the researcher. Therefore, there is only one reality. Interpretivists believe that social reality is subjective because it is socially constructed. Therefore, each person has his or her own sense of reality and there are multiple realities". Ontological assumptions shape the way in which investigators see and study research objects. Objects in business and management research could take various forms, like organizations, management, individuals, etc. (Saunders et al., 2016).

The other philosophical perspective used in this study is epistemology, which is derived from the Greek words; 'episteme' (knowledge, or science) and 'logos', as defined above (Johnson and Duberley 2000). Epistemology can be understood as being concerned about the nature of knowledge, what constitutes acceptable, valid and legitimate knowledge, and how we can communicate knowledge to others (Saunders et al., 2016; Burrell and Morgan 1979). Collis and Hussey (2009) state that epistemological assumptions:

> "… [are] concerned with what we accept as valid knowledge. This involves an examination of the relationship between the researcher and that which is researched. Positivists believe that the only phenomena that are observable and measurable can be validly regarded as knowledge. They try to maintain an independent and objective stance. On the other hand, Interpretivists attempts to minimise the distance between the researcher and what which is researched. They may be involved in different forms of participant enquiry." (p59)

Ontology is concerned with the theory of what exists. Epistemology is concerned with what human beings can know about what exists (Huff 2009). The following table (table 4.1) summarise the main features of the chosen research philosophy for this study.

<table>
<tr><th>Philosophical assumption</th><th>Positivism</th><th>Interpretivism</th></tr>
<tr><td>Ontological assumption (the nature of reality)</td><td>• Reality is objective and singular
• Separate from the researcher</td><td>• Reality is subjective and multiple
• As seen by the participants</td></tr>
<tr><td>Epistemological assumption (what constitutes knowledge)</td><td>Researcher is independent of that being researched</td><td>Researcher interacts with that being researched</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="9">Main approaches</td><td>Quantitative</td><td>Qualitative</td></tr>
<tr><td>Objective</td><td>Subjective</td></tr>
<tr><td>Scientific</td><td>Humanist</td></tr>
<tr><td>Traditional</td><td>Phenomenological</td></tr>
<tr><td>Artificial location</td><td>Natural location</td></tr>
<tr><td>Use large samples</td><td>Use small samples</td></tr>
<tr><td>Concerned with testing hypotheses</td><td>Concerned with generating theories</td></tr>
<tr><td>Produces precise results with high reliability but low validity</td><td>Produces rich findings with low reliability but high validity</td></tr>
<tr><td>Allow results to be generalised from the sample to the population</td><td>Allow findings to be generalised from one setting to another similar setting</td></tr>
<tr><td rowspan="2">Research methods</td><td>Experiments, surveys, historical analysis</td><td>Exploration of pure subjectivity, hermeneutics</td></tr>
<tr><td colspan="2">Interpretive contextual analysis, symbolic analysis</td></tr>
</table>

Table 4.1: The main features of the chosen research philosophy for this study

References: Easterby-Smith et al., 2012; Creswell, 2003; Morgan and Smircich, 1980

4.2.2: Adopted research philosophy

An objective approach that can test theories and is not dependent on social factors, but is embedded in the broadly positivist philosophy as outlined in the above section. Furthermore, the positivist investigator is likely to perceive the social world as existing externally, and the goal is to measure and test its properties through objective methods, rather than subjectivity and intuitive interpretation (Collis J. and Hussey R., 2009; Easterby-Smith et al., 2012). Positivism incorporates two key philosophical assumptions, as mentioned by Easterby-Smith et al. (2012): “first, an ontological assumption, that reality is external and objective; and second, an epistemological assumption, that knowledge is only of significance if it is based on observations of this external reality” (p23). This has a number of implications for the researcher, which are adapted from (Easterby-Smith et al., 2012), and outlined in table (4.2).

Positivist Assumptions	Implications	In this Thesis
Independence	The observer must be independent from what is being observed	Knowledge gaps, research questions, and hypotheses were developed based on the current literature in order to examine the topic on hand
Value-freedom	The choice of what to study, and how to study it, can be determined by objective criteria, rather than by human beliefs and interests	Relational and structural network characteristics and innovation elements were identified for investigation
Causality	The aim of social science should be to identify casual explanation and fundamental laws that explain regularities in human social behaviour	The impact of network relational and structural characteristics on firms' innovation in M&H technology sectors in Saudi Arabia
Hypothesis and deduction	Science proceeds through a process of hypothesising fundamental laws and then deducing what kinds of observations will demonstrate the truth or falsity of these hypotheses	Hypotheses developed from the scientific literature that enables researchers to empirically investigate and verify or refute these hypotheses
Operationalization	Concepts need to be defined in ways that enable facts to be measured quantitatively	Variables were identified from the up-to-date literature in order to be tested empirically
Reductionism	Problems as a whole are better understood if they are reduced to the simplest possible elements	Firms as the level of analysis
Generalization	In order to move from specific to the general it is necessary to select random samples of sufficient size, from which inferences may be drawn about the wider population	• Survey research method was implemented • Sample was randomly selected from M&H technology sectors in Saudi Arabia
Cross-sectional analysis	Such regularities can most easily be identified by making comparisons of variations across samples	• Research data was collected in the period of Feb, 2015-Feb, 2016 from the M&H technology sectors in Saudi Arabia • The sample size total is 121 firms

Table 4.2: Implications of Positivist Assumptions

Adapted from: Easterby-Smith et al., 2012

The main objective of this thesis is to examine the impact of network relational and structural characteristics on firms' innovation in the M&H technology sectors in Saudi Arabia. As outlined in tables (4.1) and (4.2), positivist ontological and positivist epistemological perspectives both serve this purpose in this research. Because ontological and epistemological positivism offer a quantitative deductive approach to the phenomena on hand, they offer a process of formulating hypotheses developed from the scientific literature that enable researchers to empirically investigate and verify or refute these hypotheses. Table (4.2) summarise the philosophical assumptions adopted in this thesis.

4.3: Deductive, inductive, and abductive approaches

Conducting a research project via a conceptual and theoretical structure developed from the academic literature, which is then is tested by empirical observations, is called the deductive research approach (Saunders et al., 2016; Collis and Hussey, 2009). On the other hand, the inductive research approach seeks to generate or develop a theory. It starts by collecting data and observations to explore a phenomenon. The third type of conducting a research is the abductive approach, where the investigator starts by collecting data and observations to explore a topic, identify themes and explain patterns. This approach allows generating a new or modifying an existing theory which is subsequently tested through additional data collection (Saunders et al., 2016). Table (4.3) outlines the key aspects of the three types of approaches.

	Deduction	Induction	Abduction
Logic	In a deductive inference, when the premises are true, the conclusion must also be true	In an inductive inference, known premises are used to generate untested conclusions	In an abductive inference, known premises are used to generate testable conclusions
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection
Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory, where appropriate, to build new theory or modify existing theory

Table 4.3: Deduction, induction and abduction: from reason to research

Adapted from: Saunders et al., 2016

This study employs the deductive methodology approach in line with the adopted research philosophy. It is conceptually and theoretically developed from the academic literature. From this, the conceptual research model was structured;

variables were identified, primary data was collected, which was then subjected to empirical testing and analysis.

4.4: Quantitative research design

This study seeks to investigate the network characteristics that influence firms' innovation in the M&H technology sector in Saudi Arabia. Therefore, the main network variables, as well as firms' innovation attributes, have been identified from the literature in order to empirically examine relationships between and effects of variables. For that reason, quantitative methodology is chosen for this research since it is in line with the aims of this research. In order to examine relationships between variables, quantitative research uses numerical data and various techniques to analyse these data (Saunders et al., 2016). Table (4.4) outlines the main quantitative methodology characteristics.

Characteristics	Quantitative research design
Research philosophy	Generally associated with ontological and epistemological positivism approach (assumes that the social world is real)
Theory development	Deductive approach (uses data to test hypothesis and theory)
Typical goal	To examine relationships between variables, which are measured numerically by the means of statistical and graphical analyses
Data collection	Uses structured and validated data collection instruments
Role of the researcher	• Objective (researcher is not part of the research) • Researcher is independent from participants
Research strategy	Generally associated with experimental and survey research strategy (normally uses questionnaire or structured interviews)
Outcome	Usually in a form of descriptive and inferential statistics, used to draw conclusions about a population relating to a random sample
Advantages	• Use of predetermined variables to look for • Possible to generalise findings
Disadvantages	• Generally uses fixed types of data collection instruments, such as questionnaires • Usually time consuming in terms of data collection and analysis

Table 4.4: Main quantitative methodology characteristics

References: (Saunders et al., 2016; Bob Matthews, Liz Ross, 2010)

4.5: Choosing a research strategy

Further to adopting a quantitative research design for this research, an appropriate research strategy should be selected in order to collect primary data. In this section, the empirical plan for this study will be discussed.

Following the review of the literature conducted on innovation management, innovation measurements, social networks, social network analysis (SNA), and inter-organizational studies, a survey method has been adopted for collecting primary research data. This survey method allows the investigator to collect quantitative data, which can be analysed using descriptive and inferential statistics (Saunders et al., 2016). It is designed to collect primary or secondary data from a random sample of a research population (Easterby-Smith et al., 2012). The research population refers to the full set of cases (individuals, organizations, objects) under consideration during a study, whereas the research sample is a randomly selected subset cases of that population, from which evidence is gathered. In addition, data collected using surveys can be used to suggest possible explanations for particular relationships between variables and to produce models of these relationships (Saunders et al., 2016; Easterby-Smith et al., 2012).

Conducting a survey is often a complex process that requires careful consideration. Therefore, it is important to adhere to the critical survey steps and apply them in a systematic and unbiased manner (Bethlehem, 2009). According to Sapsford (2007), the overall design of the survey process involves four main elements in initial planning and definition: problem definition, sample selection, design of measurements, and concern for respondents. These elements are illustrated in figure (4.1), where they are shown as multiple interlinked factors because any of them can be the starting point of the survey process, and any decision made during any of them may have consequences for all the others (Sapsford, 2007). The four survey elements entail:

- Problem definition: this stage involves deciding what kinds of answers are sought. What hypothesis is to be tested? What variables would be interesting to explore? What scope of research project is possible with the given resources?
- Sample selection: this stage is concerned with deciding who or what is to be counted. What is the target population? What is the sample size? What can be done to obtain a representative sample, given resource limitations?
- Deciding what is to be measured and how the main measurements stage ought to be designed. This involves answering questions like: what variables will be needed for descriptive purposes and for testing hypotheses? What is the best way to measure these variables?
- Last stage is concerned with respondents. In this stage the investigator should account for preventing any harm or discomfort to the respondents. This is achieved by assuring confidentiality and anonymity of all information gathered.

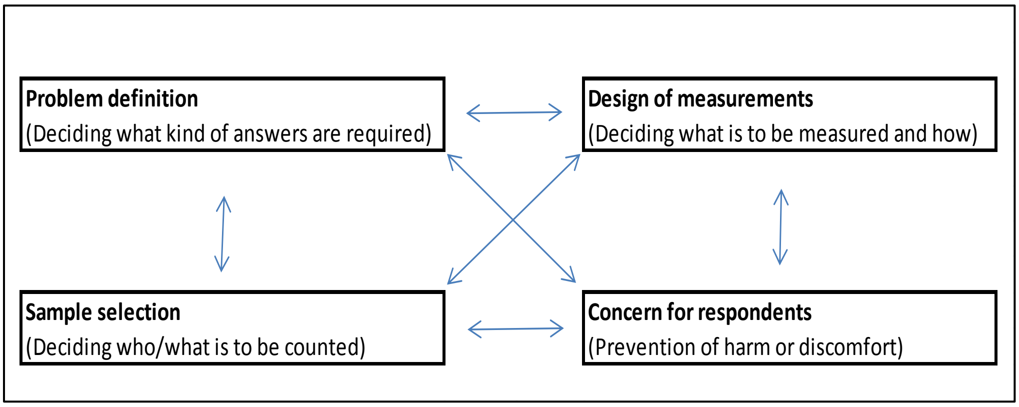

Figure 4.1: overall design of a survey

Adapted from: (Sapsford, 2007)

4.6: Collecting data through surveys

Collecting primary data relevant to the study is critical in terms of consistency with the research questions and research objectives (Ghauri and Gronhaug, 2005). Surveys can be a good method of collecting data about the population, as long as they are done well (Easterby-Smith et al., 2012). The survey is an effective tool to collect information and data about attitudes, descriptions, and cause and effect relationships. This method of data collection includes questionnaires or interviews (Ghauri and Gronhaug, 2005).

For this thesis, a questionnaire is utilized to collect primary data, a method well established in the literature. Both innovation studies and social networking data can be gathered by means of a questionnaire, as will be explored in the next section.

4.7: Research instrument (questionnaire) construction

Surveys and questionnaires are among the most used data collection instruments in the business and management fields. Data are collected through self-completed questionnaires, where respondents record their own answers. This could be achieved through a variety of distribution methods, such as postal questionnaires, web-based surveys, by telephone, and individual distribution (Collis and Hussey, 2009). Choosing a research instrument is highly dependent on the type of research, research questions, research objectives, and the type of data sought. For instance, questionnaires are usually not particularly useful for research that requires a large number of open ended questions, or exploratory research. They work best with descriptive research, where they enable the identification and description of the variability in different phenomena. In addition, they are best used in explanatory or analytical types of research where examining and explaining the relationships between variables can be achieved (Saunders et al., 2016; Ghauri and Gronhaug, 2005). Therefore, the investigator has to put careful consideration into what data is required and how it is to be collected. This research questionnaire was developed by following the four main steps in constructing questionnaires outlined by Ghauri and Gronhaug (2005). It starts by emphasising the importance of determining and specifying the type of data and information sought for the study, through to the pre-testing of the complete questionnaire. In this thesis, the questionnaire items and measurements were developed based on existing questions from the innovation and social network analysis literature. Table (4.5) outlines the main guidelines for constructing questionnaires, adapted from (Ghauri and Gronhaug, 2005).

Guidelines for constructing questionnaires	
1	Specify what type of data is required
2	Consider construction and wording of individual questions
3	Determine the logical order of questions
4	Consider the method of administration
5	Consider the form of responses
6	Pre-test questionnaire

Table 4.5: Guidelines for constructing questionnaires

Adapted from: Ghauri and Gronhaug, 2005

4.7.1: Questionnaire distribution methods

One of the main steps in constructing effective questionnaires is determining methods of administration and distribution. For this research, a self-completed questionnaire was selected as the main instrument for data collection. Two methods were chosen to distribute the questionnaire, individual distribution (delivery and collection) and web-based questionnaire. The first method was chosen in order to encourage participation from the target sample and was achieved over ninety days of visiting potential participants in the M&H technology sectors in Saudi Arabia. However, this method involves some drawbacks, such as high resource costs to cover a larger sample. In an attempt to overcome these drawbacks, the web-based questionnaire was used as a second method for distribution. Online questionnaires have some advantages, such as reduced cost, fast delivery, and easy customization for individual respondents (Wilson, 2012). A well-known online survey tool 'Qualtrics' was utilised for this purpose. Qualtrics is a web-based survey tool used in academia to help conduct research; it enables the researcher to follow-up with respondents and manage contact frequency.

4.7.2: Questionnaire content design

The purpose of the questionnaire design is to ensure the necessary primary data and information is gathered in order to examine and explore the impact of network characteristics on firms' innovation outputs. This objective can be achieved by careful consideration of the variables within network characteristics, as well as firms' innovation. Based on the literature review, the following sections discuss the main research variables that establish the context of the conceptual framework for this research. The questionnaire is divided into two main parts in addition to the general information section, innovation and social networking. The innovation section consists of questions about product innovation, process innovation, and attributes relevant to the targeted sample, such as sector, age, export process and size. In the social network section, the key aspects of the relationships and structure of a firm's network are identified and discussed.

4.8: Innovation section of the questionnaire

Innovation studies have grown rapidly over the past thirty years. Since the early nineties, one of the most used instruments of data gathering in innovation literature is the Eurostat Community Innovation Survey (CIS) (Laursen and Salter, 2006; Tether and Tajar, 2008a; Mol and Birkinshaw, 2009; Reichstein and Salter, 2006). CIS originated from the OSLO Manual issued in 1992 and organised by the European Union (EU) in order to develop and collect data on innovation activities in OECD countries (OECD, 2005). The OSLO Manual provides a methodology for collecting and interpreting innovation data and is in its third edition, which was launched in 2005; it has undergone considerable revision since the first edition in 1992. This latest edition has been updated to take into account the accumulated experience from recent rounds of innovation surveys in terms of concepts and methodological approaches. One of the main additions in the latest version is the inclusion of an annex on the implementation of innovation surveys conducted outside the OECD countries (OECD, 2005).

The reliability and validity of CIS innovation surveys have been established by extensive piloting and pre-testing before implementation within different OECD countries and across firms from a variety of industrial sectors, including services, construction and manufacturing. They are usually characterised as “subject-oriented” surveys because they ask individual firms directly whether they were able to produce an innovation (Laursen and Salter, 2006; Reichstein and Salter, 2006). Overall, CIS survey data provide direct measures of participation in innovation activities and commercialisation for a broad range of industries that more traditional measures, such as patent or R&D expenditures, do not capture (Laursen and Salter, 2006; Tether and Tajar, 2008a; Faems et al., 2005; Reichstein and Salter, 2006).

In this study, the survey sought to examine the innovation activities of firms in relation to product and process innovations. Therefore, the innovation part of the questionnaire was constructed based on the guidelines of the OECD’s OSLO manual (OECD, 2005). The survey covered manufacturing as well as service, with similar questionnaires sent to both sectors. In addition, it was concerned with the collection of innovation data at the level of the firm over a period of two years. In order to distinguish between innovative and non-innovative firms, respondents were asked if they introduced any product innovation or process innovation between 2013 and 2014.

The first part of the questionnaire asks firms general questions to capture their specific characteristics, such as sector, age, group status of companies, number of employees, and market. Thereafter, the innovation part is divided into product and process innovation, with definition provided to both types of innovation.

4.9: Control variables

Some firms’ specific characteristics have been acknowledged in the literature to relate to their innovation (Tether, 2002). In this study, for instance, several variables, such as sector of activity, firm size, the age of the firm, ability to export, and whether the firm is independent or part of a group, have been introduced in order to control possible effects of variables. Similar questions to the general information section on the CIS survey of OECD’s OSLO manual have been adopted to ask respondents about these characteristics.

4.9.1: Industry Sector

One of the criticisms of the earlier versions of OECD’s OSLO Manual was its focus on manufacturing- oriented sectors. This was accounted for in refinements to the third edition. These additions have expanded the coverage of the survey to include service sectors (OCED, 2005). A number of studies have found that the tendency to engage in innovation varies with sector (Tether, 2002; Vega-Jurado et al., 2008; Tether and Tajar, 2008a). Therefore, in order to understand differences between sectoral contexts, respondents were asked to specify their main sector activity.

4.9.2: Firm Size

The firm size variable was measured based on the number of full employees following the recommendation of OECD's OSLO Manual (OCED, 2005). Firm size is classified into three levels: 10-49 (small firms), 50-249 (medium firms), and 250 and above (large firms). To date, there has been little agreement in the literature over the effect of a firm's size on their innovativeness in terms of capabilities, performance, and inter-organisational collaboration. On one hand, researchers have argued that larger firms tend to outperform smaller firms due to having the capability to exploit external knowledge sources, to manage the interaction with other organizations and to acquire complementary assets (Laursen and Salter, 2004: Tether and Tajar, 2008a; Faems et al., 2005; Mol and Birkinshaw, 2009). On the other hand, other researchers have reported that smaller firms might outperform larger firms in terms of creativity, speed, and flexibility (Faems et al., 2005; Tether, 2002; Hall et al., 2009; Mairesse and Mohnen, 2002). Therefore, this study controls for firm size to examine the possible effect in relation to network characteristics and their impact on firms' innovativeness.

4.9.3: Age of the firm

Respondents were asked when their firm was established. This is to control for the possible effect of age when investigating the impact of network characteristics on firms' innovation.

4.9.4: Export

The market export variable is controlled for and measured by a single-item question in the questionnaire, designed to capture the most important market for a firm. Earlier studies have suggested that market scope is an important determinant in fostering innovation. Firms that supply to wider markets generally have to be innovative to overcome the expected intensive competition (Leiponen and Helfat, 2010; Radas and Bozic, 2009; Mol and Birkinshaw, 2009; Tether and Tajar, 2008a).

4.9.5: Group firms

Being part of a group of firms increases the likelihood of co-operation with other parties for innovation than in independent firms (Tether, 2002). Additionally, it might enhance sharing information, knowledge, and resources, both among the group and in other organizations (Tether and Tajar, 2008a; Mairesse and Mohnen, 2002). Hence, controlling for the effect of grouped firms (identified by dummy variable Firm_Group) is desirable when investigating the impact of network characteristics on innovation.

4.10: Innovation measures (dependent variables)

In this research, innovation output measures were left to the respondents and were determined based on the CIS survey of OECD's guidelines and the definitions of the OSLO Manual. They were constructed as binary (0, 1) variables. The OSLO manual defines product innovation as: the market introduction of a new or a significantly improved good or service with respect to its capabilities. However, the definition excludes any minor changes or simple product customization, since they are not considered as product innovation. Additionally, product innovations must be at new to the firm, but they don't need to be new to market (OECD, 2005). For process innovation, the OECD Manual define it as: the implementation of a new or significantly improved production process, distribution method, or supporting activity. These measures have been applied in many studies in innovation literature. They differ according to the purpose of the study and the structures of variables (Laursen and Salter, 2004; Loof and Heshmati, 2002; Mol and Birkinshaw, 2009).

4.11: Networking section of the questionnaire: network measures (independent variables)

The questionnaire is the most common data collection method used in examining network data and conducting social network analysis (Marsden, 2011; Wasserman and Faust, 1994). Following the survey requirements outlined by Marsden (2011), the common approach in conducting such surveys has to follow certain steps, such as defining the network type (whole or egocentric network), specifying target population or research boundaries, and level of analysis. For this research, these steps are summarized in table (4.6).

Concept	Innovation Section	Network Section
Methodology approach	Follow the methodology of conducting innovation surveys based on the "Oslo Manual" guidelines for collecting and interpreting technological innovation data (OECD, 2005). **References:** (Faems et al., 2005), (Tether and Tajar, 2008a, Laursen and Salter, 2006), (Radas and Bozic, 2009)	Social Network Analysis (SNA) methodology is going to be followed **References:** (Weterings and Boschma, 2009), (Mol and Birkinshaw, 2009)
Research boundary and sampling population	First important initial step: defining Research boundary and sampling population **Research population**: Saudi Arabia Firms, in the Medium & High Technology Sectors **References:** (Wasserman and Faust, 1994; Marsden, 2011; OECD, 2005)	
Level of analysis	Subject approach (Firm level of analysis)	Egocentric network analysis (Actor is the unit of analysis- in this research Firm level of analysis)
Data collection Instrument	This research is adapting OECD manual approach and is using similar questions that of community Innovation Survey (CIS). The selection of questions is only going to be the questions related to **Product and Process innovation** part of CIS.	Surveys and Questionnaires are the most common method used to gather network data **References:** (Marsden, 1990), (Burt, 1984), (Wasserman and Faust, 1994; Scott, 2013)

Table 4.6: research methodology outline

In line with the main objective of this survey, to collect data about individual participants in the network (organizations), an ego network type was selected. Egocentric networks can be defined as those which "consist of a focal actor, termed ego, as set of alters who have ties to ego, and measurements on the ties among these alter" (Wasserman and Faust, 1994, p. 42). Egos can be a persons, groups, organizations, or whole societies (Marsden, 2011). According to Borgatti et al. (2013), collection of ego network data should have three questionnaire steps: name generator, name interpreter, and name interrelater. First, researchers can ask the respondent to name their alters (partners), which is called 'name generator'. The second step, consists of follow-up questions asking about each name that has been mentioned in the name generator part of the survey; this is called 'name interpreter'. The third step is the 'name interrelater' step, where the respondent is asked about the ties between the alters (partners). These three steps are shown in table (4.7).

Name generator	Name interpreter	Name interrelater
Provide data about a respondent's ego centric network	Follow the name generator questions	Provide data about the ties between the alters (partners) of respondent
Depend on respondent's recall	Asks about attributes of particular relationships	
Could require high answering time if alters or name interpreter are numerous		
Allow for measuring many of network properties		
Must specify a particular type of relationship	Ask about form and content of information	
usually, asks respondents to identify alters by first name or initials only		

Table 4.7: Name generator, name interpreter, and name interrelater in social network

Reference: (Marsden, 2011; Borgatti et al., 2013)

It is essential to identify the most important network variables in order to answer the research question. There are two dimensions of networks identified in the literature which could influence firms' innovation, relational and structural characteristics. For instance, relational network embeddedness properties address the relationships among participants in the network. Such relations consist of several levels of ties among participants (i.e. strong ties and weak ties) and the strength and composition of these ties can define the character of organisations involved. Additionally, network relationship characteristics concerned with the various aspects of participants' attributes in the network, such as their traits and features (i.e., size, industry, profit, etc.), and types of partner (partner diversity). The second set of properties of network embeddedness, structural network properties, such as network density and centrality, are concerned with the pattern of ties and interactions that exist among a set of participants (Powell et al., 1996; Wasserman and Faust, 1994). Types of network embeddedness characteristics measurements are summarized in table (4.8). The following section provides a detailed discussion of the social network measures implemented in this research (independent variables).

4.11.1: Network Density

As discussed in chapter 2 there are two types of network density; 1) local density, and 2) global density. The theories underlying the hypotheses in this study are concerned with ego-network (i.e. focal firm) perspectives. Therefore, this thesis employs the local density approach since it examines the focal-firm interconnectedness of relationships with its direct partners. Ego-network density can be measure from the constructed undirected adjacency matrix of firms, using

UCINET 6.586. The ego-network density is measured from the ratio of existing ties or links in the ego-network to the number of all possible ties between the focal-firm and its partners. It may range from 0 to 1, with larger values indicating an increase in density (Casciaro, 1998; Schilling and Phelps, 2007; Phelps, 2010). Figure (4.2) shows the type of ego-network, alters, and ties in the network. The formula for density is

2L/ [n (n-1)],

Where,

n: is the number of alters (partners), and L: the number of ties between alters (partners) (Borgatti et al., 2013; Scott, 2013; Hanneman and Riddle, 2011).

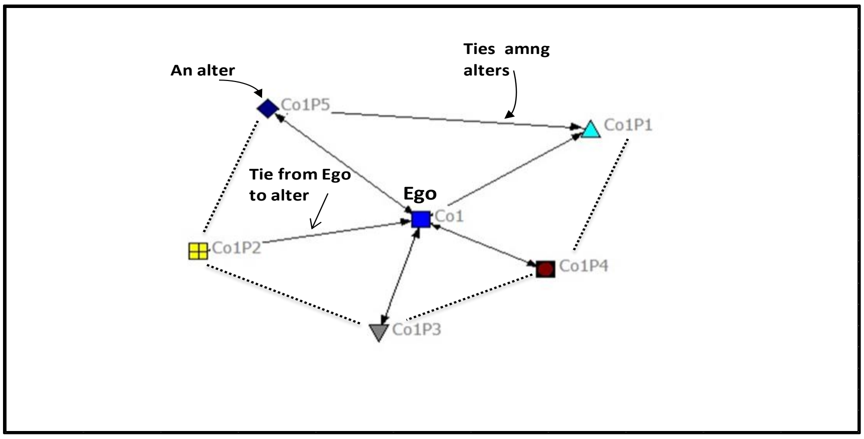

Figure 4.2: Types of ego-network, alters, and ties in the network

4.11.2: Degree centrality

Degree centrality for our sample was measured using UCINET 6.586 software. It is measured as the number of direct ties or links that involve a given node (firm), by N-1, where N is the number of nodes (partners) in the ego-network (Bellamy et al., 2014; Marsden, 2002; Borgatti et al., 2013; Scott, 2013; Wasserman and Faust, 1994). An example of degree centrality from one of the research sample ego-networks is illustrated below and shown in figure (4.3):

Number of nodes in the ego-network (N) = 6, therefore degree centrality = 6 – 1 = 5

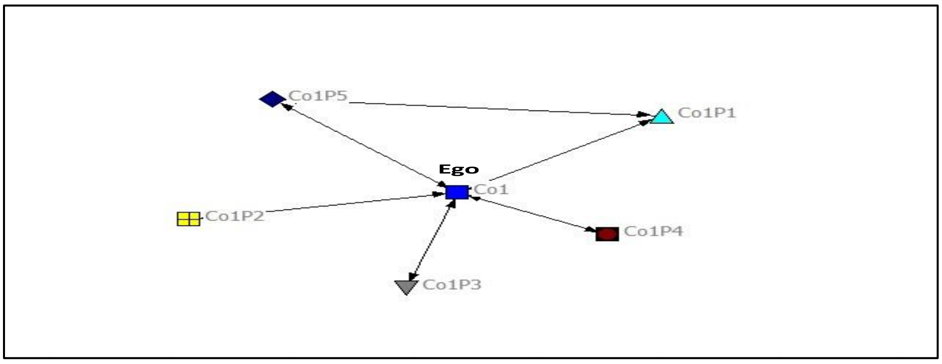

Figure 4.3: Ego network example

4.11.3: Betweenness centrality

To measure the position in a network, betweenness centrality of a focal firm-ego-network reflects the extent to which a given participant (firm) falls along the shortest path (i.e. geodesic) between two other participants in the ego-network (Casciaro, 1998; Schilling and Phelps, 2007; Phelps, 2010). To compute ego-network betweenness centrality, this study followed the method used by Borgatti and Everett (2005). First, betweenness centrality is calculated for individual firms in the network from the constructed adjacency matrix. We need only to consider a geodesic of length 2, which passes through ego without accounting for geodesics of length 1, since they don't contribute towards betweenness centrality. Following this, the results were double checked with the measurements of betweenness centrality provided by UCINET 6.586 software. The following example for one of the research samples illustrates the method of manual computation of betweenness centrality.

If A is the adjacency matrix for firm 1, then A^2 contains the number of paths of the length 2. We need to count the number of paths of length 2 for non-adjacent pairs of participants since these will be geodesics. It follows the formula

$$A^2 [1 - A]_{i,j},$$

Where,

1 is a matrix of all 1's, gives the number of geodesics of length 2 (Everett and Borgatti, 2005). Figure (4.4) shows the betweenness centrality calculation adjacency matrix used in this example.

	Co1	Co1P1	Co1P2	Co1P3	Co1P4	Co1P5
Co1	0	1	1	1	1	1
Co1P1	1	0	0	0	0	1
Co1P2	1	0	0	0	0	0
Co1P3	1	0	0	0	0	0
Co1P4	1	0	0	0	0	0
Co1P5	1	1	0	0	0	0

$$A = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$A^2 (A-1) = \begin{bmatrix} * & * & * & * & * & * \\ * & * & 1 & 1 & 1 & * \\ * & * & * & 1 & 1 & 1 \\ * & * & * & * & 1 & 1 \\ * & * & * & * & * & 1 \\ * & * & * & * & * & * \end{bmatrix}$$

Co1: Betweenness centrality = 9

Figure 4.4: Betweenness centrality calculation adjacency matrix example

The betweenness centrality of firm 1 (the ego) is the sum of the reciprocals of the entries, in the given example the betweenness centrality is equal to 9.

4.11.4: Strength of Ties

As discussed in the literature review in chapter 2, (Granovetter, 1973) defined tie strength based on four main aspects, the amount of time, emotional intensity, the intimacy, and the reciprocal services which characterize the relationships. In this study, the Rowley et al. (2000) method of measuring tie strength was followed. Tie strength was operationalized by adapting working relationships among firms in terms of frequency of interaction between partners and their level of resource commitment to the relationship. In their study, they relied on the ranking criteria rating of the strategic linkage adapted from Contractor and Lornnge (1988) (Rowley et al., 2000).

According to this approach, respondents were asked to indicate the type of relationship they had with each partner. For example, equity alliances, joint ventures, and cooperative (R&D) ventures are categorized as strong ties, and weak ties are operationalized as marketing agreements, and licensing and patent agreements. Then they were asked a follow up question about the frequency of interaction with this partner. Daily, weekly and several times a month contact are considered strong ties, while once a month and yearly contacts are considered weak ties. Therefore, the two questions construct the strength of ties variable of this research (strong and weak ties). Moreover, in order to obtain the optimum composition of firms' ties of relationships, the Granovetter (1973, 1983) Strength of Weak Ties (SWT) hypothesis was followed. SWT hypothesis operationalized that the combination of two substantively strong ties should be a strong tie (**S** o **S** = **S**), whereas any other combination of two ties will be weak tie (**S** o **W** = **W** o **S** = **W** o **W** = **W**) (Granovetter, 1973, 1983; Wasserman and Faust, 1994).

Strengthen the ties variable was constructed in order to measure the strength of ties among the ego-firm and its partners during the research interval (2012-2014). This was achieved by asking the respondents if there is an increase, no change, or decrease in the frequency of interaction with each partner in 2012-2013. This enables the capture of the level of effect of strength of each type of tie on the ego-firm's innovation during the interval under investigation.

4.11.5: Repeated collaboration (continuity)

Repeated collaboration (continuity) refers to the firm's decision to form a means of collaboration with other organizations and to continue these collaboration efforts over time with the same or different organizations (Soh, 2003). To calculate the repeated collaboration (continuity) of a firm, respondents were asked for how long they have been in relationship with each partner (Baer, 2010; Burt, 1984). Furthermore, to allow for the delay between establishing a relationship between the ego-firm and its new partners and obtaining outcomes, a one year lagged variable was used. The year 2013 is used in this research to analyze the impact of repeated collaboration (continuity) on the ego-firm's innovation. A similar approach has been used in the study by Nieto and Santamaria (2007).

4.11.6: Network diversity of actors (partners)

Network diversity of actors (partners) refers to the ego-firm's network member's composition, comprising diverse sources of knowledge, information, and resources that allow firms to create new combinations of capabilities and knowledge (Gilsing and Duysters, 2008). To calculate the ego-firm's network diversity, respondents were asked to define the type of each partner. The types of partners were similar to the sources of external resources and knowledge used in the community innovation survey, according to the OSLO Manual (OECD, 2005). A similar approach is used by other studies, for example (Laursen and Salter, 2006; Nieto and Santamaria, 2007; Faems et al., 2005; Tether, 2002), where a binary variable (0, 1) is used to classify network diversity, in which an ego-firm with two partners and more is considered having a diverse network, and zero otherwise.

Variables Network structural properties	Definition	Significance	How is it measured	References
Density	· The degree to which a firm's contacts are connected between each other · is a measure of connectedness between members in a network , defined as the degree to which a firm's contacts are connected between each other	One of the main measures of network structure. Local density examines the interconnectedness of relationships among a focal firm's direct partners	Calculated as the number of ties between a respondent's contacts (contact-to-contact ties) divided by the maximum number of possible ties between those contacts	(Lee, 2007), (Rowley et al., 2000), (Burt, 2000), (Rodan and Galunic, 2004),
Centrality	firm's position in a network, a central actor is one that is at the centre of a number of connections that has a great many direct contact with other actors in the network	· Centrality makes organizations an obligatory passage point for the information flowing through a network structure · Provide benefit of access to the flow of information and resources	two types of measures: · Degree centrality · Betweenness centrality	(Scott, 2013), (Owen-Smith and Powell, 2004), (Ibarra, 1993),
Degree centrality	is the degree to which a firm is involved with other actors in the network	· Centrality makes organizations an obligatory passage point for the information flowing through a network structure · Provide benefit of access to the flow of information and resources	· Measured by the number of immediate partners that an actor has in their network. · firm's centrality is the number of other firms connected to that firm, ignoring how well those partners are connected (Powell et al., 1996)	(Owen-Smith and Powell, 2004), (Ibarra, 1993),
Betweenness centrality	· is concerned with the position of a firm which lies between other firms in the network	· Betweenness centrality measures the centrality of a focal firm in a network. It indicates a firm's ability to absorb (or interrupt) information flows through tightly sealed network pipes	· Measure of "betweenness centrality," which captures the extent to which a firm is located on the shortest path (i.e., geodesic) between any two actors in its network · betweenness measure based on egocentric network data could be a reliable substitute for complete (socio-centric) network data	(Owen-Smith and Powell, 2004), (Gilsing et al., 2008), (Schilling and Phelps, 2007), (Marsden, 1990)

Network relational properties				
Ties strength		depends on the type of ties, for instance:	· Defines tie strength based on a 'combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie.'	
(strong/weak ties)	Is a social lines that link actors to one another and/or establish a linkage between a pair of actors	· Strong ties provide organizations with two primary advantages. First, strong ties are associated with the exchange of high-quality information and tacit knowledge. Gain access to external resources, share risks and cost, or pool complementary skills.	· Measures tie strength by the frequency of interaction between partners and their level of resource commitment to the relationship. For example, equity alliances, joint ventures, and cooperative (R&D) ventures are categorized as strong ties, and weak ties are operationalized as marketing agreements, and licensing and patent agreements.	Wasserman and Faust, 1994), (Rowley et al., 2000)
		· Weak ties: are conduits across which an actor can access novel information. Weak ties are more likely than strong ties to be 'local bridges' to distant others possessing unique information		
Strengthen the ties	Is the average frequency of interaction during a specified period (1 year lag time)	Measures the effect of ego's interaction/contact with its partners on a one year lag basis to capture the subsequent effect of ties type	· Measures the type of interaction/contact with partners and the level of resources commitment	(Baer, 2010, Smith et al., 2005)
Repeated Collaboration (Continuity)	· Repeated Collaboration (Continuity) is the decision to follow a path of collaboration over time—with the same or different · Number of partners with who firm forms repeated alliances in the industry network.	· Continuity of technological collaboration to encourage product innovation, particularly its degree of novelty. · Firm improves its new product performance as it increases the number of repeated partners and its centrality position relative to others in the technology collaboration network.	· Measured by counting the number of different partners with repeated alliances based on cumulated number of alliances. · Record the number of years a firm had participated in collaborative networks. The variable can take integral values between 0 and 4, depending on the number of years the firm had been involved in collaborative networks.	(Nieto and Santamaria, 2007), (Soh, 2003),
Network partners Diversity	having relationships with various types of partners/ sources	· Increasing network diversity increases the relative novelty of the knowledge a firm can access. · multiple different sources to access various skills and mobilize heterogeneous competencies, and learn new knowledge, leading to the enhance of firm absorptive capacity thereby increasing the organization's capability to innovate · Collaboration with different partners should enhance innovation due to the amount and variety of knowledge to be shared.	· Four dichotomous variables to measure the effects of different types of partners: (1) collaboration with ROs exclusively (2) collaboration with clients exclusively; (3) collaboration with suppliers exclusively; and (4) collaboration with competitors exclusively. · Firms asked to specify whether they participated in R&D or other innovation-related projects with other organizations; such as competitors, customers, consultants, suppliers, etc.	(Phelps, 2010), (Capaldo, 2007), (Nieto and Santamaria, 2007), (Faems et al., 2005)

Table 4.8: network embeddedness characteristics definitions, significance, and measurements

The type of questions and item measurements used to collect data on network characteristics were developed based on the SNA approach. These questions are outlined in table (4.9) below.

	Measurements of network density and centrality	
	Looking back over the years 2012 & 2013, who were your company in business/inter-organizational relationship with (for example, Joint ventures, R&D Agreements, Licensing Agreements, Distribution/marketing Agreements, etc.), **Please list your partner's name; or if you prefer just provide their initials.**	(Burt, 1984), (Marsden , 2011), (Marsden, 1990),(Wasserman and Faust, 1994), (Baer, 2010)
	Please think about your partners you have just mentioned in Q5 and Q6, and specify to the best of your knowledge if any of these partners have had business/inter-organizational relationship/knowledge or information transfer with each other in 2012 &/or 2013. (for example: if you think (**partner 1**) and (**Partner 4**) have had business/inter-organizational relationship/knowledge or information transfer in 2012 &/or 2013, then mark cell **1D**)	(Casciaro et al., 1999; Borgatti et al., 2013).

Cell		A	B	C	D	E
	Partner name	Partner 1	Partner 2	Partner 3	Partner 4	Partner 5
1	Partner 1				x	
2	Partner 2					
3	Partner 3					
4	Partner 4					
5	Partner 5					

	Measurements of Ties strength	
	What type of business /inter-organizational relationship did you have with this partner in 2012 & 2013? (Please, *Tick all that apply*)	(Burt, 1984), (Marsden, 1990) (Levin and Cross, 2004), (Rowley et al., 2000)
	➢ Equity alliances	
	➢ Joint ventures	
	➢ R&D Agreements	
	➢ Second Source Agreements (For example: SSA for components, subassemblies and fully assembled products	
	➢ Component Sourcing Agreements	
	➢ Know-how and Patent Licensing Agreements	
	➢ Distribution/marketing Agreements	
	➢ Informal relationship/interaction (i.e. Formation of social relationships and networks at conferences, trade fairs, exhibitions, Professional and industry associations, etc.)	
	➢ Other (please specify)	
	On average, how frequently did you communicate/ interact/contact with each partner in 2012 & 2013? *(please, choose only one answer for each partner)*	(Baer, 2010), (Burt, 1984),
	➢ Daily	
	➢ Several times a week	
	➢ Several times a month	
	➢ Once a month	
	➢ Several times a year	
	➢ Once a year or less	

	Measurements of Strengthen the ties	
	During years 2012 & 2013, did your Co. frequency of interaction/contact with this partner: *(please, choose only one answer for each partner)*	(Baer, 2010, Smith et al., 2005)
	➢ Increased	
	➢ Remained the same	
	➢ Decreased	
	Measurements of Continuous collaboration (continuity)	
	Up to the end of 2013, for how long have your Co. been in business/inter-organizational relationship with this partner? *(please, choose only one answer for each partner)*	(Burt, 1984), (Baer, 2010)
	➢ Less than 1 year	
	➢ 1 to 3 years	
	➢ 4 to 6 years	
	➢ 7 to 9 years	
	➢ 10 or more years	
	Measurements of Network Partners Diversity	
	What is the main type of your partners you mentioned? (Please, *Tick all that apply*)	(Nieto and Santamaria, 2007), (Faems et al., 2005), (Baer, 2010)
	➢ Suppliers of equipment, materials, components, or software	
	➢ Clients or customers	
	➢ Competitors or other companies in your sector	
	➢ Consultants, commercial labs, or private R&D institutes	
	➢ Universities or other higher education institutions	
	➢ Government or public research institutes	
	➢ Other (please specify)	

Table 4.9: The type of questions and items measurements used to collect data on network characteristics

4.12: Research questionnaire and measurement items

As discussed in the previous sections, the research method was developed according to the literature. It was categorized into three sections: general information, innovation, and network characteristics. The complete questionnaire of this study is shown in appendix D.

4.13: Research sample

This section discusses the sampling strategy implemented in this research. As highlighted previously in the overall design of the survey in figure (4.1), deciding who and what to sample is a critical step in any research. There are two types of sampling techniques. The first is probability or representative sampling, where each case in the target population has a known chance of being included in the sample, which allows for statistical inferences. The second technique is non-probability sampling, where the chance, or probability, of each case being selected from the target population is not known. This technique makes it impossible to make valid statistical inferences about the population (Ghauri and Gronhug, 2005; Saunders et al., 2016). This study employs the probability sampling method. It is generally associated with the survey strategy, which serves this research objective and allows making inferences from the research sample about the population in order to answer the research question (Ghauri and Gronhug, 2005; Saunders et al., 2016).

4.13.1: Target population and sampling frame

A sampling frame is a complete list of all units from which the actual sample will be drawn from the target population. Identifying the population of interest – the target population – is essential before implementing data collection (Saunders et al., 2016). The OECD sector classification for high-technology and medium-technology (M&H technology) sectors (OECD, 2011) and similar classifications, used in many innovation studies (Hagedoorn and Duysters, 2002; Amara and Landry, 2005) are followed to identify and select what type of firms should be included in the target population. Additionally, each sector of industry has been identified by its International Standard Industrial Classification (ISCI) code in order to classify and identify participants by specific industry activity. The sector of industry classification with firms' ISCI codes is outlined in chapter five, in table (5.3).

4.13.2: Context: emerging economies

The fact that innovation is an important strategic element in an organization's competitiveness and productivity is nowadays broadly accepted, and is well-established in developed countries. As a matter of fact, innovation management literature is rich in diverse studies and approaches towards innovation networks and collaborative links in relation to developed countries. In contrast, little attention has been devoted to this area of research on emerging economies (Zeng et al., 2010; Kafouros and Forsans, 2012). Therefore, this study aims to contribute the literature to fill this knowledge gap concerning work on emerging economies context.

4.13.3: Research sample: Medium &High (M&H) technology in Saudi Arabia

The research population and sample were identified based on the sampling frame method from three governmental data basses accessed in Nov-Dec, 2014, namely, the Ministry of Commerce and Industry (MCI), the Saudi Industrial Property Authority (MODON), and the Communications and Information Technology

Commission (CITC). The sample was randomly selected from different M&H technology manufacturing and service sectors, following ISIC code. The field survey was conducted between February 2015 and January 2016. The respondents were approached by two methods as outlined in the questionnaire distribution section (4.7.1 **Questionnaire distribution methods**).Top management in the firm, such as directors, general managers, and managers, were contacted in person or via e-mails to invite them to participate in the study. The targeted respondents are very important to the research objective since innovation as well as network characteristics require respondents to be fully aware of firm related activities and business relations. The composition of respondent firms is shown in chapter 5, table (5.3).

4.13.4: Response rate

In order to encourage firms to participate in the questionnaire, an invitation letter was sent to each participant along with a survey-link for the web based survey, introducing the research topic and explaining the objectives of the study. Additionally, an assurance of confidentiality and anonymity was given to the firms. Follow-up e-mails and telephone calls were made on a regular basis to remind respondents to send back the questionnaire, and in some cases to complete missing data. Lastly, incentives in the form of a summary of the research results were given to respondents to encourage them and increase the response rate (Easterby-Smith et al., 2012).

The target population identified from the database accounted for 614 firms in the M&H technology sector in Saudi Arabia. 540 questionnaires were sent to the firms, representing 88% of the target population (540/614). A number of reasons contributed to the missing 12% of the target population such as, change of industry activity, no or invalid contact information, refusal to participate, and recently established businesses. The received sample was 133, but 12 responses were dropped from the final count due to missing data and invalid or incomplete entries. The final valid response was 121 firms, representing 22% of the distributed questionnaires (121/540), and 20% of the target population (121/614).

4.14: Pilot study of the research questionnaire

A pilot study was conducted with the draft version of the questionnaire as a pre-test. The questionnaire was administrated to five experts from academia and industry. A full survey was sent with the research objectives and aims to two experts from academia with the aim of validating the first draft of the questionnaire and improving its quality. They were asked to evaluate the questionnaire against the research objectives, to identify and judge errors in the formatting and nature of questions, and to determine the overall appropriateness of the questionnaire (Wilson A. 2012). Additionally, another questionnaire was sent to three firms from the target population to get their comments on and responses to the first draft. They were asked to answer the full survey in a normal fashion and to identify errors in wording or translation of the questions and the definitions provided.

The pre-testing of the research instrument allows the researcher to revise some of the questions and improve the quality of the questionnaire. In this instance, based on the experts' review and feedback, some questions were revised and more clarifications were provided. Once the pilot study had been completed and the amendments made, the final version of the questionnaire was ready to be distributed to the target population. The pilot study was a necessary stage in order to increase response rate (Easterby-Smith et al., 2012) and enhance the reliability and validity of the questionnaire (Saunders et al. 2016). Some of the expert's comments about the first draft of the questionnaire are summarized in Table (4.11).

Respondent 1 (Academia)	**Comments:** • Use consistent terminology throughout the definitions and questions • Consider adding other types of business/inter-organizational relationships • Length of the survey
Respondent 2 (Academia)	**Comments:** • Make sure to capture different effects on different types of innovation • Clarify and define some measurement procedures
Respondents 3, 4, 5 (Industry)	**Comments:** • Clarify some questions with definitions and examples • Listing partner by initials is preferred over naming the partner • Make questions concise and precise • Length of the survey could be improved

Table 4.10: Experts' comments about the first draft of the questionnaire

4.15: Reliability and validity

Reliability and validity are central to any research and to ensuring the quality of data, research design, and the overall accuracy of the study results (Saunders et al. 2016). Reliability estimates the consistency of the measurements in the results if the research were repeated (Saunders et al. 2016; Easterby-Smith et al., 2012). Assessing reliability in this research is explained in the next chapter in the discussion of research results.

Validity refers to the appropriateness of the measures used and whether the research instrument captures what it was designed to measure (Field, 2009). Two types of validity were discussed in this section: face validity and content validity. Face validity refers to ensuring that the questions and measures are reasonable for the elements of the study (Collis and Hussey, 2009). Content validity refers to whether elements of a measurement instrument represents the full range of the construct area (Field, 2009; Bearden et al., 2011). To ensure face validity and content validity of the instrument, the guidelines by Bearden et al. (2011) were followed:

- An adequate mapping and evaluation of the measurement items based on a solid theoretical background.
- Ensure the measurement scales were developed from existing relevant literature and constitute reliable and valid measures of the construct, i.e. the innovation domain for product innovation and process innovation measures, and the social network domain for network characteristics measures.
- To screen the research instrument by allowing a group of experts to view it to help ensure its adequacy. This has been achieved by pilot testing the questionnaire with five experts in the field, from both academia and industry.
- Instrument items should be developed to represent the construct and should be easy to respond to.

4.16: Methods of data analysis

Statistical package software and social network analysis software were employed in this research to analyse the collected data. Data were coded and entered into these analysis packages for further data screening and analysis. These are essential steps in any data analysis procedure in order to obtain meaningful insights from the collected data, and to look for patterns that can be used to answer the research questions (Easterby-Smith et al., 2012). The programmes used for data analysis are Microsoft Excel, the Statistical Package for the Social Sciences (SPSS 24.0), and the social network analysis package UCINET 6.586.

4.16.1: Social network data

To calculate the network characteristics measures, the social network analysis approach outlined by Borgatti et al. (2013) was followed, where an undirected adjacency matrix for the data was constructed. The rows and columns in the adjacency matrix represent the nodes (firms). An entry of 1 represents a tie or a relationship between two different entities, and the absence of the tie or relationships between nodes is assigned a 0. Additionally, the matrix is considered a one-mode matrix, where both rows and column refer to the same single set of entities (Borgatti et al., 2013). Then, the variables representing the network characteristics (network density and centrality) were computed using the social network analysis package UCINET 6.586 (Borgatti, et al., 2002).

4.16.2: Statistical testing

All the gathered data from the questionnaire were coded and entered into SPSS. Further rigorous examination of the data was undertaken, such as detecting missing data and identifying outliers to look for any significant effect on the analysis and identify how could we reduce any impact.

Statistical analysis methods were used to analyse innovation and network characteristics variables (product and process innovations, network density, network betweenness centrality, tie strength variables and control variables). Statistics methods, such as descriptive statistics, as well as inferential statistical analyses, were employed in this study. Descriptive statistics are widely used in research to summarize, describe or display quantitative data (Collis and Hussey, 2009). Whereas inferential statistics are used to draw conclusions about the target population from quantitative data based on sample data (Collis and Hussey, 2009; Easterby-Smith et al., 2012).

4.16.3: Binary logistic regression modelling

To investigate and test the research measurements and hypothesis, a Logistic Regression Modelling (LR) analysis was adopted. Regression methods, in general, have become an integral component of any data analysis aiming to describe the relationship between an outcome (dependent variable) and one or more explanatory variables (independent variables, also called predictors) (Hosmer et al., 2013). Logistic regression is the most frequently used regression model for the analysis of data that have discrete outcome variables, taking on two or more possible variables. It is a mathematical modelling approach that can be used to describe the relationship of several predictors to categorical dependent variable values (Hosmer et al., 2013; Krickeberg et al., 2010). Despite the similarities between the methods employed in linear regression and logistic regression, linear regression cannot be applied to a situation in which the outcome (dependent variable) is categorical. The linearity assumption that underlies linear regression modelling will be violated when the outcome variable is categorical. Therefore, to be able to use linear regression analysis, the observed data should fulfil the assumption of having a linear relationship (Berry, 1993; Field, 2009). To overcome this issue with categorical data, the literature suggests transforming the data using logarithmic transformation. The logistic regression modelling allows this transformation of expressing a non-linear relationship in a linear way. It expresses the linear regression equation in logarithmic terms (the logit), and thus solve the problem of violating the assumption of linearity (Berry and Feldman, 1985; Field, 2009; Hosmer et al., 2013).

In this research, the outcome variables – product innovation and process innovation – are in the form of categorical values. The independent variables are in the form of binary as well as continuous variables, which can be handled properly using logistic regression modelling (Hosmer et al., 2013; Field, 2009). Therefore, logistic regression is the most suitable type of analysis for this study. It serves the research aim and objectives by investigating the relationship and impact of network characteristics on firms' innovation.

4.17: Research ethical considerations

Ethical considerations were addressed in this research by following the University of Strathclyde's Code of Practice on Investigations on Human Beings for Ethical Policies. In addition, the research followed the key principles of ethics in conducting research outlined by Easterby-Smith et al. (2012), as shown in table (4.12):

1	Ensuring that no harm comes to participants
2	Respecting the dignity of research participants
3	Ensuring the fully informed consent of research participants
4	Protecting the privacy of research subjects
5	Ensuring the confidentiality of research data
6	Protecting the anonymity of individuals or organisations
7	Avoiding deception about the nature or aims of the research
8	Honesty and transparency in communication about the research
9	Avoidance of any misleading or false reporting of research findings

Table 4.11: Key principles in research ethics

Source: Easterby-Smith et al., 2012, p95

4.18: Conclusion

This chapter provided a rationale for the research design and methodology undertaken in this thesis. First, the adopted research philosophy was addressed, including an overview of philosophical perspectives, positivist philosophy, and the main methods and approaches used within this approach. It justified the use of the deductive approach and quantitative research method in order to achieve the aim and objectives of this research. Furthermore, the research design, research instrument and measures were described in detail. The research sample, including target population, sampling frame, and response rate were explained in relation to the research context. A pilot study was conducted to ensure the validity and the quality of the research instrument. Finally, a description of the data analysis, including statistical testing and SNA employed in this research was provided.

Chapter 5

Quantitative Findings and Data Analysis

5.1: Introduction

The research question and conceptual framework were developed in the previous chapter. In this study, the quantitative method was applied to test the hypotheses. In this chapter, the quantitative findings and data analysis is going to be presented. The research conceptual model was tested using the data collected via the research instrument (questionnaire). This chapter explains the statistical method, data analysis, and results of hypothesis testing in terms of direct and interaction effects of firms’ relational and structural network embeddedness on their product and process innovation.

5.2: Data processing and editing

All the data were entered into SPSS (IBM SPSS Statistics 24.0) and prior to conducting the research analysis, a rigorous examination of the entered data was undertaken. Following the recommendation from using social network analysis (SNA) and the statistical method, data was thoroughly screened. General data processing methods were applied to account for missing data. The received sample was 133 responses, and 12 responses were dropped from the final sample. 4 responses were deleted from the sample due to having more than 10% missing data (Hair et al., 2010). The remaining 8 responses were dropped because of firm size (belonging to a small firm). The final number of valid responses rate is 121 firms, representing 22% of the distributed questionnaires (121/540), and 20% out of the target population (121/614). Moreover, the specific assumptions of each type of analysis were evaluated, which will be discussed accordingly. Table (5.1) showed the description of the variables included in the research analysis.

Variables		Description	Measurement
Dependent Variables	Product _innovation	The market introduction of a new or a significantly improved good or service with respect to its capabilities	Dummy variable: 1 if the firm has introduced product innovation, 0 otherwise
	Process _innovation	The implementation of a new or significantly improved production process, distribution method, or supporting activity	Dummy variable: 1 if the firm has introduced process innovation, 0 otherwise
Independent Variables	Ties Strength (Strong/weak Ties)	Tie strength can be defined based on a combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie	Measures tie strength by the frequency of interaction between partners and their level of resource commitment to the relationship. For example, equity alliances, joint ventures, and cooperative (R&D) ventures are categorized as strong ties, and weak ties are operationalized as marketing agreements, and licensing and patent agreements.
	Strengthen_theTies	Measures the effect of ego's interaction/contact with its partners on a one year lag basis to capture the subsequent effect of ties type	Is the average frequency of interaction during a specified period (1 year lag time)
	Continuity	Repeated Collaboration (Continuity): is the decision to follow a path of collaboration over time—with the same or different partners. Number of partners with who firm forms repeated alliances in the industry network.	The number of years a firm had participated in collaborative networks. The variable can take integral values between 0 and 5, depending on the number of years the firm had been involved in collaborative networks
	Partners _Diversity	Network partners Diversity : having relationships with various types of partners/ sources	Firms asked to specify whether they participated in business /inter-organizational relationship with other organizations; such as competitors, customers, consultants, suppliers, etc.
	Network Density	Network Density: a measure of connectedness between members in a network	Calculated as the number of ties between a respondent's partners, divided by the maximum number of all possible ties between those partners
	Betweenness Centrality	Betweenness centrality: is concerned with the position of a firm which lies between other firms in the network	Measure by the extent to which a firm is located on the shortest path (i.e., geodesic) between any two actors in its network
	Degree centrality	Degree centrality: the degree to which a firm is involved with other actors in the network	Measured by the number of immediate partners that an actor has in their network.
Control Variables	Firm_Age	Age: Year of establishment	Year of establishment
	Firm_Size	Size of the firm: Number of full time employees	Dummy variable: 1 if the firm is Large size firm, and 0 if Medium size
	Sector_Type	Type of firms sector: sector classification (manufacturing/Service)	Dummy variable: 1 if the firm is in the manufacturing sector ; 0 if belong to service sector
	Firm_Group	part of a group of firms	Dummy variable: 1 if the firm belong to a group of companies, and 0 if otherwise
	Firm_Export	measured by a single-item question to capture if the firm exports	Dummy variable: 1 if the firm export, and 0 if otherwise

Table 5.1: Description of the variables included in the research analysis

5.3: Non-response bias

Statistical analyses were performed to identify non-response bias, in order to determine whether significance differences exist between early and late respondents for key measures variables. The analysis was carried out by using a chi-square test. In this study, a cut-off point was used in order to differentiate between early and late respondents (sending the first reminder). 54 responses were received before the first reminder; these are categorized as early respondents. The late respondents accounted for the rest of the sample size (n=67). The two groups were tested for non-response bias on the sample demographic characteristics of firm size, whether they export, the group status of the firm. In addition, dependent and independent variables were also tested in order to compare early and late respondents. Table (5.2) shows the chi-square test results, which indicate no difference between the two groups of samples at a 5% significance level.

Variables	Chi-Square Value	p-Value
Firm_Size	0.396	0.529
Firm_Group	0.052	0.82
Firm_Export	0.002	0.967
Product _innovation	0.413	0.521
Process _innovation	0.068	0.795
Ties Strength (strong)	2.1	0.147
Strengthen_theTies	2.011	0.156
Continuity	0..008	0.927
Partners _Diversity	0.27	0.604

Table 5.2: Chi-square test for non-response bias

5.4: Respondents’ characteristics

The research data from the usable responses were checked, coded, and entered into SPSS. The final response is outlined in Table (5.3), manufacturing firms make up 72% of the sample and service firms make up 28% of the total sample size. Additionally, the large firms only represent 38% of the sample, whereas medium sized firms make 62% of the sample.

Sectors	ISCI	N	%
Manufacturing Sector:	20 - Manufacture of chemicals and chemical products	11	9%
	202 - Manufacture of plastics products	22	18%
	21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	22	18%
	27 - Manufacture of electrical equipment	26	21%
	28 - Manufacture of machinery and equipment	6	5%
	Total manufacturing firms	**87**	**72%**
Service Sector:	61 - Telecommunications	10	8%
	62 - Computer programming, consultancy and related activities	15	12%
	63 - Information service activities	9	7%
	Total Service firms	**34**	**28%**
Total respondents		**121**	**100%**
Firm Size:	Large	**46**	**38%**
	Medium	**75**	**62%**

Table 5.3: composition of respondents

5.5: Choosing statistical techniques for hypothesis testing

A general principle in any quantitative study is deciding on the appropriate statistical test. For instance, the appropriateness of a specific type of statistical analysis depends on the form of research hypothesis and the measurements scale of the variables (Easterby-Smith et al., 2012). In this study, the outcome variables – product innovation and process innovation – are categorical values. The independent variables are in the form of binary as well as continuous variables, which can be handled properly using logistic regression modelling (Hosmer et al. 2013; Field, 2009). Therefore, this research used logistic regression modelling for the analysis. It summarises the key findings effectively in order to meet the research aim and objectives.

5.6: Measurement validation

As discussed in the methodology (chapter-4), the research innovation types and measures were defined and constructed based on the Oslo Manual (OECD, 2005), implemented in many Community Innovation Surveys (CIS). Therefore, the reliability and validity of the survey measures has been established by extensive piloting and pre-testing before implementation within different OECD countries and across firms from a variety of industrial sectors, including services and manufacturing firms (Leiponen and Helfat, 2010; Laursen and Salter, 2006; Reichstein and Salter, 2006; Raymond et al., 2010; Laursen and Salter, 2004; Castellacci, 2008). Furthermore, the main variables were tested for construct reliability. The Cronbach alpha (α) values of product innovation and process innovation are 0.786 and 0.853, respectively. The literature suggests that any value of Cronbach alpha (α) greater than 0.7 is considered a satisfactory level of reliability (Field, 2009; Hair et al. 2010). Moreover, the logistic regression modelling reliability assessment was applied for each model which will be discussed accordingly.

5.7: Social network analysis

Social network relational and structural variables were structured and calculated based on the methodology discussed in section (4.11) in chapter 4. This study used UCINET 6.586 software, a social network analysis package (Borgatti et al., 2002) to compute the three independent variables, network density, degree centrality and betweenness centrality. Figure (5.1) presents the whole sample network configuration with examples for some ego-firms' networks. The descriptive statistics of these variables are presented in table (5.4).

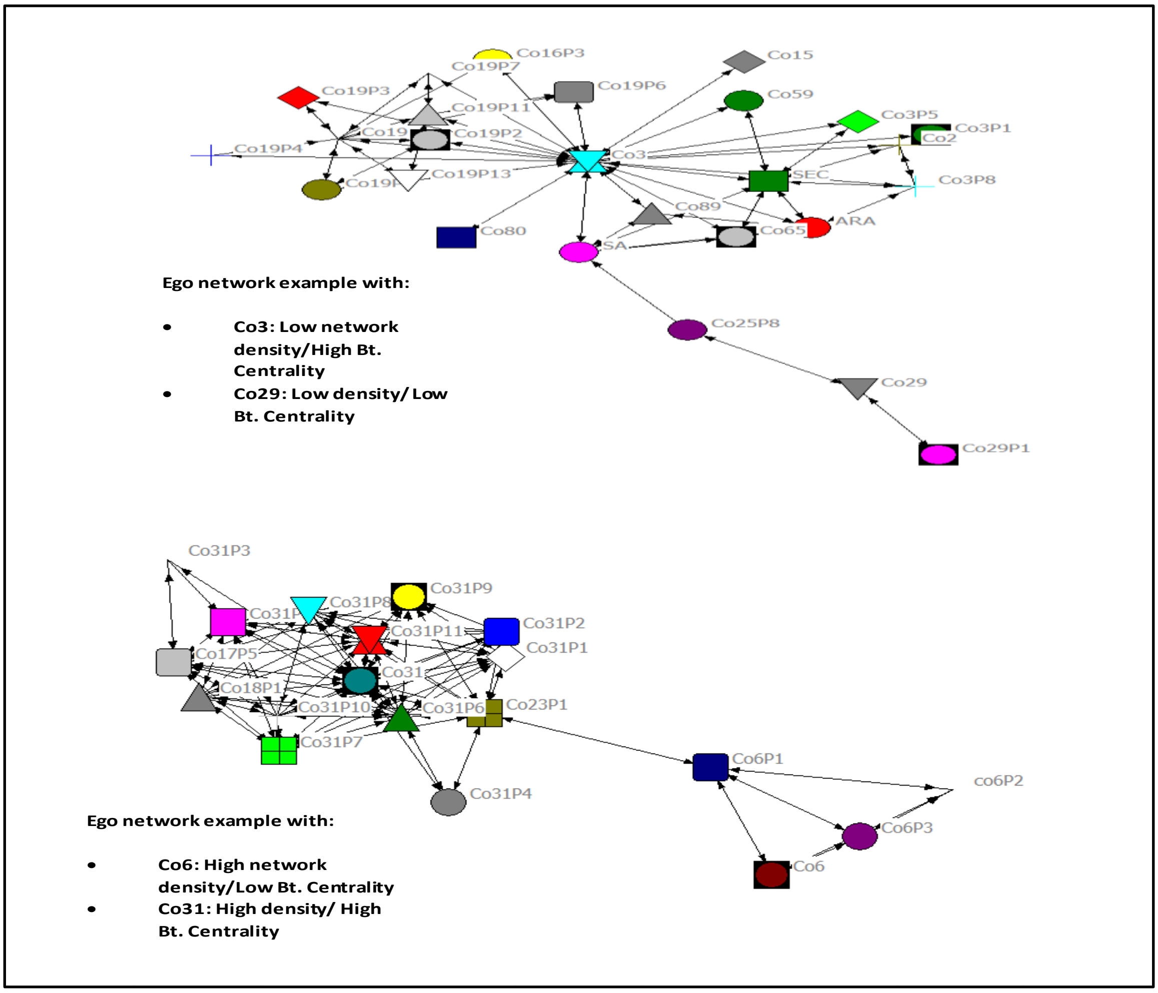

Figure 5.1: Ego-Network examples of network structural characteristics (network density and betweenness centrality)

Statistics		
Network Density		
N	Valid	121
	Missing	0
Mean		28.8755
Median		16.6700
Std. Deviation		31.73639
Range		100.00
Minimum		0.00
Maximum		100.00

Statistics		
Betweenness Centrality		
N	Valid	121
	Missing	0
Mean		7.2896
Median		3.0000
Std. Deviation		9.09451
Range		34.70
Minimum		0.00
Maximum		34.70

Table 5.4: descriptive analysis for network density and betweenness centrality

5.8: Logistic regression modelling (LR)

5.8.1: Introduction to LR

Logistic regression modelling (LR) was used to address the main research question and test the proposed hypotheses. The results of logistic regression seek to investigate statistically significant associations between predicators (independent variables) and dependent variables. As illustrated in figure (3.1) in chapter 3, this study used six independent variables: 1) strong/weak ties, 2) strengthen the ties, 3) repeated collaboration (continuity), 4) network partners' diversity, 5) network density, and 6) betweenness centrality. The independent variables constitute the key network relational and structural embeddedness characteristics, which are modelled and analysed to predict their significant influence on the dependent variables of firm's innovation (product and process innovations). LR was selected to test hypotheses in this study for three reasons. First, LR is likely to be the most appropriate type of analysis method to explain an outcome (dependent variable), which is a dichotomous categorical variable (Hosmer et al., 2013; Field, 2009). Second, LR analysis can handle binary, continuous, or a mix of both independent variables. Finally, due to the categorical dependent variables, the assumption of the other regression analyses (linear regression) of normality, linearity, and homoscedasticity are violated. Therefore, LR is suitable for this research as it allows the admission of both continuous and categorical data in to the regression model. LR modelling doesn't rely on strictly meeting these assumptions and it applies logit transformation to better deal with research data (Hosmer et al., 2013; Field, 2009).

LR is used to fit a model to categorical (dependent) response (Y) data, such as whether a firm is a product innovator or not. For each possible independent variable (X) or set of values for the independent variables (Xs), there is a probability (p) for a firm to be a product innovator. The linear logistic regression equation fitted by maximum likelihood is given by equation (1):

$$Y = \beta_o + \beta_1 X_1 \quad \text{------------------} \quad \text{Eq. (1)}$$

Where:

Y: the outcome (dependent) variable,

$\beta_{o:}$ constant (Y- intercept),

X_1: predictor (independent) variable

And β_1: the regression coefficient of the predictor

The logit transformation of equation (1) yields the logistic regression form, when there is only one predicator (independent) variable (X), the logistic regression equation from which the probability (p) of categorical (dependent) response (Y) is predicted is given by equation (2):

$$P(Y)= \frac{e^{(\beta o + \beta 1\ X1i)}}{1+ e^{(\beta o + \beta 1\ X1i)}} \quad \text{-------- Eq. (2)}$$

Where:

P (Y): the probability of Y (the outcome) occurring,

e: the base of natural logarithms,

β_0: constant (Y- intercept)

X_1: predictor (independent) variable

And β_1: the regression coefficient of the predictor

Additionally, the logistic regression equation can be extended to include several predicators (independent variables) to become:

$$P(Y)= \frac{e^{(\beta o + \beta 1\ X1i + \beta 2\ \ X2i + ... + \beta n\ Xni)}}{1+ e^{(\beta o + \beta 1\ X1i + \beta 2\ \ X2i + ... + \beta n\ Xni)}} \quad \text{-------- Eq. (3)}$$

The logistic regression equation yields to values between 0 and 1. Where a value close to 0 means that (Y) is very unlikely to have occurred (in this research product or process innovator). On the other hand, a value close to 1 means that (Y) is very likely to have occurred. Figure (5.2) illustrates graphically the logistic regression (the logit) curve which takes an S-shaped curve and ranges from -∞ to +∞. Additionally, similar to linear regression, each predictor variable in the logistic regression equation has its own regression coefficient, which measures the predictor's independent contribution to variation on the outcome (DV). (Hosmer et al., 2013; Field, 2009; Miles and Shevlin, 2001).

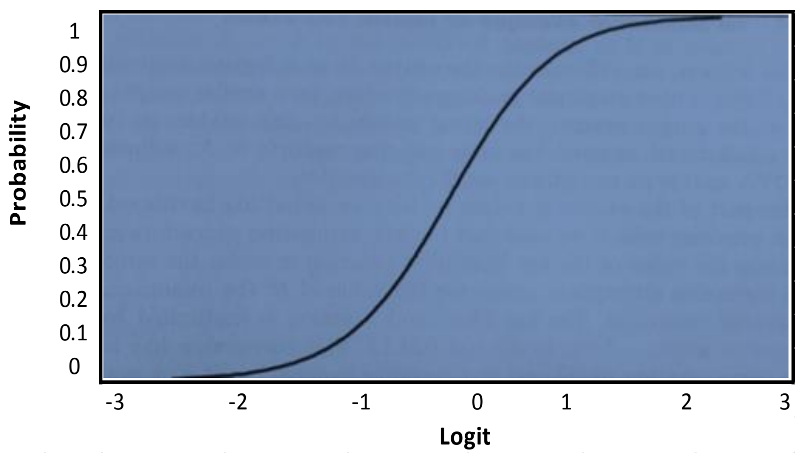

Figure 5.2: Logistic regression (LR) schematic curve. The logit against probability

Adopted from: Miles and Shevlin, 2001

5.8.2: Logistic regression modelling (purposeful selection of predictor's method)

To conduct required analysis, the research was informed by the methodology outlined by (Hosmer et al., 2013) for including and/or excluding variables in the LR, which is called purposeful selection of covariates (Hosmer et al., 2013). The main purpose of using this method is to select the network variables (IV) that result in a best fitted logistic model to determine the impact on and relationships between network characteristics and firms' innovation (DV). There are some advantages in applying the approach, as addressed by Hosmer et al., 2013. For instance, the LR using purposeful selection of variables approach involved seeking a model that accurately reflected the true outcome of the data. Furthermore, it is likely to yield a numerically stable model, and is more easily adopted in practice; it also prevents the production of an over-fit logistic model (Hosmer et al., 2013).

In the following sections, the procedure of implementing the purposeful selection of predictors will be introduced. The two logistic regression analysis assumptions, continuous variables linearity and multi-collinearity, will be also assessed. The assessment of linearity forms part of the procedure for each continuous independent variable with each dependent variable, whereas multicollinearity is assessed once, as indicated below. In addition, a general analysis diagnostic for possible outliers in the sample was performed for the variable betweenness centrality.

5.8.3: Multicollinearity

As recommended by Ryan (2009), in order to perform a logistic regression analysis it is recommended multicollinearity between variables must be tested. In this study, the correlation test showed high correlation (r=0.837) between betweenness centrality and degree centrality variables. Therefore, and to avoid such bias which might affect the logistic regression analysis, degree centrality was excluded from the whole model. The correlation between variables is shown in Appendix C.

5.8.4: Data diagnostic for cases outliers

Inspection of the raw data for betweenness centrality revealed that there are six cases of outliers as shown in Figure (5.3). These outlier scores could influence the rest of the data and cause bias. According to Ford (2009), there are several options to reduce the impact of outlier score. One option is to remove the scores with outliers (Hair et al., 2010; Field, 2009). A second option is to correct for it by changing the score into the average mean plus two standard deviations (Field, 2009). In this research, the outlier scores in the betweenness centrality variable were corrected for by changing the score to the mean plus two standard deviations.

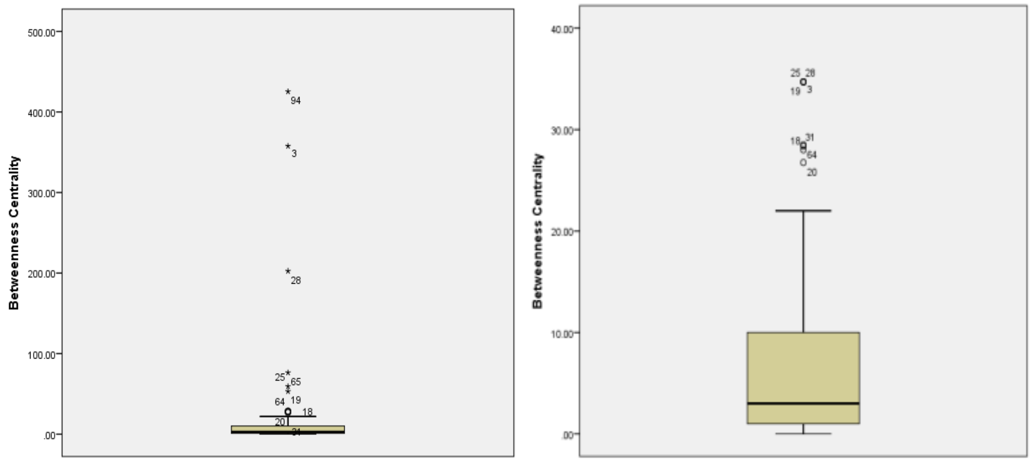

Figure 5.3: Betweenness centrality variable analysis for outliers

5.9: Dependent variable (DV): product innovation

Step 1: The first step is to fit the logistic regression model for each predictor (control and independent variables). The results of the analysis are shown in Table (5.5).

Variables	B	S.E.	Sig.	Exp(B)
Sector_Type (Service)	0.953	0.444	**0.032**	2.593
Firm_Size (Medium)	0.088	0.379	0.817	1.092
Firm_Age	0.000	0.015	0.994	1.000
Firm_Group (Part of Group)	0.358	0.382	0.348	1.430
Firm_Export (Export)	1.137	0.428	**0.008**	3.118
Strengthen the Ties (Strengthen)	0.885	0.431	**0.040**	2.423
Ties Strength (Strong Ties)	-0.808	0.382	**0.034**	0.446
Continuity	0.704	0.395	**0.074**	2.022
Partners _Diversity	0.943	0.392	**0.016**	2.568
Network Density	0.021	0.007	**0.003**	1.021
Betweenness Centrality	0.089	0.031	**0.004**	1.093

Table 5.5: Results of fitting logistic regression models, N=121 (Note: Each row in the table presents the results for the estimated regression coefficient from a model containing only that variable)

Step 2: The second step is to fit the logistic model containing all variables that are significant at the 25% level. Clearly, from Table (5.5), the control variables (sector type and export), and the independent variables (strengthen the ties, tie strength (strong ties), continuity, partner diversity, network density, and betweenness centrality) are all significant at the recommended 25% significance level. Table (5.6) below show the results of the LR fitted model.

Main Effects Model				
Variables	B	S.E.	Sig.	Exp(B)
Sector_Type (Service)	-1.443	0.555	0.009	0.236
Firm_Export (Export)	1.032	0.545	0.058	2.807
Strengthen the Ties (Strengthen)	1.033	0.557	0.064	2.808
Ties Strength (Strong Ties)	-0.747	0.491	0.128	0.474
Continuity	0.959	0.528	0.069	2.609
Partners _Diversity (diversity)	1.062	0.522	0.042	2.891
Network Density	0.026	0.008	0.001	1.026
Betweenness Centrality	0.149	0.048	0.002	1.161
Constant	-2.223	0.930	0.017	0.108

Table 5.6: Results of fitting the logistic model with all variables significant at the 0.25 level (Main Effects Model), N=121

Step 3: Next we check to see if any of the removed variables (size, age, and group) in step 2 were confounders. Confounders are variables used to adjust the effects of other variables on the model (Hosmer et al., 2013). The results of testing for confounders are shown in appendix A (table A1). The results show that the largest percentage change is 17% for the variable 'strong ties', which doesn't exceed the criterion of 20% change, according to the recommendations of Hosmer et al. (2013).

Step 4: The logistic model in Table (5.6) is the preliminary main effects model for product innovation, including the essential variables. In this step, we check the assumption that the scale of the logit for continuous variables (density and betweenness centrality) increases/decreases linearly as a function of the dependent variable (product innovation).

First, for the variable network density:

The logistic regression was run with the variable ‘network density’ to obtain the logit of the logistic regression model equation, as shown in table (5.7):

Variables in the Equation				
Variables	**B**	**S.E.**	**Sig.**	**Exp(B)**
Network Density	.021	.007	.003	1.021
Constant	-.229	.253	.367	.796

Table 5.7: LR for network density variable (IV) and product innovation (DV)

The logit equation is in the form

y= $\beta_o + \beta_1 X$;

Where; β_o is the constant, β_1 is the estimated coefficient of a variable, and X is a given variable value.

The logit equation for the variable in hand (density) is:

Y= -.229+0.021*Network Density

Figure (5.4) shows the plotted network density versus logit scale.

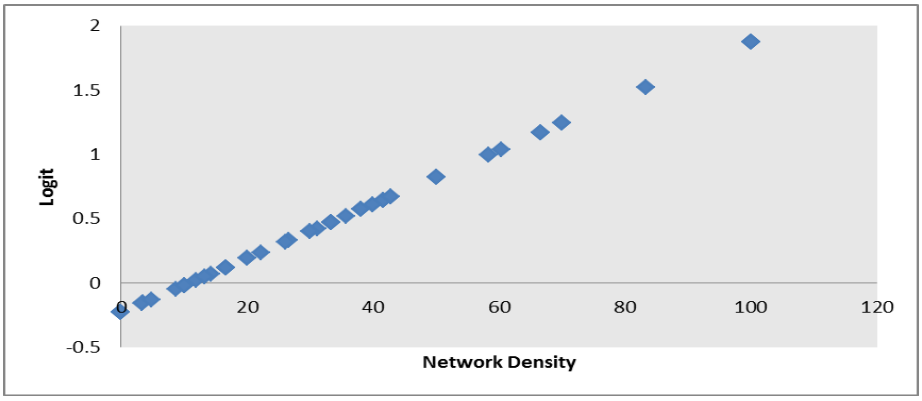

Figure 5.4: Plot of estimated logistic regression coefficients of network density versus logit

Secondly, the logistic regression coefficients of the variable network betweenness centrality were run:

The same procedure was followed as for network density; the logistic regression for betweenness centrality was run to test for linearity. The estimated logistic regression is shown on table (5.8) for betweenness centrality:

Variables in the Equation				
Variables	**B**	**S.E.**	**Sig.**	**Exp(B)**
Betweenness Centrality	0.089	0.031	0.004	1.093
Constant	-0.241	0.250	0.335	0.786

Table 5.8: LR for network betweenness centrality (IV) and product innovation (DV)

The logit equation for the variable betweenness centrality is:

Y= -0.241+0.089* Betweenness Centrality

Figure (5.5) shows the plotted network betweenness centrality versus logit scale.

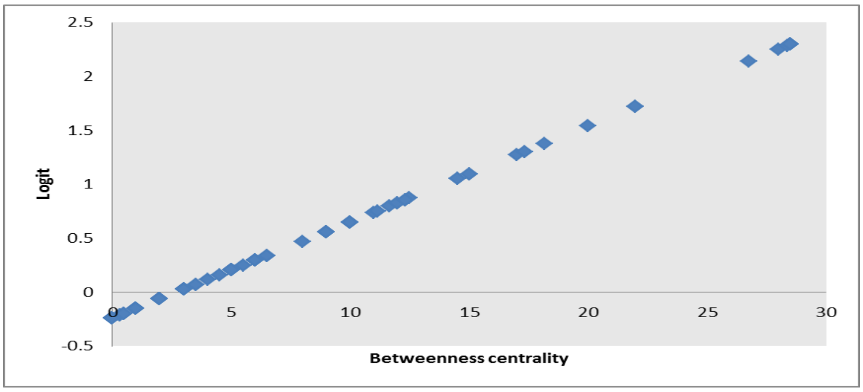

Figure 5.5: Plot of estimated logistic regression coefficients of betweenness centrality versus logit scale

Step 5:

In this final step in the purposeful selection procedure, the possible interactions among the main variables were explored. The interaction effect on the outcome variable (DV) is the effect of two or more variables in combination (Field, 2009; Timothy Keith, 2006). This allowed exploration of the potential joint effects of different network relational and structural elements on firms' innovation. Moreover, it has the advantage of eliminating researcher bias in selecting variables in order to test the interaction effects. The procedure starts by introducing the possible network relational and structural interaction variables, one by one, to the main effects model in Table (5.6). For the purpose of this research, 2-way and 3-way interactions among all independent variables were examined for possible interaction effects. The results of assessing the significance of the possible interaction terms are summarised in Table (5.9) for 2-way interaction. The results indicate three interaction terms that have significant interaction at the 25% level. These interaction terms are (Network Density by Strengthen the Ties), (Betweenness centrality by Tie-strength (Strong Ties)), and (Network Density by Continuity).

2-way Interaction	B	S.E.	Sig.	Exp(B)
main effects model				
Network Density by Strengthen the Ties (Strengthen)	-0.023	0.019	**0.213**	0.977
Betweenness Centrality by Strengthen the Ties (Strengthen)	0.054	0.111	0.631	1.055
Network Density by Ties Strength (Strong Ties)	-0.013	0.016	0.406	0.987
Betweenness Centrality by Ties Strength (Strong Ties)	0.179	0.097	**0.066**	1.196
Network Density by Continuity	-0.038	0.02	**0.055**	0.963
Betweenness Centrality by Continuity	0.049	0.089	0.584	1.05
Network Density by Partners _Diversity (diversity)	0.003	0.015	0.825	1.003
Betweenness Centrality by Partners _Diversity (diversity)	0.074	0.091	0.418	1.076
Strengthen the Ties (Strengthen) by Ties Strength (Strong Ties)	0.516	1.092	0.636	1.676
Strengthen the Ties (Strengthen) by Continuity	0.288	1.149	0.802	1.333
Partners _Diversity (diversity) by Strengthen the Ties (Strengthen)	-0.22	1.101	0.841	0.802
Ties Strength (Strong Ties) by Continuity	0.949	1.064	0.372	2.584
Partners _Diversity (diversity) by Ties Strength (Strong Ties)	-0.099	1.034	0.924	0.906
Partners _Diversity (diversity) by Continuity	-0.674	1.208	0.577	0.509
Betweenness Centrality by Network Density	0.001	0.002	0.542	1.001

Table 5.9: Addition of the 2-way interactions to the main effects model, N=121 (Note: Each interaction term in the table presents the results for the estimated regression coefficient from a model containing only that term)

For 3-way interaction, Table (5.10) summarises the results showing the interaction terms between (Betweenness Centrality by Network Density by Tie Strength (Strong)), (Betweenness Centrality by Network Density by Partners Diversity) and (Betweenness Centrality by Strengthen the ties by Tie Strength (Strong)). In 3-way interaction modelling, a stricter interaction significance level of 20% is used as inclusion criteria for 3-way interaction terms. This is due to the inclusion of all the lower order terms in the LR model (e.g. including the main variables, the 2-way interaction variables, and the 3-way interaction variables) (Kleinbaum and Klein, 2010; Field, 2009) which increase the number of covariates (IV) in the LR model that might cause problems of overestimation or underestimation in the LR model and poor model fit. In addition, containing the lower order variables in the LR model improved the estimation of odds ratios in the model (Hosmer et al., 2013).

According to Hosmer et al. (2013), the recommended number of sample cases per variable is 5-10 cases per covariate (IV) (Hosmer et al., 2013).

3-way Interaction	B	S.E.	Sig.	Exp(B)
main effects model				
Betweenness Centrality by Network Density by Strengthen the Ties (Strengthen)	-0.003	0.005	0.609	0.997
Betweenness Centrality by Network Density by Ties Strength (Strong Ties)	-0.025	0.01	**0.008**	0.975
Betweenness Centrality by Network Density by Continuity	0.004	0.005	0.378	1.004
Betweenness Centrality by Network Density by Partners _Diversity (diversity)	0.007	0.005	**0.151**	1.007
Strengthen the Ties (Strengthen) by Ties Strength (Strong Ties) by Continuity)	-1.322	2.439	0.588	0.267
Partners _Diversity (diversity) by Strengthen the Ties (Strengthen) by Ties Strength (Strong Ties)	2.544	2.343	0.277	12.732
Network Density by Strengthen the Ties (Strengthen) by Ties Strength (Strong Ties)	-0.042	0.042	0.319	0.959
Betweenness Centrality by Strengthen the Ties (Strengthen) by Ties Strength (Strong Ties)	-0.23	0.178	**0.197**	0.795
Partners _Diversity (diversity) by Ties Strength (Strong Ties) by Continuity)	-2.07	2.448	0.398	0.126
Network Density by Ties Strength (Strong Ties) by Continuity)	0.013	0.042	0.759	1.013
Betweenness Centrality byTies Strength (Strong Ties) by Continuity	-0.166	0.245	0.498	0.847
Network Density by Partners _Diversity (diversity) by Ties Strength (Strong Ties)	0.028	0.032	0.384	1.029
Betweenness Centrality by Partners _Diversity (diversity) by Ties Strength (Strong Ties)	-0.162	0.2	0.417	0.85
Network Density by Partners _Diversity (diversity) by Continuity	-0.003	0.068	0.96	0.997
Betweenness Centrality by Partners _Diversity (diversity) by Continuity	0.172	0.228	0.45	1.187

Table 5.10: Addition of the 3-way interactions to the main effects model, N=121 (Note: Each interaction term in the table presents the results for the estimated regression coefficient from a model containing only that term)

To summarize, the five steps outlined by (Hosmer et al., 2013) of model building using a purposeful selection procedure start with the selection of variables, examination of the scale in the logit for continuous variables, and selection of possible interactions among the terms in the model. In the next sections, we will examine the model fit of network relational characteristics (model-1). The discussion of the other models goodness of fit and reliability assessments (models 2 to 5) is included in appendix A.

5.10: Network relational characteristics (model-1)

This section presents results of the logistic regression model of network relational characteristics and its potential impact on firms' product innovation. Table (5.11a and b) shows the general LR number of the sample and the categorical variables coding included in the model. A summary of the logistic regression outcome for model-1 is illustrated in Table (5.12). The rest of this section intends to discuss the essential steps in assessing the goodness of model fit of the logistic regression.

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	121	100.0
	Missing Cases	0	0.0
	Total	121	100.0
Unselected Cases		0	0.0
Total		121	100.0

Table 5.11, a: Sample characteristics

Categorical Variables Codings

		Frequency	Parameter coding (1)
Partners _Diversity	No Partner Diversity	42	0.000
	Partner Diversity	79	1.000
Firm_Export	Non-Exporter	32	0.000
	Exporter	89	1.000
Strengthen_the Ties	No Strengthen of Ties	85	0.000
	Strengthen of Ties	36	1.000
Ties Strength	Weak Ties	54	0.000
	Strong Ties	67	1.000
Continuity	Non-Continuity	39	0.000
	Continuity	82	1.000
Sector_Type	Service	34	0.000
	Manufacuring	87	1.000

Table 5.11,b: LR model categorical variables coding

Model-1				
Variables	B	S.E.	Sig.	Exp(B)
Sector_Type(1)	-1.361	0.504	**0.007**	0.256
Firm_Export(1)	0.700	0.481	0.146	2.013
Strengthen_the Ties(1)	1.044	0.492	**0.034**	2.841
Ties Strength (1)	-0.861	0.430	**0.045**	0.423
Continuity(1)	0.589	0.449	0.190	1.803
Partners _Diversity (1)	1.153	0.460	**0.012**	3.167
Constant	-0.141	0.702	0.841	0.868

Table 5.12: Network Relational Characteristics (Model-1)

5.11: Tests for goodness of model fit

It is an essential step in the development of any logistic regression model to perform a goodness of model fit assessment. Assessing the fit of the model indicates whether the probabilities produced by the logistic model accurately reflect the true outcome in the data (Hosmer et al., 2013). There are various measures to evaluate logistic regression model goodness of fit, which are introduced and discussed below for Model-1.

1- Chi Square test (Omnibus Tests of Model Coefficients)

The Chi Square goodness-of-fit statistical tests if there is a significant difference between the full model (contains all main effects predictors) and the constant only model (Douglas, 2012; Barbra, 2007). For Network Relational Characteristics (Model1), the overall model is statistically significant at 5%, as shown in Table (5.13). Thus, based on the probability of chi-square (shown as 'Sig' in table (5.13) in the Omnibus test we can conclude that there is a relationship between the dependent variable and the independent variables.

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	28.462	6	0.000
	Block	28.462	6	0.000
	Model	**28.462**	**6**	**0.000**

Table 5.13: Chi-Square test (Omnibus Tests of Model Coefficients) for model-1

2- Hosmer and Lemeshow Test

The Hosmer and Lemeshow goodness-of-fit test is obtained by calculating the Chi-Square statistic from a table of the number actually observed and the number predicted by the logistic regression model (Hosmer et al., 2013), where the good model fit produces a non-significant chi-square (Barbra, 2007). Table (5.14) illustrates the Hosmer and Lemeshow goodness-of-fit test for Network Relational Characteristics (Model-1).

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	3.257	7	**0.860**

Table 5.14: Hosmer and Lemeshow goodness-of-fit test for Model-1

3- Classification Tables

Another approach to determining how well the logistic regression model performs is via classification tables (Hosmer et al., 2013). This is can be achieved by assessing the model's ability to correctly predict the outcome category (dependent variable) (Barbra, 2007). To be able to classify the outcome variable, a cut-off point must be defined and each estimated probability compared to this cut off point; the most commonly used value for a cut-off point is 0.5 (Hosmer et al., 2013), so this value was selected for this research. Tables (5.15a and b) show the results of Network

Relational Characteristics (Model-1) classification tables with the constant only, and with the independent variables. There is a noticeable improvement in the logistic regression model with the inclusion of the independent variables from 57.9%, with the constant only model into 69.4% prediction capability. In the classification table (5.15b), the results of classifying all cases with predicted values below the cut-off point (0.5) as '0' (labelled as Not Innovator), and all cases above the cut-off point (0.5) as '1' (labelled as Product Innovator). The classification table (5.15b) shows that, overall, the logistic model correctly classifies 69.4% of the respondents. 52.9% of cases are correctly classified by the model as 'not innovators', and 81.4% of the cases are correctly classified as 'product innovators'.

Classification Table[a,b]

Observed			Predicted: Product_Innovation: Not- Product Innovator	Predicted: Product_Innovation: Product-Innovator	Predicted: Percentage Correct
Step 0	Product_Innovation	Not- Product Innovator	0	51	0.0
		Product-Innovator	0	70	100.0
	Overall Percentage				57.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]

Observed			Predicted: Product_Innovation: Not- Product Innovator	Predicted: Product_Innovation: Product-Innovator	Predicted: Percentage Correct
Step 1	Product_Innovation	Not- Product Innovator	27	24	52.9
		Product-Innovator	13	57	81.4
	Overall Percentage				69.4

a. The cut value is .500

Table 5.15, a & b: The results of Network Relational Characteristics (Model-1) classification tables

4- Receiver Operating Characteristic Curve (ROC)

One of the common and useful classification assessments of the logistic regression models is the area under the Receiver Operating Characteristic Curve (ROC) (Hosmer et al., 2013). It has become the standard for evaluating a fitted model's ability to assign higher probability of the outcome to the observations that develop the outcome (y=1) than the observations that don't develop the outcome (y=0) (Hosmer et al., 2013). ROC plots the probability of the model to predict an event correctly, which is called (sensitivity, or true positive) versus (1-specisfity), which is the proportion of negative data mistakenly classified as positive (false positive) (Hosmer et al., 2013; Wan Tang, 2012). The area under the ROC curve ranges from 0.5 to 1.0 and provides a measure of the models in order to discriminate between those respondents who experience the outcome of interest versus those who don't. An area under ROC curve ≥ 0.7 is considered a good discrimination; the higher the value, the better the prediction ability (Hosmer et al., 2013). For network relational characteristics (Model-1), the area under the ROC curve shown in Figure (5.6) is equal to 0.773, which is illustrated in Table (5.16), and indicates a good model discrimination ability.

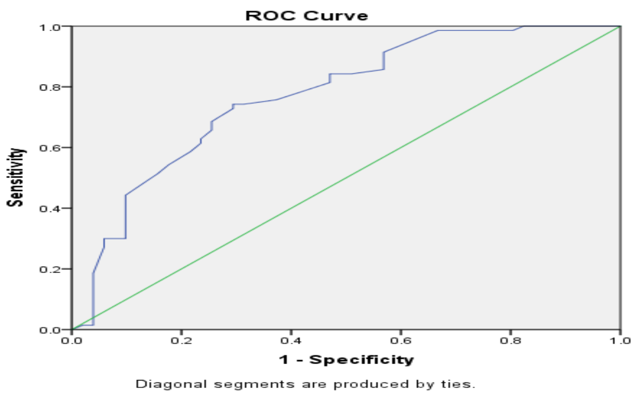

Figure 5.6: ROC plot for Network Relational Characteristics (Model-1)

Area Under the Curve

Test Result Variable(s):

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval Lower Bound	Asymptotic 95% Confidence Interval Upper Bound
0.773	0.044	0.000	0.687	0.858

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Table 5.16: Area under the curve (AUC) statistics in model-1

5.12: Network structural model and main effects model characteristics (Model-2 and 3)

A similar approach was applied to model structural variables (Model-2) and the combined relational and structural variables (Model-3), which is the logistic regression main effects model. The main effects model (model-3) will be used as the research hypothesis testing model because it takes into account both network relational embeddedness and structural embeddedness variables, leading to an interpretation of the effect of each variable, while controlling for others (Keith, 2006). Table (5.17) is the summary table for all the regression models for product innovation (DV) with LR diagnostic assessments. Additionally, the logit transformation of the main effects model (Model-3) can be derived from the predicted probabilities resulting from LR modelling. First, the odds ratio, denoted (OR), of an event happening (i.e. product innovation) can be calculated from the derived product probability using the formula:

Odds Ratio (OR) = P (event)/ [1-P (event)],

Where,

P (event) refers to the probability of a particular event occurring,

And [1-P (event)] refers to the probability of the event not occurring.

The next step in calculating the logit transformation of the LR model is to take the natural logarithm (log) of the odds ratio, which gives the logit (Hosmer et al., 2013; Miles and Shevlin, 2001). The relationship between the logit transformation and the predicted probabilities of product innovation in the main effects model (Model-3) is presented graphically as a logit curve, shown in Figure (5.7).

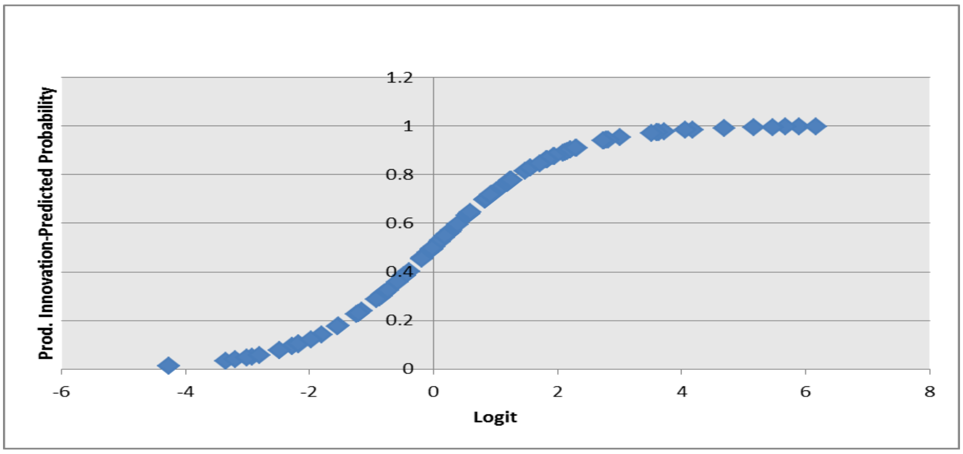

Figure 5.7: Logit plot against the predicted probability of product innovation in Model 3 (main effects model)

Variables	Model-1 Relational (R) Characteristics		Model-2 Structural (S) Characteristics		Model-3 Main Effects Model (RS)	
	Exp(B)	S.E.	Exp(B)	S.E.	Exp(B)	S.E.
Sector_Type (1)	**3.900 ****	0.504	**2.959 ****	0.507	**4.235 ****	0.555
Firm_Export (1)	2.013	0.481	**4.438 ****	0.516	**2.807 ***	0.545
Strengthen_theTies (1)	**2.841 ****	0.492			**2.808 ***	0.557
Ties Strength (1) (Strong Ties)	**0.423 ****	0.430			0.474	0.491
Continuity (1)	1.803	0.449			**2.609 ***	0.528
Partners _Diversity (1)	**3.167 ****	0.460			**2.891 ****	0.522
Network Density			**1.026 *****	0.007	**1.026 *****	0.008
Betweenness Centrality			**1.157 *****	0.044	**1.161 ****	0.048
LR-Model assessment tests						
model Chi-square	28.462***		41.33***		53.237***	
Hosmer–Lemeshow goodness-of-fit	0.86		0.54		0.49	
Overall % of correct predictions (constant only)	57.90		57.90		57.90	
Overall % of correct predictions (all varables)	69.40		76.90		76.90	
ROC, Area under the Curve	0.773		0.806		0.852	
* Significance at 10%, ** Significance at 5%, *** Significance at 1%. N=121						

Table 5.17: Results of LR modelling for Network Relational, structural and main effects model (Model 1, 2 & 3) for product innovation

5.13: Testing of interaction terms between network relational and structural characteristics:

One of the advantages of applying logistic regression analysis is testing for interaction among dependent variables. This approach has the advantage of predicting the joint effects of different variables on the outcome variable (DV), firms' product innovation.

5.13.1: 2-way interactions

The LR modelling starts by testing the interaction effect between two variables on firms' product innovation (DV). As previously discussed in step 5, from the purposeful selection of predictors method, illustrated in Table (5.9), the interaction terms that have significant interaction at the 25% level are (Network Density by Strengthen the ties), (Betweenness Centrality by Tie Strength (Strong ties)), and (Network Density by Continuity) terms. These terms are introduced to the main effects model (model-3) in Table (5.17) to test the joint effects of network relational and structural variables on product innovation. The results are shown in table (5.18).

Model-4 **2-way interactions**	**Exp(B)** **OR**	**S.E.**
Sector_Type (1)	4.431 **	0.611
Firm_Export (1)	3.257 **	0.596
Strengthen_theTies (1)	5.664 **	0.829
Ties Strength (1) (Strong Ties)	0.163 **	0.767
Continuity (1)	18.453 **	1.017
Partners _Diversity (1)	2.592 *	0.56
Network Density	1.082 **	0.025
Betweenness Centrality	1.097 *	0.054
Network Density by Strengthen_theTies (1)	0.967	0.02
Betweenness Centrality by Ties Strength (1) (Strong Ties)	**1.296 ****	0.115
Network Density by Continuity (1)	**0.949 ****	0.024
LR-Model assessment tests		
model Chi-square	65.26***	
Hosmer–Lemeshow goodness-of-fit	0.634	
Overall % of correct predictions (constant only)	57.9	
Overall % of correct predictions	80.2	
ROC, Area under the Curve	0.888	
* Significance at 10%, ** Significance at 5%, *** Significance at 1%. N=121		

Table 5.18: Results of 2-way interaction LR Model-4 for product innovation

Figure (5.8) shows the logit plot against the predicted probability of product innovation in Model 4. Additionally, the results in table (5.18) show the effect of the interaction term (Betweenness Centrality by Strong ties), which exerted a positive and significant relationship with firms' product innovation at the 5% level.

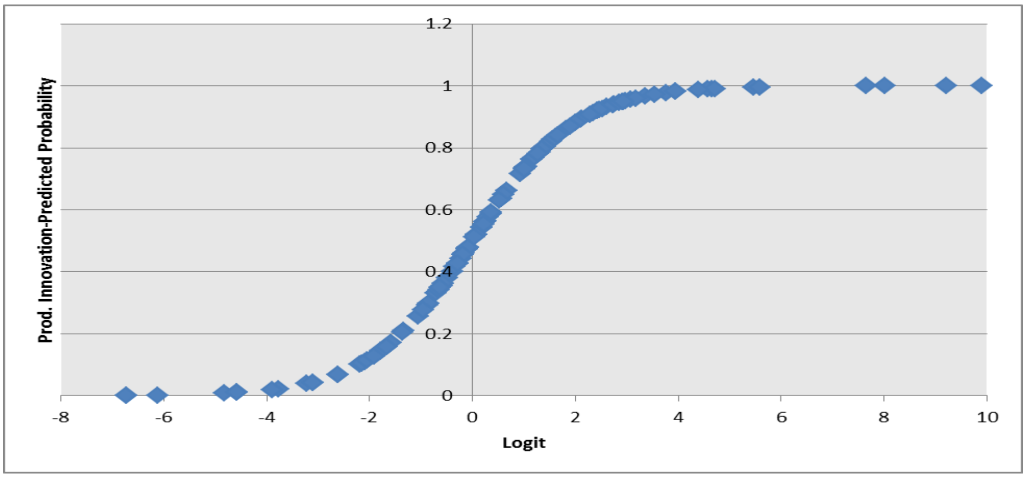

Figure 5.8: Logit plot against the predicted probability of product innovation in Model 4 (2-way interaction)

Another interaction term showed a significant relationship with firms' product innovation at the 5% level; (Network Density by Continuity) term showed a negative relationship with product innovation.

5.13.2: 3-way interactions

As discussed in step 5, for 3-way interaction between variables, a 20% level of significance was selected to be the base for the inclusion of interaction terms in the LR model. The results in Table (5.10) show the results of the individual interaction terms assessment. The 3-way interaction terms (Betweenness Centrality by Network Density by Tie Strength (Weak)), (Betweenness Centrality by Network Density by Partner Diversity), and (Betweenness Centrality by Strengthen the ties by Tie Strength (Weak)) were introduced to the main effect model in Table (5.17) to test the joint effects of network relational and structural variables on product innovation. The results of this are shown in table (5.19). Additionally, the logit plot against the predicted probability of product innovation for 3-way interaction model

(Model-5) is presented in figure (5.9). The results in table (5.19) show the effect of the interaction terms between the three variables (Betweenness Centrality by Network Density by Tie Strength (Weak)) that have a negative and significant relationship with firms' product innovation at the 5% level.

Model-5 3-way interactions	Exp(B) OR		S.E.
Sector_Type (1)	4.835	**	0.655
Firm_Export (1)	2.544		0.667
Strengthen_theTies (1)	1.615		1.252
Ties Strength (1) (Weak Ties)	2.722		1.17
Continuity (1)	1.86		0.633
Partners _Diversity (1)	1.503		1.048
Network Density	1.022		0.016
Betweenness Centrality	0.962		0.188
Betweenness Centrality by Network Density	1.026	**	0.012
Betweenness Centrality by Ties Strength (1) (Weak Ties)	1.184		0.186
Network Density by Ties Strength (1) (Weak Ties)	1.029		0.022
Betweenness Centrality by Network Density by Ties Strength (1) (Weak Ties)	**0.97**	**	0.012
Betweenness Centrality by Partners _Diversity (1)	1.037		0.154
Network Density by Partners _Diversity (1)	0.991		0.019
Betweenness Centrality by Network Density by Partners _Diversity (1)	1.003		0.004
Betweenness Centrality by Strengthen_theTies (1)	0.931		0.235
Strengthen_theTies (1) by Ties Strength (1) (Weak Ties)	1.481		1.838
Betweenness Centrality by Strengthen_theTies (1) by Ties Strength (1) (Weak Ties)	1.046		0.294
LR-Model assessment tests			
model Chi-square	72.251***		
Hosmer–Lemeshow goodness-of-fit	0.732		
Overall % of correct predictions (constant only)	57.9		
Overall % of correct predictions	83.5		
ROC, Area under the Curve	0.905		
* Significance at 10%, ** Significance at 5%, *** Significance at 1%. N=121			

Table 5.19: Results of 3-way interaction LR model on firms' product innovation (Model-5)

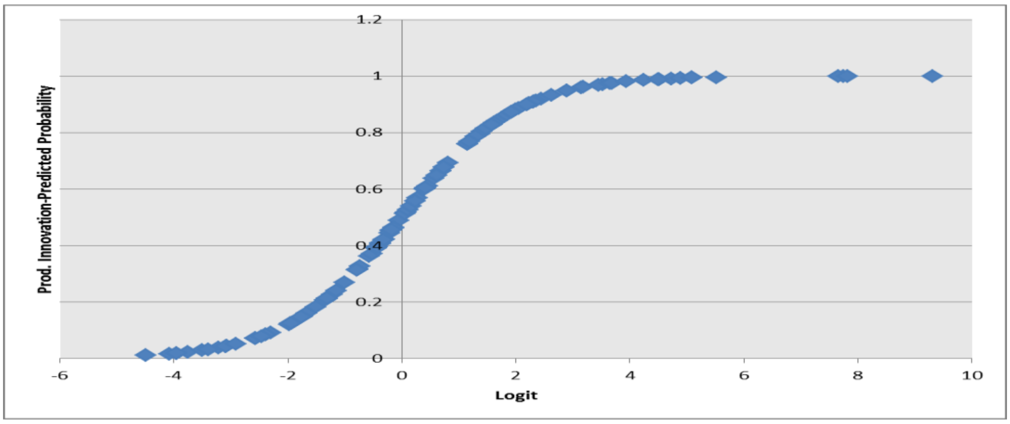

Figure 5.9: Logit plot against the predicted probability of product innovation in Model 5 (3-way interaction)

5.14: Dependent variable (DV): process innovation

Following the same procedure of purposeful selection of predictors (Independent Variables) outlined in section (5.9), the main effect variables in the analysis of the impact of network relational and structural characteristics on firms' process innovation were identified.

Step 1: the first step is to fit a logistic regression model for each covariate (control and independent variables). This is shown in Table (5.20).

Variables	B	S.E.	Sig.	Exp(B)
Firm_Age	-0.006	0.015	0.692	0.994
Sector_Type (Service)	0.43	0.449	0.337	1.538
Firm_Size (Medium)	-0.033	0.399	0.934	0.968
Firm_Group (Part of Group)	0.391	0.397	0.325	1.478
Firm_Export (export)	0.268	0.431	0.534	1.307
Strengthen the Ties (Strengthen)	0.544	0.446	**0.223**	1.722
Continuity	0.519	0.406	**0.201**	1.681
Ties Strength (Strong Ties)	-1.272	0.428	**0.003**	0.28
Partners _Diversity	0.664	0.4	**0.097**	1.943
Network Density	0.019	0.007	**0.013**	1.019
Betweenness Centrality	0.063	0.029	**0.032**	1.065

Table 5.20: Results of fitting logistic regression models, N=121 (Note: each row in the table presents the results for the estimated regression coefficient from a model containing only that variable)

Step 2: The second step is to fit the logistic model containing all variables that are significant at the 25% level. Clearly from Table (5.20), none of the control variables are significant at the specified level. The independent variables (strengthen the ties, tie-strength (weak and strong), continuity, partner diversity, density, and betweenness centrality) are all significant at the recommended 25% significance level. Table (5.21) below shows the result of the fitted model.

Main Effects Model				
Variables	**B**	**S.E.**	**Sig.**	**Exp(B)**
Strengthen the Ties (Strengthen)	0.422	0.495	0.394	1.525
Ties Strength (Strong Ties)	-1.183	0.465	**0.011**	0.307
Continuity	0.539	0.47	0.252	1.714
Partners _Diversity	0.605	0.456	0.184	1.831
Network Density	0.019	0.007	**0.008**	1.02
Betweenness Centrality	0.07	0.036	**0.047**	1.073
Constant	-0.385	0.655	0.557	0.681

Table 5.21: Results of fitting the logistic model with all variables significant at the 0.25 level (Main Effects Model), N=121

Step 3: Next, it was assessed whether any of the removed variables (sector, size, age, export, and group) in step 2 were confounders. The results of testing for confounders are shown in appendix B. The results show that the largest percentage change is 17% for the variable strengthen of tie, which doesn't exceed the criterion of 20% change according to the recommendations of Hosmer et al. (2013).

Step 4: The logistic model in Table (5.21) is the preliminary main effects model for process innovation, including the essential variables. In this step, we check the assumption that the scale of the logit for continuous variables (network density and betweenness centrality) increases and/or decreases linearly as a function of the dependent variable (process innovation).

First, for the variable network density:

The logistic regression with the variable 'network density', as shown in table (5.22), was run to obtain the logit of the logistic regression model equation:

Variables in the Equation				
Variables	**B**	**S.E.**	**Sig.**	**Exp(B)**
Network Density	0.019	0.007	0.013	1.019
Constant	0.235	0.257	0.361	1.265

Table 5.22: LR for network density variable (IV) and process innovation (DV)

The logit equation is in the form

$y = \beta_o + \beta_1 X$;

Where; β_o is the constant, β_1 is the estimated coefficient of a variable, and X is a given variable value.

The logit equation for the variable in hand (density) is:

y=0.235+0.019*Network Density

Figure (5.10) shows the plotted network density versus the logit scale.

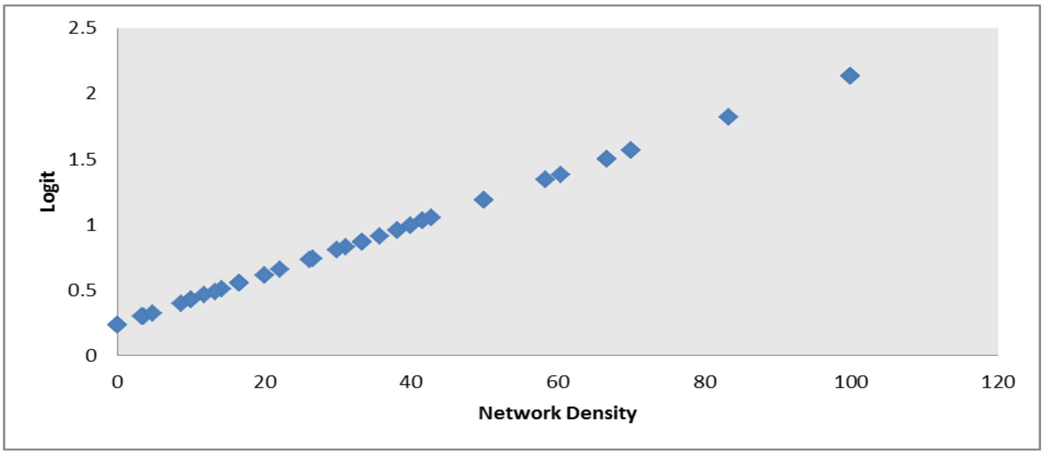

Figure 5.10: Plot of estimated logistic regression coefficients of network density versus logit

Secondly, the logistic regression coefficients of the variable network betweenness centrality were estimated:

This followed the same procedure as for network density. The logistic regression for betweenness centrality, as shown in table (2.32), was run to test for linearity. The estimated logistic regression is shown on table (5.23) for betweenness centrality:

Variables in the Equation				
Variables	**B**	**S.E.**	**Sig.**	**Exp(B)**
Betweenness Centrality	0.063	0.029	0.032	1.065
Constant	0.312	0.251	0.215	1.366

Table 5.23: LR for betweenness centrality variable (IV) and process innovation (DV)

The logit equation for the variable betweenness centrality is

Y= 0.312+.063* betweenness centrality

Figure (5.11) shows the plotted network betweenness centrality versus logit scale.

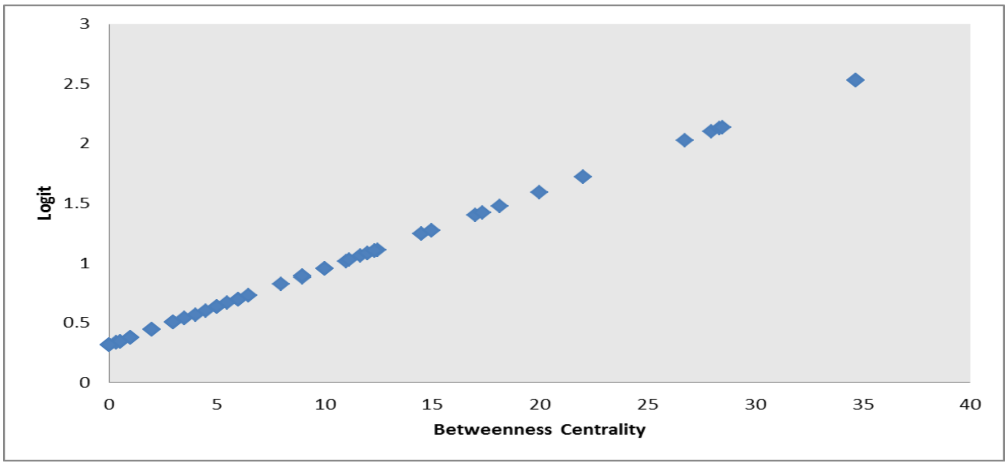

Figure 5.11: plot of estimated logistic regression coefficients of betweenness centrality versus logit scale

Step 5:

In this final step in the purposeful selection procedure, the possible interactions among the main affects variables were explored. For interaction assessment, network relational and structural interaction terms were introduced one by one to the main effects model in Table (5.21). For the purpose of this research, 2-way and 3-way interactions among all independent variables were examined for possible interaction effects. The results of assessing the significance of the possible interaction terms are summarised in Table (5.24) for 2- way interaction. The results indicate three interaction terms (Strengthen the ties by Tie Strength (Strong)), (Network Density by Tie Strength (Strong)), (Network Density by Continuity) and were significant at the 25% level.

2-way interaction assessment	B	S.E.	Sig.	Exp(B)
Main effects model				
Network Density by Strengthen the Ties (Strengthen)	0.013	0.024	0.58	1.013
Betweenness Centrality by Strengthen the Ties (Strengthen)	-0.014	0.076	0.85	0.986
Strengthen the Ties (Strengthen) by Ties Strength (Strong Ties)	2.396	1.023	**0.019**	10.978
Strengthen the Ties (Strengthen) by Continuity	-0.724	1.052	0.491	0.485
Partners _Diversity by Strengthen the Ties (Strengthen)	0.914	1.02	0.37	2.495
Network Density by Ties Strength (Strong Ties)	-0.028	0.021	**0.188**	0.972
Betweenness Centrality by Ties Strength (Strong Ties)	0	0.071	0.997	1
Ties Strength (Strong Ties) by Continuity	0.856	1.069	0.423	2.353
Partners _Diversity by Ties Strength (Strong Ties)	0.988	0.953	0.3	2.686
Network Density by Continuity	-0.026	0.018	**0.156**	0.975
Betweenness Centrality by Continuity	0.083	0.077	0.282	1.087
Partners _Diversity by Continuity	-0.712	0.995	0.474	0.491
Network Density by Partners _Diversity	-0.009	0.015	0.568	0.991
Betweenness Centrality by Partners _Diversity	-0.022	0.074	0.77	0.979
Betweenness Centrality by Network Density	0.001	0.002	0.561	1.001

Table 5.24: Addition of the 2-way interactions to the main effects model, N=121 (Note: each interaction term in the table presents the results for the estimated regression coefficient from a model containing only that term)

For 3-way interaction terms, Table (5.25) summarises the interaction terms between (Betweenness Centrality by Network Density by Tie Strength (Weak)), and (Betweenness Centrality by Strengthen the ties by Continuity) at the selected significance level of 20%.

3-way interaction assessment Main effects model	**B**	**S.E.**	**Sig.**	**Exp(B)**
Betweenness Centrality by Network Density by Strengthen the Ties (Strengthen)	-0.003	0.004	0.404	0.997
Betweenness Centrality by Network Density by Ties Strength (Weak Ties)	-0.007	0.004	**0.117**	0.993
Betweenness Centrality by Network Density by Continuity	-0.003	0.004	0.446	0.997
Betweenness Centrality by Network Density by Partners _Diversity	0.003	0.004	0.458	1.003
Strengthen the Ties (Strengthen) by Ties Strength (Weak Ties) by Continuity	-0.749	1.884	0.691	0.473
Partners _Diversity by Strengthen the Ties (Strengthen) by Ties Strength (Weak Ties)	1.881	2.21	0.395	6.558
Partners _Diversity by Strengthen the Ties (Strengthen) by Continuity	-1.616	1.972	0.413	0.199
Network Density by Strengthen the Ties (Strengthen) by Continuity	-1.689	604.512	0.998	0.185
Network Density by Strengthen the Ties (Strengthen) by Ties Strength (Weak Ties)	-0.118	0.059	0.046	0.889
Network Density by Partners _Diversity by Strengthen the Ties (Strengthen)	0.013	0.047	0.781	1.013
Betweenness Centrality by Strengthen the Ties (Strengthen) by Ties Strength (Weak Ties)	-0.121	0.178	0.495	0.886
Betweenness Centrality by Strengthen the Ties (Strengthen) by Continuity	-0.33	0.207	**0.11**	0.719
Betweenness Centrality by Partners _Diversity by Strengthen the Ties (Strengthen)	-0.076	0.171	0.656	0.927
Network Density by Ties Strength (Weak Ties) by Continuity	-3.187	449.949	0.994	0.041
Network Density by Partners _Diversity by Ties Strength (Weak Ties)	0.044	0.044	0.319	1.045
Betweenness Centrality by Ties Strength (Weak Ties) by Continuity	-0.244	0.213	0.253	0.784
Betweenness Centrality by Partners _Diversity by Ties Strength (Weak Ties)	-0.126	0.183	0.491	0.881
Network Density by Partners _Diversity by Continuity	0.135	0.136	0.322	1.145
Betweenness Centrality by Partners _Diversity by Continuity	0.01	0.185	0.957	1.01
Partners _Diversity by Ties Strength (Weak Ties) by Continuity	-1.338	2.257	0.553	0.262

Table 5.25: Addition of the 3-way interactions to the main effects model, N=121 (Note: each interaction term in the table presents the results for the estimated regression coefficient from a model containing only that term (lower order term and higher order terms))

5.15: Network Relational, structural and main effects model, 2-way and 3-way interaction models (Models 6,7,8,9, & 10)

This section outlines the results of the logistic regression model of network relational, structural, main effects model, 2-way and 3-way interaction characteristics and its potential impact on firms' process innovation. Table (5.26) and Table (5.27) show the LR sample and categorical variables coding in the model. Table (5.28) summarises the logistic regression outcome of network relational, structural, main effects model, and 2-way and 3-way interaction terms. In addition, the necessary model goodness-of-fit tests are included in the table, while the details of these reliability assessment tests are shown in Appendix B.

Case Processing Summary			
Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	121	100
	Missing Cases	0	0
	Total	121	100
Unselected Cases		0	0
Total		121	100

Table 5.26: Included sample in LR model

Categorical Variables Codings			
			Parameter coding
		Frequency	(1)
Partners _Diversity	No Partner Diversity	42	0.000
	Partner Diversity	79	1.000
Ties Strength	Weak Ties	54	0.000
	Strong Ties	67	1.000
Continuity	Non-Continuity	39	0.000
	Continuity	82	1.000
Strengthen_the Ties	No Strengthen of Ties	85	0.000
	Strengthen of Ties	36	1.000

Table 5.27: The categorical variables coding in the model

Variables	Model-6 Relational (R) Characteristics		Model-7 Structural (S) Characteristics		Model-8 Main Effects Model (RS)		Model-9 2-way interaction		Model-10 3-way interaction	
	Exp(B)	S.E.	Exp(B)	S.E.	Exp(B)	S.E.	Exp(B)	S.E.	Exp(B)	S.E.
Strengthen_the Ties(1)	1.59	0.471			1.525	0.495	0.354	0.817	0.766	1.782
Ties Strength(1) (Strong Ties)	**0.28** **	0.442			**0.307** **	0.465	0.303 *	0.712	1.303	1.075
Continuity(1)	1.54	0.434			1.714	0.47	3.779 **	0.665	1.022	0.822
Partners _Diversity(1)	**2.24** *	0.43			1.831	0.456	1.504	0.481	1.196	0.52
Network Density			**1.021** **	0.007	**1.02** ***	0.007	1.066 **	0.026	1.145 *	0.079
Betweenness Centrality			**1.082** **	0.033	**1.073** **	0.036	1.072 *	0.037	1.172	0.172
Strengthen_the Ties(1) by Ties Strength(1) (Strong Ties)							**11.18** **	1.069	3.435	1.54
Strengthen_the Ties(1) by Tie_Strength(1) (Weak Ties)							**0.089** **	1.069		
Network Density by Ties Strength(1) (Strong Ties)							0.969	0.023	0.881	0.079
Network Density by Continuity(1)							0.975	0.018		
Betweenness Centrality by Ties Strength(1) (Strong Ties)									0.681 *	0.213
Betweenness Centrality by Network Density by Ties Strength(1) (Strong Ties)									**1.013** **	0.006
Betweenness Centrality by Network Density									0.994	0.004
Network Density by Strengthen_the Ties(1)									0.912	0.078
Network Density by Strengthen_the Ties(1) by Ties Strength(1) (Strong Ties)									1.112	0.086
Betweenness Centrality by Strengthen_the Ties(1) by Continuity(1)									**0.628** *	0.282
Betweenness Centrality by Strengthen_the Ties(1)									1.19	0.188
Betweenness Centrality by Continuity(1)									1.332 *	0.149
Strengthen_the Ties(1) by Continuity(1)									2.134	1.747
LR-Model assessment tests										
model Chi-square	15.234***		15.397***		26.812***		36.722***		47.059***	
Hosmer–Lemeshow goodness-of-fit	0.63		0.735		0.054		0.052		0.225	
Overall % of correct predictions (constant only)	66.9		66.9		66.9		66.9		66.9	
Overall % of correct predictions (all varables)	72.7		71.9		77.7		78.5		79.3	
ROC, Area under the Curve	0.71		0.716		0.759		0.811		0.842	
* Significance at 10%, ** Significance at 5%, *** Significance at 1%. N=121										

Table 5.28: Results of LR modelling of network relational, structural, main effects model, 2-way and 3-way interaction models

5.16: Hypothesis testing results

After running the analysis and examining the reliability and goodness-of-fit of the LR models, the next step in the analysis is to examine the outcomes of the LR analysis and find supporting evidences for the proposed theoretical model. In LR analysis, the Odds Ratio, denoted (OR), is widely used as a measure of association between independent and dependent variables. It measures how likely or unlikely (in terms of odds) it is for the outcome to occur in the presence of predictors (i.e. independent variables). For categorical independent variables, OR measures the association of how likely the outcome (e.g. product innovation) is to occur among those subjects (e.g. firms) with the value of 1 (e.g. diversity of partners) as compared to those subjects with the value of 0 (e.g. no diversity of partners) (Hosmer et al., 2013). For continuous independent variables, OR is the amount of change in the dependent variable associated with a change in one unit in the independent variable (Hosmer et al., 2013; Field, 2009). A similar approach was used in the innovation management field (Vega-Jurado et al., 2008; Nieto and Santamaria, 2007; Amara and Landry, 2005; Tether, 2002).

Logistic regression (LR) modelling was implemented to test the impact of network relational embeddedness and structural embeddedness variables on firms' product and process innovation. Additionally, the significance level of each independent variable is assessed in order to test the conceptual research model. The following sections show the hypothesis testing for both product and process innovation, which was based on the results provided by the logistic regression main effects Models 3 and 6, respectively. This selection allows taking into account both network relational embeddedness and structural embeddedness variables, allowing the interpretation of the effect of each variable, while controlling for others (Keith, 2006).

5.17: Hypothesis testing results for firms' product innovation

5.17.1: Main effects model analyses (Model 3)

As outlined in the purposeful selection of predictors' method section (5.9), the main effects model (Model 3) in table (5.17) shows the combined effect of network relational and structural characteristics on product innovation. The first hypothesis (H1a) proposed that the strong ties of an ego-firm network are negatively related to product innovation; this was found to be not significant (OR=0.474, ρ>0.05). Therefore, hypothesis (H1a) was not supported. Concerning hypothesis (H2a), the positive relation between strengthen of ties and product innovation was found to be partially supported (RO= 2.808, ρ=0.064). Similarly, repeated collaboration (continuity) was found to be positively related to product innovation (RO= 2.609, ρ= 0.069) and hypothesis (H3a) was partially supported. In contrast, hypothesis (H4a), which stated that there is a positive relationship between diversity of partners and firms' product innovation, was supported since the result of logistic regression is both positive and significant (OR=2.891, ρ< 0.05). Hence, an ego-firm that has diverse partners on its network is 2.9 times (189%) more likely to develop product innovation than a firm that does not have partner diversity in their network.

For network structural variables, the regression analysis confirms the expected positive association between network density and product innovation (OR=1.026, ρ< 0.05). This implies that an increase by one unit in an ego-firm's network density increases the likelihood of product innovation by 1.026 times (2.6%), which is in support of hypothesis (H5.1, a) and rejects hypothesis (H5.2, a). This is consistent with the network closure (dense network) argument by Colman (1988, 1990) and contrary to Burt's, that of sparse network (structural holes) (Burt, 1992, 2000). Lastly, the results found that there is a positive and significant relationship between betweenness centrality and firms' product innovation. An increase by one unit of an ego-firm's network betweenness centrality increases the likelihood of product innovation by 1.161 times (16%), (OR=1.161, ρ< 0.05) which supports hypothesis (H6a).

5.17.2: Interaction effects analysis (Models 4 and 5)

The results of logistic regression indicate that there are several network relational and structural embeddedness variables that have significant interaction effects on firms' product innovation.

First, 2-way interaction:

Considering the 2-way interaction terms, as indicated by Model 4 in table (5.18), betweenness centrality interaction with strong ties indicates a significant interaction effect at the 5% level. Hypothesis (H7.1) predicts a positive effect between the interaction of relational embeddedness characteristics and betweenness centrality. The logistic regression results found that the interaction effect between betweenness centrality and strong ties is positively and significantly related to firms' product innovation (OR=1.296, ρ< 0.05). Hence, the interaction effect of betweenness centrality and strong ties on the ego-firm is 1.296, or (30%), times more likely to produce product innovation than the interaction effect between betweenness centrality and weak ties. Therefore, hypothesis (H7.a) was only supported for the interaction term between betweenness centrality and strong ties.

The second 2-way interaction term that was found to be significant was that between network density and repeated collaboration (continuity). The interaction effect has a negative and significant effect on firms' product innovation (OR=0.949, ρ< 0.05). Therefore, focal-firm is affected by the interaction between density and continuity to the extent of 5% (1-0.949) less likelihood to produce product innovation than firms with interaction between density and non-repeated collaboration (non-continuity).

Furthermore, the results indicate that the third 2-way interaction effect between density and strengthen of ties was negative, but not significant (OR=0.967, ρ>0.05). Therefore, for 2-way interaction, hypothesis (H8.a) was only supported for the interaction effects on firms' product innovation between density and repeated collaboration (continuity).

Second, 3-way interaction:

As shown in table (5.19) for Model 5, the results indicated that the only significant 3-way interaction was between betweenness centrality, density and strong ties; this was positive and significantly related to firms' product innovation (OR= 1.031, ρ< 0.05). This suggests that the interaction effect of betweenness centrality, density and strong ties on the ego-firm is 1.031 (3%) times more likely to produce product innovation than the effect of the interaction on the ego-firm between betweenness centrality, density and weak ties.

The other 3-way interaction terms (i.e. between betweenness centrality, density and partner diversity, and between betweenness centrality, strengthen the ties, and strong ties) showed insignificant effects on firms' product innovation. Therefore, the findings suggest that hypothesis (H10.a) was only supported for the interaction term between betweenness centrality, density and strong ties.

5.18: Control variables analysis

For the analysis of product innovation, the study controlled for the effect of sector type (manufacturing and service firms) and firms' export capability on product innovation. The results for the main effects model (Model 3) in table (5.17) showed that the control variable for service firms are 4.2 times more likely to effect product innovation than manufacturing firms (OR= 4.235, ρ< 0.05). Furthermore, export capabilities show a weak and positive association with firms' product innovation (OR= 2.807, ρ= 0.058), in which the ego-firm that is able to export is 2.8 times likelier to have an effect on firms' product innovation, when compared to non-exporting firms.

5.19: Hypothesis testing results for firm's process innovation

5.19.1: Main effects model analyses (Model 8):

The logistic regression results of firms' process innovations are outlined in table (5.28). The main effects model (Model 8) shows the joint effect of network relational and structural characteristics on firms' process innovations. Hypothesis (H1b) was supported since an ego-firm's strong ties are negative and significantly related to their process innovation (OR= 0.307, $\rho<0.05$). Moreover, there is a 69% (1-0.307) decrease in the likelihood of an ego-firm with strong ties producing process innovation than an ego-firm with weak ties. On the contrary, the results showed no support for the effects of strengthen the ties (H2b), repeated collaboration (continuity) (H3b), and diversity of partners (H4b) on firms' process innovation, with (RO= 1.525, $\rho>0.05$), (RO= 1.714, $\rho>0.05$), and (RO= 1.831, $\rho>0.05$), respectively.

The structural characteristics of the ego-firm network were found to have positive and significant impacts on firms' process innovations. Network density is positively and significantly related to process innovation (OR=1.020, $\rho< 0.05$), supporting hypothesis (H5.1, b) and rejecting hypothesis (H5.2, b). Thus, an increase by one unit in an ego-firm's network density leads to a 1.02 times (2%) increase in the likelihood that their process innovation will improve. These findings, like those in the product innovation analysis, are consistent with the network closure (dense network) argument by Colman (1988, 1990). Betweenness centrality was found to have a positive and significant effect (OR=1.073, $\rho< 0.05$) on firms' process innovation in support of hypothesis (H6b). This means there is a 7.3%, or 1.073 times, likelihood of producing process innovation with every one unit increase in network betweenness centrality.

5.19.2: Interaction effects analysis (Models 9 and 10)

First, 2-way interaction:

Table analysis (5.28) shows Model 9 for the 2-way interaction effect on firms' process innovation. The interaction effect between strengthen the ties and weak ties is negatively and significantly related to firms' process innovation (OR= 0.089, $\rho < 0.05$). Therefore, hypothesis (H9, b) was not supported and the focal–firm is 91% less likely to produce process innovation due to the interaction between strengthen the ties and weak ties, than firms with interaction between strengthen the ties and strong ties. Moreover, the other investigated 2-way interaction terms in Model 9 (i.e. between density and strong ties, and between density and repeated collaboration (continuity)) showed negative, but insignificant relationships with process innovation; hence, there is no supporting evidence for these interaction terms.

Second, 3-way interaction:

Model 10 in table (5.28) illustrates that the 3-way interaction effect between betweenness centrality, density and strong ties is positively and significantly related to firms' process innovation (OR= 1.013, $\rho < 0.05$), which supports hypothesis (H10, b). This indicates that the interaction effect of betweenness centrality, density and strong ties on the ego-firm makes them 1.013, or 1%, times more likely to yield process innovation than the effect of the interaction on the ego-firm between betweenness centrality, density and weak ties.

The other 3-way interaction effect is between betweenness centrality, strengthen the ties and repeated collaboration (continuity), which was partially significant and negatively related to firms' process innovation (OR= 0.628, $\rho = 0.099$). Similar results were found when examining the combination of other variables on the interaction terms (i.e. running the logistic regression for the interaction term betweenness centrality, no strengthen of the ties, and no continuity (changing the reference case (i.e. the model coding)). Moreover, running further logistic regression with different coding for strengthen the ties and no continuity, and later to no strengthen of the ties with continuity, then testing the interaction terms with betweenness centrality, yields a positive and significant relation for firms' process innovation (OR= 1.593, ρ= 0.099). Hence, Hypothesis (H10, b) is partially supported for the 3-way interaction effect between betweenness centrality, no strengthen of the ties and repeated collaboration (continuity). This implies that the interaction terms between betweenness centrality, strengthen the ties and repeated collaboration (continuity), or between betweenness centrality, no strengthen of the ties and no repeated collaboration (continuity) make the focal-firm about 37% (1-0.628) less likely to produce process innovation than a focal-firm that has an interaction effect between betweenness centrality, strengthen the ties, and no continuity, or an interaction effect between betweenness centrality, no strengthen of the ties, and continuity of collaboration. Finally, the analysis of the logistic regression found no support for the effect of the 3-way interaction between network density, strengthen the ties and strong ties on firm's process innovation.

5.20: Conclusion:

This chapter provided a detailed discussion of the statistical method and analysis in this research. The findings were presented for each model, from the linear effect of relational and structural network embeddedness to the interactive effect of these characteristics on firms' product and process innovation. The final section of this chapter provided a detailed explanation of the tested hypotheses of the study. Figure (5.12) below presents the final conceptual model for the research, which includes the dependent (i.e. product and process innovation), independent variables (e.g. strong ties, network density, etc.) and control variables (e.g. sector and export), and the links between them. Meanwhile, figures (5.13) and (5.14) show the results of hypothesis testing of the 2-way interaction and 3-way interaction final effect models, respectively. Additionally, a summary of the tested hypotheses and the outcome of logistic regression analysis are presented in table (5.29).

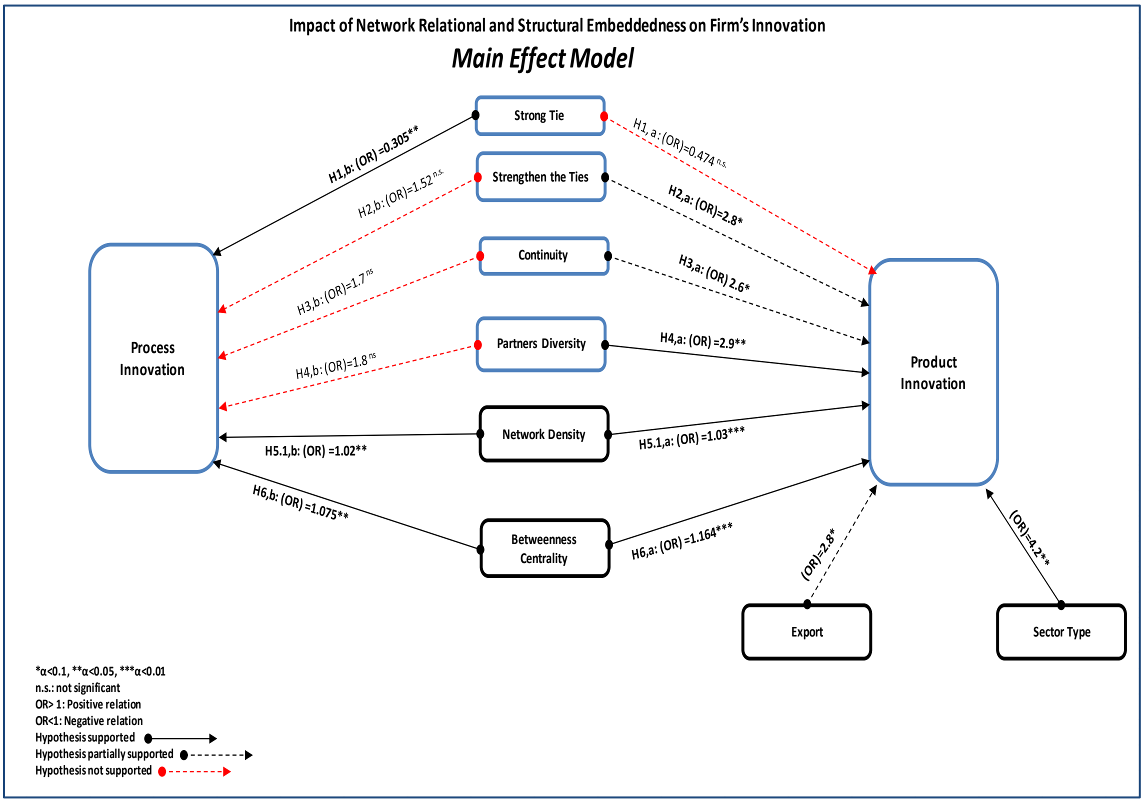

Figure 5.12: Final main effect model

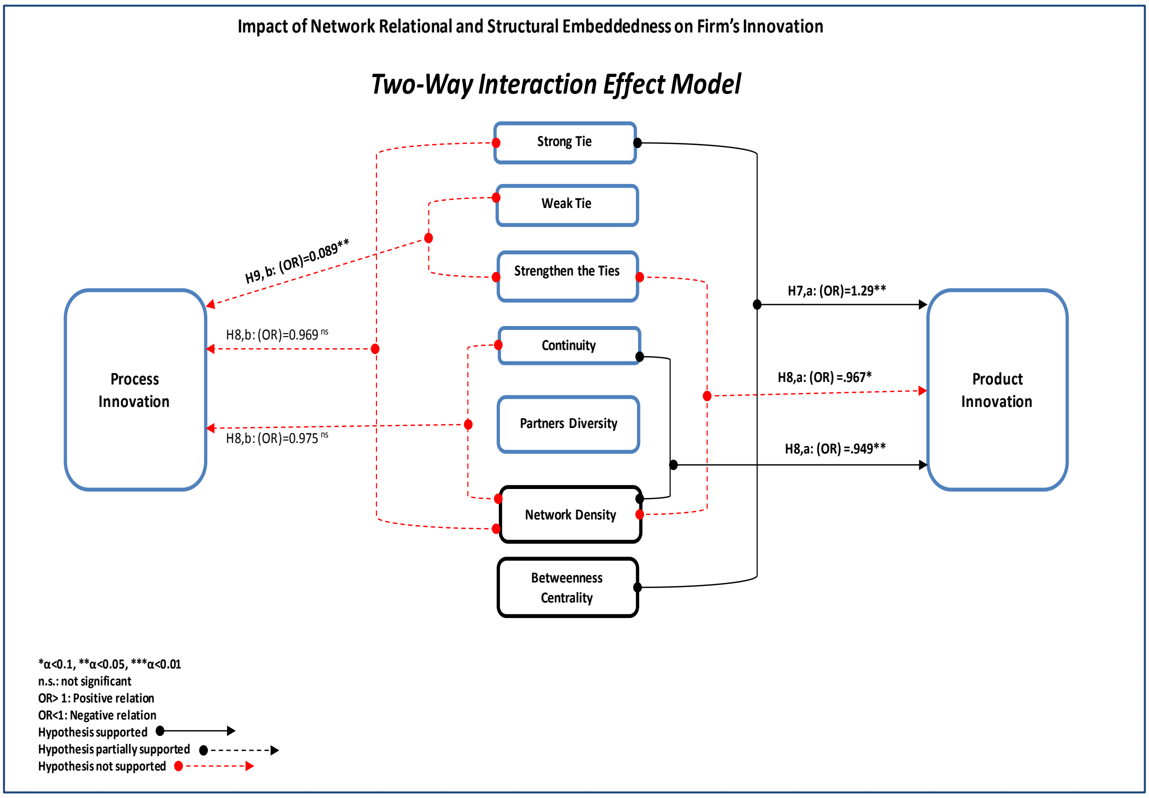

Figure 5.13: Final model of the 2-way interaction effect

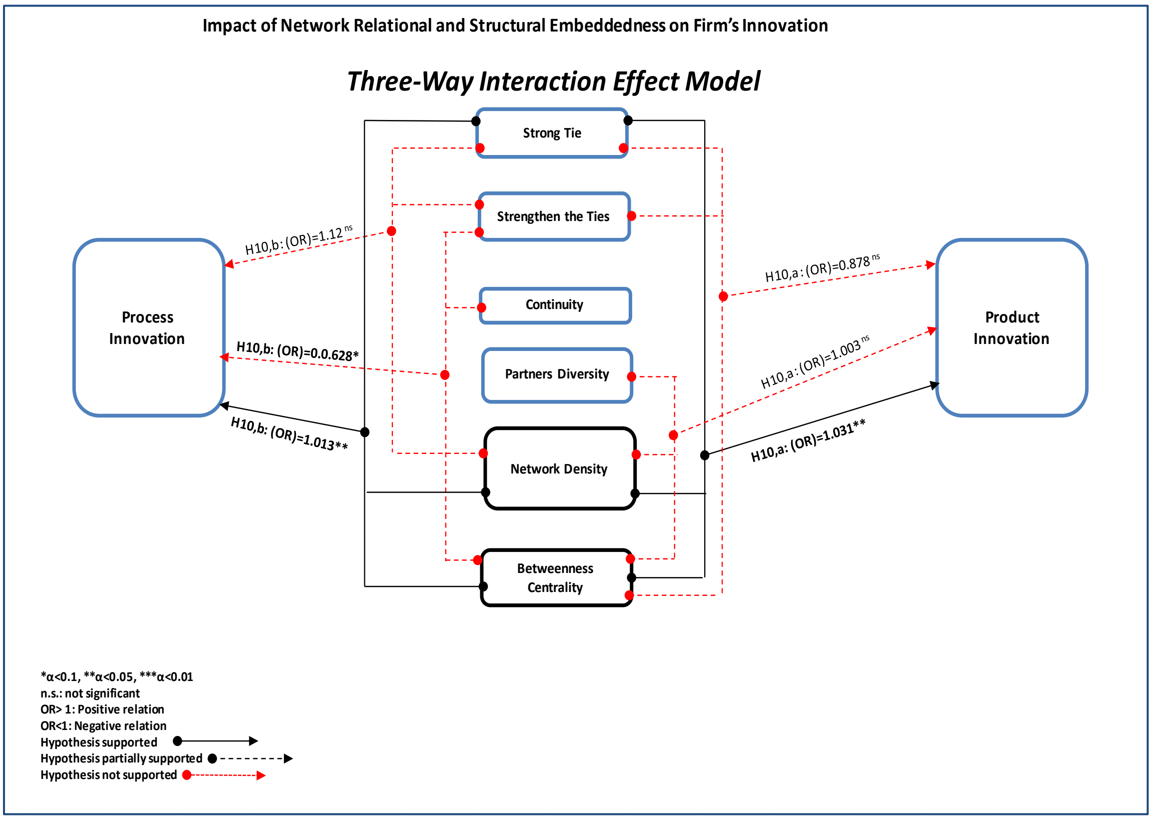

Figure 5.14: Final model of the 3-way interaction effect

No.	Research Hypothesis	Dependent Construct	Effect sign	Results of hypotheses testing
H1	Strong ties in an ego-firm network are negatively related to firm's innovation	a) Product innovation,	-	Not supported
		b) Process innovation.	-	Supported
H2	Strengthen the ties in an ego-firm network is positively related to firm's innovation	a) Product innovation,	+	partially supported
		b) Process innovation.	+	Not supported
H3	An ego-firm's repeated collaboration (continuity) is positively related to firm's innovation	a) Product innovation,	+	Partially supported
		b) Process innovation.	+	Not supported
H4	An ego-firm network partners diversity is positively related to firm's innovation	a) Product innovation,	+	Supported
		b) Process innovation.	+	Not supported
H5.1	The increase of an ego-firm's network density is positively related to firm's innovation	a) Product innovation	+	Supported
		b) process innovation	+	Supported
H5.2	The increase of an ego-firm's network density is negatively related to firm's innovation	a) Product innovation,	-	Not Supported
		b) Process innovation.	-	Not supported
H6	The ego-firm network betweenness centrality is positively related to firm's innovation	a) Product innovation,	+	Supported
		b) Process innovation.	+	Supported
H7	The 2-way interaction of Relational Embeddedness characteristics and Structural Embeddedness characteristics in terms of Betweenness Centrality has a positive effect on firm's innovation	a) Product innovation,	+	Only supported for the interaction term between Betweenness centrality and strong ties
		b) Process innovation.	+	No interaction effect was found
H8	The 2-way interaction of relational embeddedness characteristics and structural embeddedness characteristics in terms of the increase of network density has a negative effect firm's innovation	a) Product innovation,	-	· only supported for the interaction term between density and repeated collaboration (continuity) · Not supported for the interaction term between density and strength the ties
		b) Process innovation,	-	· Not supported for the interaction term between density and Strong ties, · Not supported for the interaction term between density and repeated collaboration (continuity)
H9	The 2-way interaction of relational embeddedness characteristics in terms of weak ties and strengthen the ties has a positive effect on firm's innovation	a)product innovation,	+	No interaction effect was found
		b) Process innovation.	+	Not supported
H10	The 3-way interaction of relational embeddedness characteristics and structural embeddedness characteristics has a positive effect on firm's innovation	product innovation,	+	· Supported for the interaction term between betweenness centrality, density and strong ties · Not supported for the interaction effect between betweenness centrality, density and partner diversity, · Not supported for the interaction effect between betweenness centrality, strength the ties, and strong ties
		b) Process innovation.	+	· Supported for interaction effect between betweenness centrality, density and strong ties · Partially supported for the interaction effect between betweenness centrality, no strength of the ties and repeated collaboration (continuity). · Not supported for the 3-way interaction effect between network density, strengthen the ties and strong ties

Table 5.29: Summary of research hypotheses, dependent and independents variable

Chapter 6

Discussion

6.1: Introduction

The aim of this chapter is to discuss the main findings of this study, and address how they meet the objectives and research question. This chapter describes and explains in detail the research results, and their connections and contradictions to extant studies.

The present study was motivated by the desire to understand the possible impact of firms' network embeddedness, in terms of their relational and structural characteristics, on types of innovation (product and process innovation) in the medium and high technology sectors in the context of emerging economies. Prior studies have noted the importance of firms' network embeddedness and its possible influence of enhancing or hampering their innovation outcomes. Yet, very few studies have explicitly examined the type of effect that these characteristics have on firms' innovation.

The primary focus of this study is to contribute to existing knowledge and to address several gaps identified in the literature. It was evident, as discussed in chapter 2, that there has been little empirical work investigating the impact of network relational embeddedness and structural embeddedness characteristics on innovation outcomes at the firm level. In addition, far too little attention has been paid to the relationship between firms' network embeddedness characteristics and their joint effect and firms' innovation types (i.e. product and process innovation) in general, particularly in the context of emerging economies. Therefore, the present study attempts to contribute to this area of research through the conceptual framework model shown in Figure (6.1), and its main objective is to answer the central question in this thesis:

To what extent do firms' network embeddedness characteristics (i.e. relational and structural embeddedness characteristics) impact their innovation outcomes (i.e. product and process innovation)?

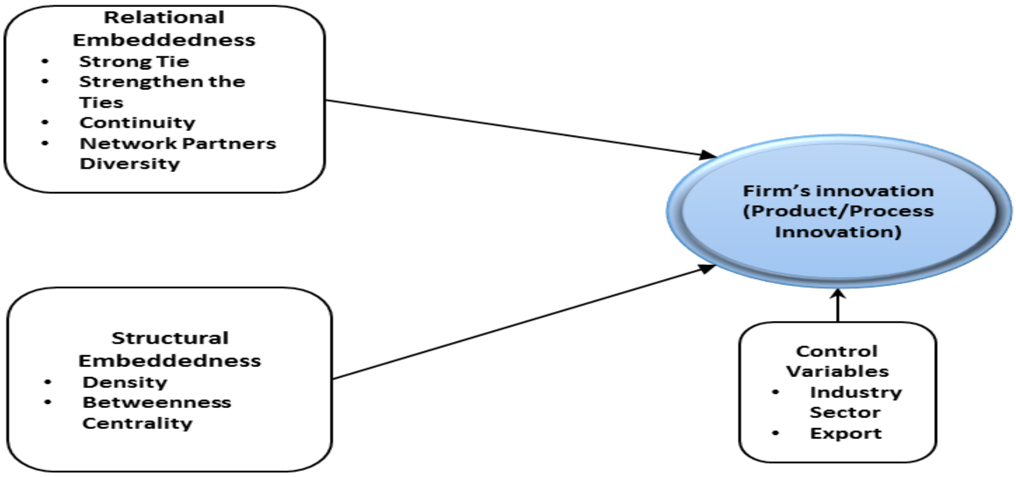

Figure 6.1 Overview of the conceptual research model

6.2: Discussion of statistical analysis

This section presents the results of testing the research hypotheses, which are critically discussed in details and in light of the current literature supporting and/or contradicting views. In order to address the knowledge gaps in the extant literature, ten hypotheses were developed and proposed. Several hypotheses related to the possible direct impact of firms' network relational and structural embeddedness characteristics on firms' product and process innovation (H1-H6). The remainder address the combined effects of network relational and structural embeddedness characteristics (H7-H10), in order to investigate and assess the interaction effects of different combinations of network aspects on firms' product and process innovation. In the following section, these hypotheses and findings related to them are discussed in detail.

6.2.1: Strength of ties and firms' product and process innovation

First, for product innovation, hypothesis (H1a):

Hypothesis (H1a) predicted a negative relationship between strong ties and product innovation, which was not supported by the data (OR=0.474, $\rho>0.05$). This study found that the effect of strength of network relational embeddedness aspects in terms of strong/weak ties on firms' product innovation was not significant. One reason for this might be that including network structural embeddedness variables (i.e. network density and betweenness centrality) in model-3 has produced a latent effect (indirect effect) on the strong/weak ties variable. This can be seen from the significant effect of strong ties in model-1 for network relational embeddedness variables before including network density and betweenness centrality (OR=0.423, $\rho< 0.05$). Unfortunately, the study data has its limitations, in that it doesn't support running other tests to confirm this potential effect. However, it does open an avenue for future research.

Second, for process innovation, hypothesis (H1b):

Hypothesis (H1b) predicted a negative relationship between strong ties and firms' process innovation. The analysis findings provide strong support for this proposition (OR= 0.307, $\rho<0.05$). The effects of strong ties on the focal-firm can reduce the likelihood of developing process innovation by 69% less than the effect of weak ties. Strong ties enable firms to exchange information and tacit knowledge with their network members. They can act as a channel for transmitting knowledge and providing valuable resources among network members. However, in the case of process innovation, relying on strong ties can hinder firms' ability to innovate. This view aligns with Uzzi's (1997) 'over-embeddedness' concept, overreliance on strong ties in a focal-firm network is a source of overlapping information, blocking firms from novel ideas and learning which may threaten innovation, rather than enhancing it. Moreover, innovation opportunities can be captured when receiving valuable and timely information, which a network that is rich in strong ties might seal itself off from (Gulati et al. 2002). This explains the negative effect of strong ties on process innovation, where firms might isolate themselves in a confined set of closed networks, apart from its market and industry (Capaldo, 2007).

The results of this research also suggest that a focal-firm with weak ties is 3.3 times more likely to produce process innovation than firms with strong ties (OR= 3.26, $\rho<0.05$). This is in line with earlier studies, such as Granovetter's (1973) weak ties argument, wherein actors with weak ties benefit more from their network since weak ties tend to connect distance actors in different networks (Granovetter, 1973). They provide the focal actor with access to diverse sources of knowledge and novel information (Gilsing and Duysters, 2008) and provide an advantage, stimulating and speeding up innovation (Capaldo, 2007). This leads the focal-firm to better develop its process innovation since it can learn about and take advantage of new opportunities and resources found outside its immediate network circle, identifying and exploiting these opportunities earlier than others.

From a theoretical perspective, whilst this study didn't confirm the relationship between strong ties and product innovation, its findings are insightful concerning the effect of strong/weak ties on firms' process innovation. The evidence suggests that strong ties could cause a locked-in situation in a closed circle network, which reduces the focal-firm's chances to identify and exploit new process innovation opportunities available in the market and industry. Whereas, weak ties provide a better network position in learning and accessing novel knowledge and valuable resources, which is essential for process innovation.

Hypothesis (H2a), first, for product innovation,

Hypothesis (H2a) argued a positive association between strengthen the ties and firms' product innovation. The LR results indicate that this positive association was limited by its significant statistics, hence, there is weak support for hypothesis (H2a). Recall that the strengthen of the ties construct is the level of frequent interaction between the focal-firm and its partners during the interval specified by the research (2012-2013), as explained in the methodology chapter. Therefore, strengthen the focal-firm's ties was relevant to its product innovation during this period, since it has a positive relationship and was only supported at 10% (RO= 2.808, ρ=0.064). Furthermore, this result is similar in terms of its statistically significant outcome to the one explained in hypothesis (H1a), when considering network relational embeddedness variables in model-1. In the main effect hypothesis testing model (model-3), the introduction and control of structural embeddedness variables (i.e. network density and betweenness centrality) suggests they have a potential indirect effect on the strengthen the ties variable. Hence, further research is recommended.

Second, for process innovation hypothesis (H2b):

In regards to firms' process innovation, the findings did not support the predicted positive relationship between strengthen the ties and firms' process innovation, hypothesis (H2b). Further to examining the remaining models (6-10), strengthen the ties variable didn't show any statistical significance in any model except where it interacts with other variables, which will be discussed shortly. Therefore, as a direct effect, strengthen the ties construct seems not to play any role in explaining firms' process innovation. This is could be due to the nature of the cross-sectional data of this study, were the influence of strengthen the ties might need a longer period of time to capture its direct effect on firms' process innovation. Therefore, this result is limited by its timeframe and encourages further work at different time intervals (e.g. longitudinal study).

6.2.2: Repeated collaboration (continuity) and firms' product and process innovation

First, for product innovation, hypothesis (H3a);

Hypothesis (H3a) predicted a positive relationship between repeated collaboration (continuity) and firms' product innovation. The results for model-3 show that the effect of focal-firm repeated collaboration (continuity) on product innovation was weak and only significant at 10% significance level (RO= 2.609, ρ= 0.069). Despite this small effect, a repeated collaboration factor makes it 2.6 times more likely for firms to develop product innovation than those that do not practice continuous collaboration. In part, this finding is consistent with earlier literature that emphasises the key role that continuous collaboration with different organizations brings to firms' innovation performance (e.g. Nieto and Santamaria, 2007; Soh, 2003). However, given the small effect found in this research, the study cannot claim any support for positive association between repeated collaboration (continuity) and firms' product innovation.

Second, for process innovation hypothesis (H3b):

Hypothesis (H3b) suggested a positive relationship between repeated collaboration (continuity) and firms' process innovation. The LR results of model-8 showed the positive effects of repeated collaboration (continuity) (H3b) on firms' process innovation, but this was not supported since it's statistically insignificant (RO= 1.714, ρ>0.05). After examining the study data, there are two plausible explanations for the lack of support for this hypothesis. This is might be due to the cross-sectional data acquired for the focal-firm in this study, which didn't capture the relationship between repeated collaboration among network members. Another reason could be the type of partners the focal-firm cooperates with. This could be an opportunity to investigate in future research, taking into account the focal-firm's nature of collaboration and the nature of their partners.

6.2.3: Network diversity of partners and firms' product and process innovation

First, for product innovation, hypothesis (H4a):

Hypothesis (H4a) argued that partners' diversity in networks is positively related to firms' product innovation. The LR results for model-3 found that the partners' diversity of a focal-firm is significant and positively related to product innovation, supporting hypothesis (H4a) (OR=2.891, ρ< 0.05). Where focal-firms networks are diverse, they are almost three times more likely to develop product innovation than firms without diverse partners.

The findings of the current research are in accordance with those of Tsai's (2009) study; Tsai suggested that more diverse partners allow access to broad knowledge networks, which increase firms' product innovation. Moreover, this positive effect reflects the findings of Faems et al. (2005), wherein heterogenous networks of collaborative partners are necessary for firms to introduce improved or new products (Faems et al., 2005). Collaborating and working with diverse partners is always linked to better innovation performance since they are a source of heterogeneous knowledge, resources, and know-how (Kim and Lui, 2015; Phelps, 2010; Beckman and Haunschild, 2002; Kaufmann and Todtling, 2001). In addition, being tied to diverse partners has the potential to increase firms' early recognition of business opportunities and novel knowledge (Rodan and Galunic, 2004; Capaldo, 2007). For instance, to be able to innovate and continue innovation, firms in the biotechnology sector maintain close links with diverse organizations, such as university research centres, hospitals, government agencies, etc. (Debresson and Amesse, 1991). Accordingly, firms with different linkages with similar partners may not benefit as much as those who have alliances with diverse partners, which could offer access to a larger pool of knowledge (Baum et al., 2000).

Although the diversity of network partners in this study showed a positive return for the focal firm on its product innovation, some findings in the literature suggest that partners' diversity can have a decreasing return at a certain threshold. For example, this study's findings are in line with the ideas of Laursen and Salter (2006), who suggested that firms that use a higher number of knowledge sources have access to a greater breadth of information for innovation. This study found that the search breadth of firms, which reflects a wide range of knowledge and information sources for innovation, is significant and positively related to product innovation. However, when examining firms with low, moderate, and high diversity of partners, the authors concluded that too much diversity has a negative implication on firms' product innovation (Laursen and Salter, 2006). A similar claim was made by Sampson (2007), concerning the effect of diversity of R&D partnerships on firms' innovation. The author suggested that some diversity between partners leads to better innovation performance. Nevertheless, when partners are highly diverse, firms' learning and knowledge sharing is less valuable and might hinder their innovation (Sampson, 2007). Hence, both studies share the same recommendation in regards to accounting for diverse network governance and the cost involved in maintaining such diversity. Therefore, firms seeking better innovation performance are encouraged to establish a network of relationships with key partners that have rich knowledge and valuable resources.

Second, for process innovation hypothesis (H4b):

Hypothesis (H4b) suggested a positive relationship between partners' diversity in networks and process innovation. The LR for model-8 showed that the effect of partners' diversity was positively related to process innovation. However, this effect was not statistically significant, hence, hypothesis (H4b) was not supported (RO= 1.831, $\rho>0.05$). However, the data suggests partial support for this prediction when considering network relational variables, as in model-6 (RO= 2.244, $\rho=0.06$). Nevertheless, the introduction of structural variables in model-8 seems to reduce the statistical significant of the network diversity effect. Therefore, this study cannot infer any effect for network partners' diversity on firms' process innovation. Further research regarding the role of partner's diversity in a network would be very interesting in the area of process innovation.

6.2.4: Network density and firms' product and process innovation

For product innovation and process innovation, hypothesis (H5.1a&b), (H5.2 a&b):

Hypotheses (H5.1a&b) argued a positive effect of an increase in ego-firm network density on firms' product and process innovation. Whereas, hypotheses (H5.2 a&b) argued that an increase in ego-firm network density is negatively related to firms' product and process innovation. The LR analysis (in model-3 and model-8) confirms the expected positive association between increase in network density and product innovation and process innovation with (OR=1.026, ρ< 0.05) and (OR=1.020, ρ< 0.05), respectively. This implies that an increase by one unit in an ego-firm's network density increases the likelihood of its product innovation by 1.026 times, about (2.6%), which is in support of hypothesis (H5.1, a) and rejects hypothesis (H5.2, a). In addition, an increase by one unit in an ego-firm's network density led to process innovation being 1.02 times (2%) more likely, which is in support of hypothesis (H5.1, b) and rejects hypothesis (H5.2, b). Networks with more interconnectedness between the focal-firm and its partners positively affect the focal-firm's product and process innovation. This study's findings supports Coleman's (1988; 1998; and 1990) network closure (dense network) argument and fails to support Burt's (1992) argument that structural holes (sparse network) has an impact on firms' product and process innovation. From Coleman's (1988; 1998; and 1990) perspective, a focal-actor embedded in a network characterized as being more structurally bonded will benefit from increased trust and cooperation, which in turn enhances the exchange of knowledge and valuable resources amongst network members (Coleman, 1988; 1998; and 1990). In the setting of this study, this likely reflects an increased connection between the focal-firm and its partners. This tends to enhance reputation effects, norms and shared identities, which facilitate intense interaction between network actors , improving collaboration and transfer of tacit knowledge (Hansen, 1999).

These findings are consistent with previous research linking firms' embeddedness in a dense network to improve innovation performance (Obstfeld, 2005; Zheng and Yang, 2015), exploratory innovation (Phelps, 2010), exploitative innovation (Karamanos, 2016), and product innovation (Soh, 2003). However, many scholarly works have shown that there are positive and significant associations between sparse networks and innovation supporting Burt's (1992) argument. It suggests, for instance, that innovative firms who enjoy structural holes in their network structure perform better in terms of innovation (Zaheer and Bell, 2005). Moreover, other researchers have suggested a curvilinear (inverted U-shape) relationship between network density and innovation. For example, Gilsing et al. (2008) explored the density effect on novelty creation from the global density perspective (considering both direct and indirect ties). This study also supports the inference that firms' innovation can be affected by their network structure, therefore this is the optimum configuration for density for higher value creation (Gilsing et al., 2008). Similarly, a recent study by Tan et al. (2015) supports that different network structural embeddedness, in terms of high and low density, can have different implications for a firm's innovation. For instance, their position is supported at high network density, while their network configuration at a central position would be less beneficial for firms' innovation performance. However, central position and structural hole structures complement each other in enriching firms' innovation in a low density network (Tan et al., 2015). In the following section, these different effects are empirically examined in terms of the interaction effect models.

6.2.5: Network betweenness centrality and firms' product and process innovation

For product innovation and process innovation, hypothesis (H6, a & b):

Hypotheses (H6, a & b) predicted a positive relationship between betweenness centrality and firms' product innovation and process innovation. The findings of the LR analysis (in model-3 and model-8) provide strong support for hypotheses (H6, a & b). There is a positive and significant relationship between betweenness centrality and firms' product and process innovation. A one unit increase in the focal-firm's betweenness centrality is 1.16, making product innovation about (16%) times more likely. Moreover, the likelihood of a focal-firm producing process innovation is about 7.3%, or 1.073 times greater when there is a one unit increase in that focal-firm's betweenness centrality. By being centrally positioned in a network, the focal-firm is strategically better placed to be more involved with other actors, thus increasing early access to resources, knowledge and information flow, as suggested by Lee (2007). A high ego-firm betweenness centrality indicates a firm's ability to absorb information flowing through the network (Owen-Smith and Powell, 2004). Moreover, betweenness centrality could be a measure of the influence an ego-firm has over information and resources through their network (Gilsing et al., 2008), which improves their opportunity to benefit from the network than less central firms (Gulati, 1999; Gulati et al., 2000). Therefore, the acquired knowledge and resources for the network is more important in improving and producing firms' product and process innovation outputs (Zheng, 2010).

The results are in line with findings of a study by Gilsing et al. (2008). They found that in a firm's alliance network, betweenness centrality, among other factors such as network density, can enhance early access to novel knowledge and key resources. It was found that the highest impact on explorative innovation performance is due to firms' occupying central positions (Gilsing et al., 2008). Moreover, the results of this study are also consistent with resent literature by Liu (2011) and Karamanos (2016), who observed that the betweenness centrality of a firm puts it in a place where it can access the network's flow of information, which is likely to positively contribute towards firms' innovation performance in networks (Liu, 2011; Karamanos, 2012; Gay and Dousset, 2005).

6.3: 2-way interaction between relational embeddedness characteristics and structural embeddedness characteristics in terms of betweenness centrality

In this study, one of the main objectives is to examine the possible interaction effects between different network relational and structural characteristics. This is due to lack of current literature and calls for further investigation, including a consideration of the possible combined effects of network relational and structural embeddedness characteristics on firms' product and process innovation (Zheng, 2010; Schilling and Phelps, 2007; Rowley et al., 2000; Gulati, 2002). Therefore, this study has devoted great attention to this gap in the existing literature in an attempt to uncover some of the main joint effects that firms' network relational and structural embeddedness characteristics have on product and process innovation.

Hypothesis (H7) is concerned with the 2-way interaction effects of network relational and structural embeddedness characteristics in terms of betweenness centrality on ego-firms' product and process innovation. The regression analysis (in model-4) shows that the only supported 2-way interaction term is that between betweenness centrality and strong ties for firms' product innovation. However, the LR results for firms' process innovation (model-9) shows no significant interaction terms with betweenness centrality. This indicates a significant and positive interaction effect between betweenness centrality and strong ties on product innovation; hence, the data strongly supports hypothesis (H7a) for this interaction term (OR=1.296, $\rho < 0.05$). This implies that the interaction effect of betweenness centrality and strong ties on the ego-firm is 1.296, or (30%), times more likely to produce product innovation than the interaction effect between betweenness centrality and weak ties.

Figure (6.2) depicts the interaction of betweenness centrality and strong/weak ties. The interaction effect is indicated by the two crossed, fitted lines; if the lines were parallel there would be no interaction effect (Jaccard and Turrisi, 2003; Aiken and West, 1991), which indicates, for example, the relationship between betweenness centrality and ties is the same for both strong and weak ties. The middle line (solid red line) is the fitted line of the average predicted probability of model-4 to gain more insights into the interaction effect and aid interpretation (Hosmer et al., 2013). As illustrated in figure (6.2), a focal-firm that is embedded in a strong ties relationship is going to perform almost 1.3 times better with an increase of betweenness centrality than a firm with weak ties in the same situation. As figure (6.2) shows, at low betweenness centrality a focal-firm with weak ties outperformed firms with strong ties. This can be seen from the dashed line (representing weak ties), which was predicted in the LR to achieve more than average (0.58) and way below average for strong ties firms (solid line) in product innovation. However, this over-performing interaction effect of weak ties and betweenness centrality starts to weaken as betweenness centrality increases, as clearly indicated in Figure (6.2). This was confirmed by the regression analysis when the model was run while changing the reference of the variable to weak ties instead of strong ties (changing the code in the LR model). When the regression model was run for the interaction term between weak ties and betweenness centrality, the analysis shows a negative interaction effect (OR=0.771, $\rho < 0.05$). This implies that, as betweenness centrality increases, there will be almost a 23% (1-0.771) decrease in the likelihood of a focal-firm with weak ties producing product innovation compared to one with strong ties. However, hypothesis (H7) was only supported for the interaction term between betweenness centrality and strong ties for firms' product innovation.

The outcome of this analysis contributes to literature on networks and innovation. Theoretically, it is consistent with the view that an ego-firm's structural position in a network in terms of centrality could benefit by being in the transmitted knowledge and valuable information channel (Owen-Smith and Powell, 2004). Additionally, the ego-firm that lies between two or more distant actors in the network occupies a strategic position that is a possible source of resources and control (Freeman, 1979; Borgatti, 2013). Therefore, a firm with high betweenness centrality has a better chance to extract more value from its strategic position (Gulati, 2002; Burt, 1992), leading to better innovation outcomes (Mazzola et al., 2015; Karamanos, 2016; Ibarra, 1993). The analysis also has practical implications, providing new insights into the potential combined effects of network relational and structural embeddedness characteristics on firms' product innovation. For instance, it reveals that a focal-firm is now able to re-assess and evaluate its product innovation performance based on its current network characteristics, in terms of strong/ weak ties and betweenness centrality.

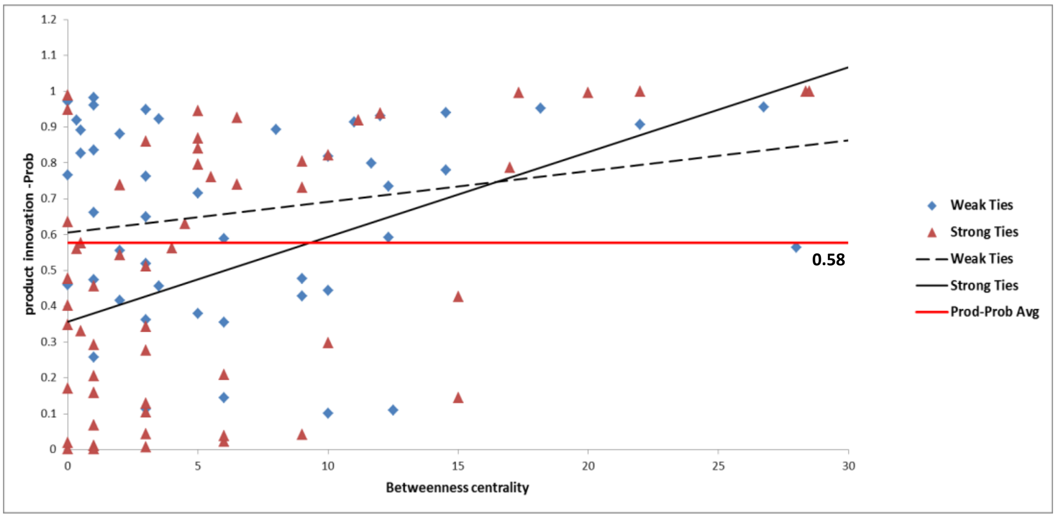

Figure 6.2: Plot showing fitted lines for the 2-way interaction effect between betweenness centrality and strong/weak ties on firms' product innovation

6.4: 2-way interaction between relational embeddedness characteristics and structural embeddedness characteristics in terms of the increase of network density

The other 2-way interaction that was proposed in this thesis is the interaction effects between relational embeddedness characteristics and structural embeddedness characteristics in terms of the increase of network density (Hypothesis H8).

First, for firm's product innovation, outlined in model-4

The study did not find support for the interaction effect between strengthen the ties and network density. The interaction term was negative, as predicted in this research, but failed to reach a statistical significance (OR=0.967, ρ= 0.10). It is worth noting that the single effect variable of network density and strengthen the ties, as shown in model-4, exhibited a significant and positive effect on firms' product innovation, whereas the interaction terms between the two variables resulted in a negative effect on product innovation. This offers an interesting proposition for further research to investigate possible negative effects of the increase in network density when combined with strengthen the ties between the focal-firm and its partners.

The other interaction term between relational and structural embeddedness characteristics in terms of the increase of network density is the interaction between repeated collaboration (continuity) and network density. The findings of the logistic regression (in model-4) show a negative and significant effect on the interaction term between repeated collaboration (continuity) and network density on firms' product innovation (OR=0.949, $\rho < 0.05$). This results is consistent with hypothesis (H8, a), which posits the negative effect of 2-way interaction between an increase in network density and repeated collaboration (one of the relational embeddedness characteristics). Figure (6.3) illustrates the interaction effect between density and continuity. Examining the regression results and the interaction plot revealed that at low network density, on one hand, firms with repeated collaboration (continuity) with network partners expected to achieve better in terms of product innovation (represented by the solid-line in the graph). On the other hand, as network density increases, there will be an almost 5% (1-0.949) less likelihood on the expected return on product innovation, with repeated collaboration (continuity) comparing to a firm with high dense network and non-repeated collaboration (non-continuity) (represented by the dash-line).

The findings of the study are in line with the existing literature in terms of the positive effect of repeated collaboration on product innovation, for example (Nieto and Santamaria, 2007; Soh, 2003). However, in the context of this study, when including the interaction effect of structural aspect (network density) and relational properties (repeated collaboration), the positive effect of repeated collaboration on firms' product innovation diminishes with an increase in network density. Additionally, there is another stream of research in favour of Burt's (1992) sparse network density view (Phelps, 2010; Hargadon and Sutton, 1997; Rowley et al., 2000). This is clearly indicated in the data by scoring above average expected product innovation return in the case of low density (sparse network density) interacting with repeated collaboration (continuity). Therefore, practitioners are highly encouraged to take into account the joint effect of repeated collaboration (continuity) and network density on their product innovation activities.

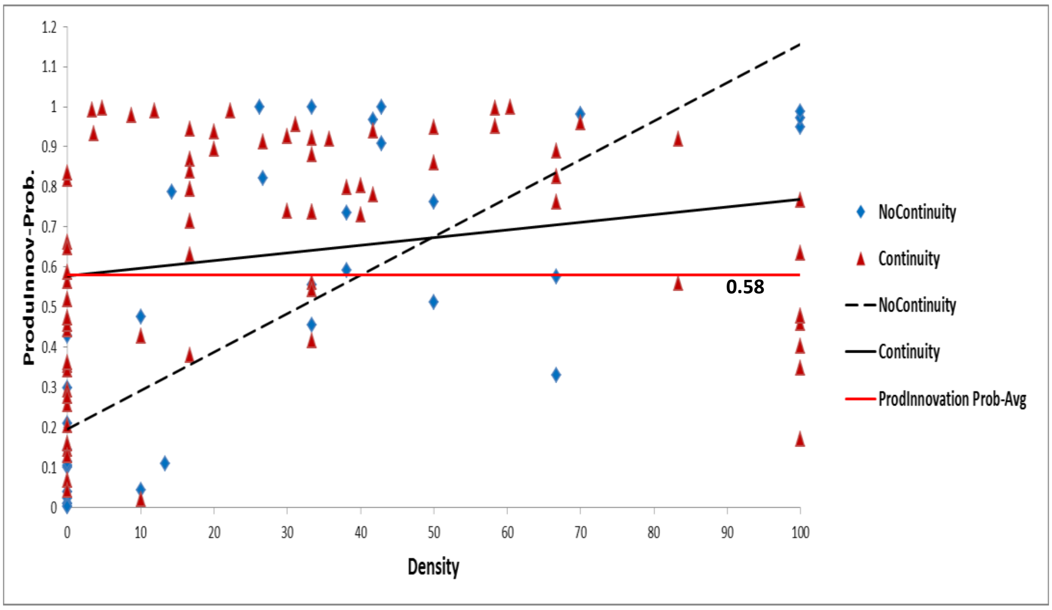

Figure 6.3: Plot showing fitted lines for the 2-way interaction effect between network density and repeated collaboration (continuity) on firms' product innovation

Second, for firms' process innovation, outlined in model-9:

The regression analysis in this study found no support for any of the interaction terms between relational and structural embeddedness characteristics in terms of the increase of network density on process innovation. There was an interaction effect between strong ties and network density (negative effect, as predicted), and between repeated collaboration (continuity) and network density (negative effect, as predicted), and both interaction terms failed to reach any statistically significant effect. Therefore, the data do not support hypothesis (H8, b), which states that there is a negative effect between the 2-way interaction of relational and structural embeddedness characteristics in terms of the increase of network density on process innovation.

Finally, in this research, hypothesis (H8) was only supported for the negative effect between the 2-way interaction term of repeated collaboration (continuity) and increase of network density on product innovation.

6.5: 2-way interaction effects among relational embeddedness characteristics in terms of strengthen the ties and weak ties

In this research, various interaction terms were examined, as indicated in the analysis chapter (chapter 5). The procedure followed in this research (i.e. purposeful selection of predictor method) was applied to all possible combinations of characteristics. This was carried out in order to serve the primary objective of this research, linking network relational and structural embeddedness characteristics to firms' innovation outcomes. One combination that showed a potential effect on firms' process innovation is the interaction term between weak ties and strengthen the ties. The results of the regression analysis (in model-9) showed that the effect of the interaction between weak ties and strengthen the ties is negative and significant (OR=0.089, $\rho < 0.05$). A focal-firm with weak ties who strengthened their ties during the specified interval in this study (2012-2013, as discussed in the methodology, chapter 4) is 91% less likely to produce process innovation relative to strong ties with strengthen of the ties. This finding contradicts the developed hypothesis, therefore hypothesis (H9, b) was not supported. There may be two plausible reasons for the lack of support for this hypothesis. First, it might be due to the data of the focal-firm in this study, which was collected as cross-sectional data did not capture the frequency of contact among the network actors. Second, it could be due to the type of predicted innovation outcome (i.e. process innovation) measured in the context of M&H technology sectors in this study. However, under further examination of different settings of the reference case (i.e. the model coding), the LR results found a positive and significant interaction effect between strong ties and strengthen the ties element. Furthermore, it supports the positive and significant interaction effect between weak ties and no strengthen of the ties.

This interaction effect can be shown graphically as in Figure (6.4), which is an illustration of the interaction effect between weak/strong ties and strengthen/no strengthen of the ties.

The findings of this study might seem to contradict Granovetter's (1973) 'strength of weak ties' (SWT) theory. Nevertheless, the positive effects of weak ties on firm innovation performance still hold. Weak ties can still be seen to carry advantages to access valuable information and resources needed for process innovation, as shown in figure (6.4) (dashed line). The analysis revealed high process innovation performance for the focal firm, where there is interaction between weak ties and no strengthen of the ties (indicated by the dashed line), relative to strong ties with no strengthen of the ties (indicated by the solid line). Nonetheless, this positive effect is weakened, resulting in a reduction in performance when weak ties and strengthen the ties aspects interact, relative to the interaction effect of strong ties with strengthen of ties. According to these findings, a focal-firm with weak ties does not need an increase of frequency of contact or interaction (i.e. strengthen the ties) with its network partners in order to perform better in terms of process innovation. Conversely, it is highly beneficial to increase frequency of interaction (i.e. strengthen the ties) with its partners if it already has strong relationships.

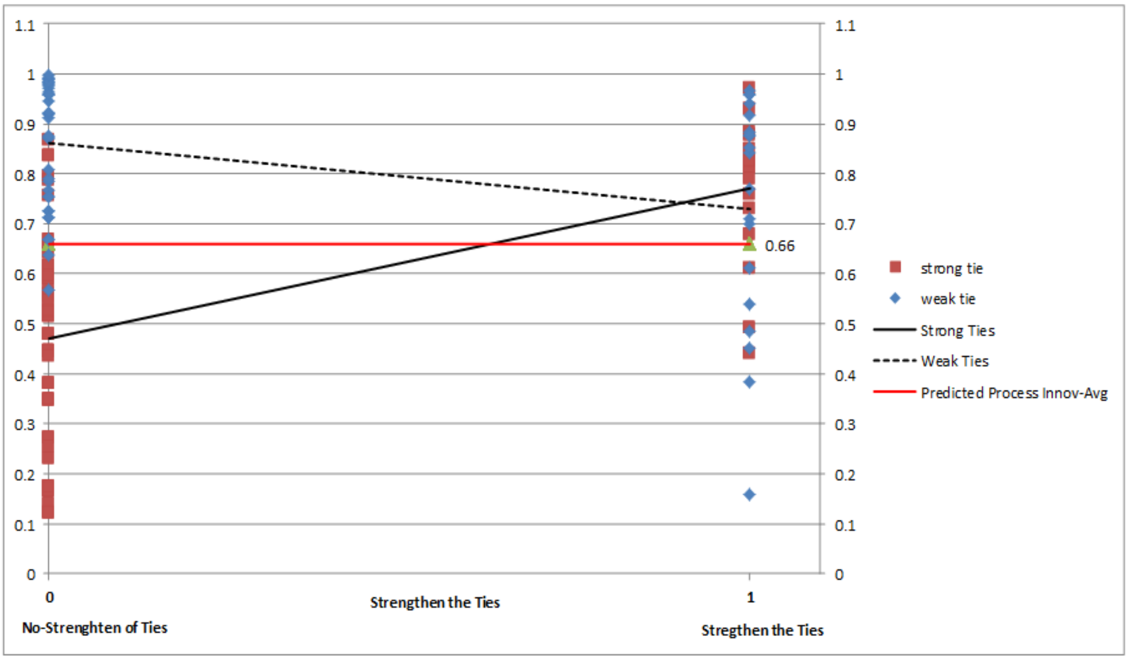

Figure 6.4: Plot showing fitted lines for the 2-way interaction effect between strong/weak ties and strengthen the ties on firms' process innovation

6.6: 3-way interaction between relational embeddedness characteristics and structural embeddedness characteristics

Hypothesis (H10) predicted a positive effect between the 3-way interaction of relational and structural embeddedness characteristics on an ego-firm's product and process innovation. For both innovation types, the LR for the interaction terms indicates that the 3-way interaction between betweenness centrality, network density and strong ties has a significant and positive effect. The results of product innovation are outlined in model-5, and for process innovation are summarized in model-10.

First, for firms' product innovation:

As hypothesis (H10, a) suggested, there is strong support for the 3-way interaction between betweenness centrality, network density and strong ties. The results showed a significant and positive interaction effect between betweenness centrality, density and strong ties on firms' product innovation (OR= 1.031, $\rho < 0.05$). Figure (6.5) shows the nature of the significant effect of the interaction term between betweenness centrality, density and strong/weak ties on firms' product innovation. The LR indicates that the interaction effect of betweenness centrality (solid black line), density (solid green-line) and strong ties on the ego-firm makes it 1.031 (3%) times more likely to produce product innovation relative to the effect of the interaction on the ego-firm, between betweenness centrality (dashed brown line), density (dashed blue line) and weak ties. The regression results and the interaction plot for patterns suggest that in the context of M&H technology sectors in emerging economies, firms need to consider the joint effects of network relational and structural embeddedness on their product innovation outcome. A focal-firm with strong ties type of relations has ample potential to develop product innovation when its high betweenness centrality position in a network is associated with an increase in density, relative to a focal-firm with weak ties. On the contrary, a firm that is characterised with low betweenness centrality and low density in its network has better product innovation if accompanied with weak ties type of relations, as can be seen in the interaction plot in figure (6.5).

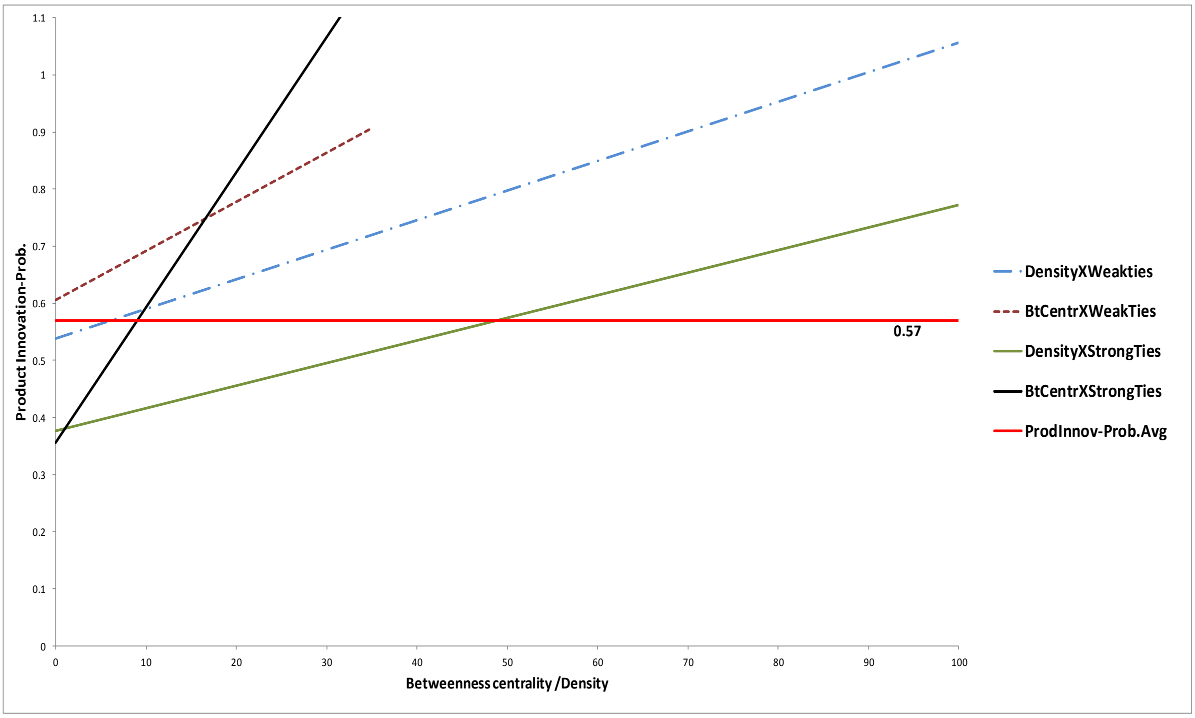

Figure 6.5: Plot showing fitted lines for the 3-way interaction effect between network density, betweenness centrality and strong/weak ties on firms' product innovation

The other 3-way interaction terms (i.e. between betweenness centrality, density and partner diversity, and between betweenness centrality, strengthen the ties, and strong ties) showed an insignificant effect on firms' product innovation. Therefore, the findings conclude that hypothesis (H10.a) was only supported for the interaction term between betweenness centrality, density and strong ties.

Second, for firms' process innovation:

The analysis found strong support for the 3-way interaction of relational and structural embeddedness characteristics on the ego-firm's process innovation in terms of betweenness centrality, network density and strong ties. Therefore, hypothesis (H10, b) is supported for this interaction term. The effect is 1.013, or 1%, times more likely on firms' process innovation (OR= 1.013, ρ< 0.05), relative to the effect of interaction between betweenness centrality, network density and weak ties. These findings can be enriched by using interaction plot of the variables, as can be seen in figure (6.6). The plot shows the interaction between betweenness centrality, network density and strong/weak ties versus the predicted process innovation of model-10 (predicted process innovation average (0.67) is represented by the solid red-line). More insights can be gained from consolidating the regression results and the interaction representation. For instance, the effect of having weak ties is far more preferable in the case of the focal-firm's peripheral (low betweenness centrality) and sparse network (low density) position. This is clearly indicated by the two dashed lines in figure. (6.6) that showed higher than average process innovation outcomes. This implies, as suggested by much of the literature (e.g. Granovetter, 1973; Rowley et al., 2000; Gilsing and Duysters, 2008; Soh, 2003), that weak ties can act as conduits that provide the focal-firm with access to heterogeneous sources of knowledge and novel information, allowing them to achieve better process innovation performance. However, this is conditional on having a network position that is both peripheral and sparse. On the other hand, strong ties (indicated by the two solid lines) in figure (6.6) can be less effective for the focal-firm than weak ties on its process innovation, unless they are accompanied by a higher betweenness centrality position and high network density.

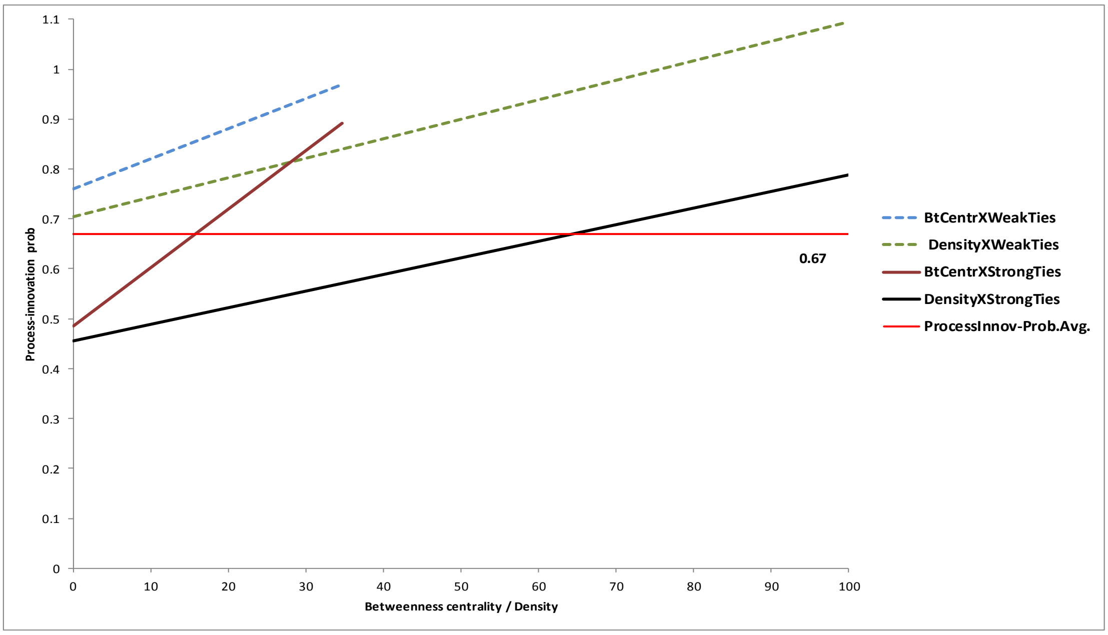

Figure 6.6: Plot showing fitted lines for the 3-way interaction effect between network density, betweenness centrality and strong/weak ties on firms' process innovation

Concerning both innovation types, even though the results of this study results disagree with Rowley et al. (2000) in regards to the negative effect of strong ties in a higly dense network on firms' performance proposed by that study, both studies agree that consideration shall be given to the interaction effect of a firm's structural and relational embeddedness. The conflicting results between this study and Rowley et al. (2000) may be due to three things. First, as Rowley et al. (2000) illustrated, the impact of network charastrastics is contingent on industry context. Second, it could be related to including the 3-way interaction, which considers betweenness centrality, whereas Rowley et al. (2000) examined only the two-way interactive effect between strong/weak ties and network density. The third explanation could be the difference in measured innovation type. Nevertheless, the findings of this thesis are in line with those of Dyer and Nobeoka (2000), who investigated the evolution of Toyota's network. In their article, the authors suggested that a highly interconnected (dense network) and strongly tied network is effective for the transmitting of tacit knowledge and early recognition of innovation opportunities residing outside the firm's boundaries, hence, improving its innovation. Redundant ties in a dense network ease the share of valuable information among network actors. Moreover, strong ties are associated with building trustworthy relationships necessary for the transfer of novel knowledge (Dyer and Nobeoka, 2000). However, neither network centrality nor interaction effects were considered among different characteristics in their study.

Moreover, the findings of the current study have not been able to demonstrate any significant association between betweenness centrality and network density on firms' innovation types, as in Gilsing et al.'s (2008) study. The authors found evidence of the positive effect that an interaction between betweenness centrality and network density have on firms' innovation performance (Gilsing et al., 2008). However, this study has only considered two main aspects of network structure providing support to the importance of the joint effect of these properties. In accordance with Gilsing et al.'s (2008) findings, this thesis provides evidence of the key role of network structural embeddedness in terms of centrality and density, as well as relational embeddedness in terms of strong/weak ties on an ego-firm's product and process innovation. As demonstrated in this section, different focal-firm network structures (central/peripheral, dense/sparse) with various types of relational linkages (strong/weak) have strong combined effects among the network actors.

The other 3-way interaction term found to be effecting firms' process innovation. The results of this study for model-10 indicated that there is no support for hypothesis (H10, b) in terms of the positive effect of the 3-way interaction term between betweenness centrality, strengthen the ties, and repeated collaboration (continuity), or for the 3-way interaction term between betweenness centrality, no strengthen of the ties, and no repeated collaboration (no continuity). LR results showed a negative and significant level only at 10% (OR= 0.628, ρ=0.099). However, when examining other combinations between these variables by changing the reference case (i.e. the model coding), analysis found a weak and positive effect of the interaction between betweenness centrality, strengthen the ties, and no-continuity on firms' process innovation (OR= 1.593, ρ= 0.099). Moreover, the regression outcome was the same for the effect of the interaction between betweenness centrality, no strengthen of the ties, and repeated collaboration (continuity) on firms' process innovation. Therefore, these results must be interpreted with caution since hypothesis (H10, b) is partially supported for the 3-way interaction positive effect between betweenness centrality, no strengthen of the ties and repeated collaboration (continuity), and for the positive effect of the interaction between betweenness centrality, strengthen the ties, and no-continuity on firms' process innovation.

To ease interpretation, table (6.1) summarizes the different predictions and outcomes of the 3-way interaction between these variables. In addition, as shown in figure (6.7), further interpretation of the interaction term effects can be enriched by plotting interaction variables at different reference settings against predicted process innovation in model-10. For instance, the plot shows that at a very low centrality position, a focal-firm who practiced strengthening ties and continuously collaborated with its network partners is expected to perform well considering its process innovation outcome (solid blue-line), relative to the other three reference settings. However, the returns on the expected process innovation diminishes as the central position of a focal-firm increases, to the benefit of a focal-firm with either strengthening ties and no continuous collaboration (solid brown-line) or towards firm' with no strengthening of ties and continuity (dashed green-line), relative to the other reference settings.

Hypothesis prediction	Relative to the interaction effect between	Effect sign	Result of hypothesis testing
positive effect between the 3-way interaction of betweenness centrality, strengthen the ties, and continuity	betweenness centrality, strengthen the of ties, and no continuity Or betweenness centrality, no strengthen of the ties, and continuity	+	Not supported
positive effect between the 3-way interaction of betweenness centrality, strengthen the ties, and no continuity	betweenness centrality, strengthen the ties, and continuity Or betweenness centrality, no strengthen of the ties, and no continuity	+	Partially supported
positive effect between the 3-way interaction of betweenness centrality, no strengthening ties, and continuity	betweenness centrality, strengthen the ties, and continuity Or betweenness centrality, no strengthen of the ties, and no continuity	+	Partially supported
positive effect between the 3-way interaction of betweenness centrality, no strengthening of ties, and no continuity	betweenness centrality, strengthen the ties, and no-continuity Or betweenness centrality, no strengthen of the ties, and continuity	+	Not supported

Table 6.1: A summary of the different settings of the 3-way interaction term between betweenness centrality, strengthen the ties, and repeated collaboration (continuity) impact on firms' process innovation

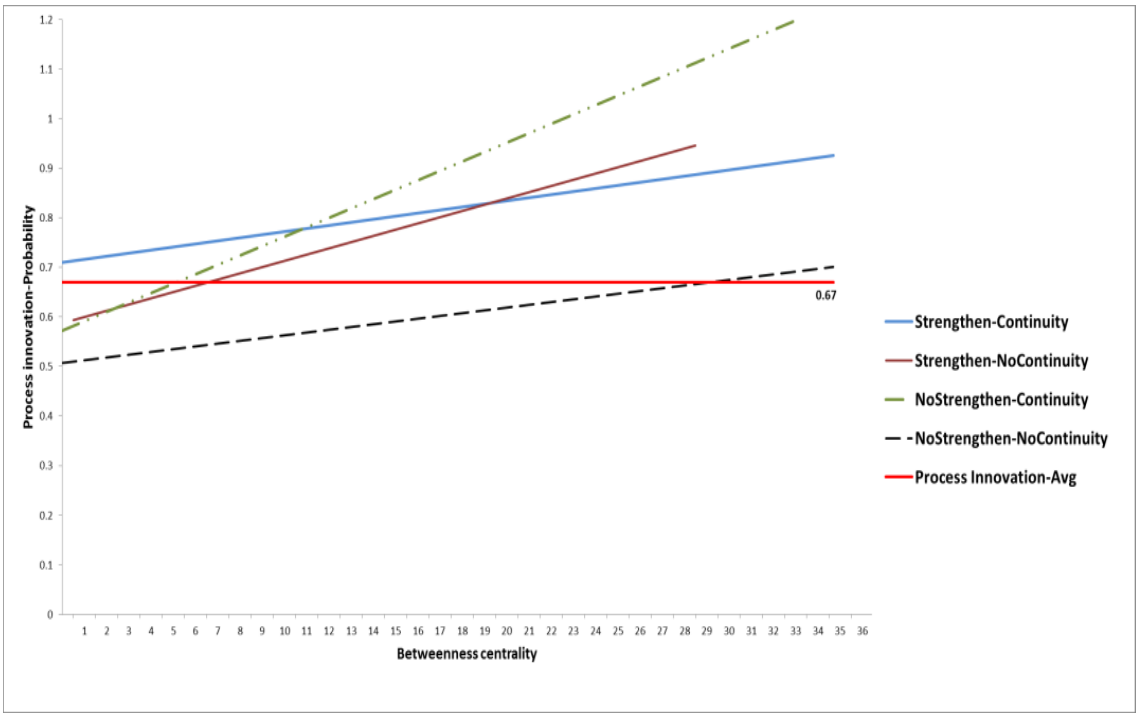

Figure 6.7: Plot showing fitted lines for the 3-way interaction effect between betweenness centrality, strengthen the ties and repeated collaboration (continuity) on firms' process innovation

Even though the findings of this thesis did not strongly confirm the joint effect of netwrok structural embeddedness in terms of betweenness centrality with relational embeddedness aspects of strengthen the ties and repeated collaboration (continuity), it is quite in line with the consideration proposed by Gulati (1998; 2002), that the effect of networks on firms' outcomes and innovation depends on the independent and interactive influence of both relational and structural embeddedness characteristics. Overall, it is in agreement with Granovetter's (1973) argument in regards to the focal firm strengthening their ties with its network partners as a source of valuable information and resources, leading to better innovation outcomes. In addition, the study's findings are in accordance with those of Reichstein and Salter (2006), who found that continuous collaboration is important in enhancing firms' process innovation. However, the inclusion of the interaction effect in this study showed that the effect of one factor on the focal-firm's process innovation is conditional on other network structural and relational aspects. This provides more insights into the role that the joint consideration of these factors possibly plays in shaping firms' innovation performance.

Finally, in regards to other 3-way interaction between network density, strengthen the ties and strong ties, the analysis of the logistic regression (LR) found no support for the effect of the 3-way interaction between these network characteristics on firms' process innovation.

6.7: Control variables: industry sector and export

As demonstrated by table (5.17) in analysis (chapter-5), industry sector and export were the only control variables that showed a statistically significant effect on firms' product innovations. Whereas, for process innovation, none of the suggested control variables were significant when controlling for both relational and structural embeddedness characteristics. The regression analysis of the main effect model (model-3) revealed that the industry sector (manufacturing and service firms) has a strong statistical effect on product innovation, controlling for both relational and structural embeddedness characteristics. It was found that firms belonging to the service sector are expected to perform almost 4.2 times better at product innovation than firms in the manufacturing sector (OR= 4.235, $\rho < 0.05$). This implies that in the context of emerging economies, sector type in M&H technology sectors does effect firms' product innovation; in this study, this effect is in favour of service firms over manufacturing firms.

In terms of export activities, the results of logistic regression (LR) analysis in the main effect model (model-3) found a weak and positive association between a firm's export behaviour and its product innovation, controlling for both relational and structural embeddedness characteristics (OR= 2.807, $\rho = 0.058$). In the context of this study, exporting plays a positive role, making product innovation about 2.8 times more likely for exporting firms than non-exporting firms.

6.8: Conclusion

This chapter discussed the main findings of the logistic regression analysis. In addition, the research hypotheses were critically discussed in light of the current debate in the literature. The outcome of this thesis was presented to shed light on the direct and interaction effect among different network relational and structural embeddedness characteristics on firms' product and process innovation. Furthermore, a summary of this thesis discussion in relation to the context of emerging economies and the reviewed literature is provided in tables 6.2 and 6.3 at the end of this chapter.

Network construct	The discussed Literature				This thesis (the context of emerging economies)		
	Authors	Innovation performance measures	Operationalization of Network construct	Key findings	Innovation performance measures	Operationalization of Network construct	Key Findings
Strength of ties	(Rowley et al., 2000)	Firms performance (net income and return on assets)	Ties strength (Strong/weak ties)	Strong ties in a highly interconnected strategic alliance network negatively impact firm performance	Product/ process innovation	Ties strength (Strong/weak ties/strengthen the ties)	• Negative relationship between strong ties and firms' process innovation. The effects of strong ties on the focal-firm relying on strong ties can hinder firms' ability to innovate • There is weak support of the positive association between strengthen the ties and firms' product innovation • There is a negative effect of the 2-way interaction between weak ties and strengthen the ties on firm's process innovation
	(Capaldo, 2007)	Product innovation performance	Strong/weak Ties	• Strong ties benefit lead firms in sustaining innovation to a certain limits. Lead firms need to integrate these ties with a large number of weak ties to avoid being locked in a limited number of relationships (diversity of ties) • A combination of weak and strong ties (diversity of Ties) provide the lead firms with the capability to innovate			
	(Ruef, 2002)	Innovation output (patent and trademark applications, and Innovation index according to the perspective of entrepreneurs)	Strong/weak ties	actors (entrepreneurs) whose relying on strong ties as a source of new ideas are less likely to innovate than actors relaying on weak ties			
	(Gilsing and Nooteboom,	technological exploration/ exploitation networks	(Strong/weak ties)	In technological exploration network environment, density			

	2005)			and strong ties are more favourable. However, content in terms of types of knowledge and technology should be taken into account.			
Repeated Collaboration (Continuity)	(Nieto and Santamaria, 2007),	degree of novelty of product innovation	The number of years a company had participated in business/inter-organizational relationship networks.	• Continuity of collaboration of the collaborative network is highly significant dimensions in product innovation degree of novelty. • Collaboration with suppliers, clients and research organizations has a positive impact on the novelty of innovation, while collaboration with competitors has a negative impact.	Product/process innovation	The number of years a company had participated in business/inter-organizational relationship networks.	Weak and positive relationship between repeated collaboration (continuity) and firms' product innovation
	(Soh, 2003).	new product performance	the number of different partners with repeated alliances	Repeated collaboration improves firm's new product performance			

Network construct	The discussed Literature				This thesis (the context of emerging economies)		
	Authors	Innovation performance measures	Operationalization of Network construct	Key findings	Innovation performance measures	Operationalization of Network construct	Key Findings
Network diversity of partners	(Nieto and Santamaria, 2007),	degree of novelty of product innovation	Diversity of partners	Diversity of partners has a highly positive impact on the degree of innovation novelty	Product/process innovation	Network diversity of partners	Network diversity of partners is significant and positively related to product innovation
	(Faems et al., 2005).	technologically improved product	the type of partners	Positive relationship between inter-organizational collaboration and innovative performance, and this performance depend on the type of partners involved.			
	(Phelps, 2010).	Exploratory innovation using patent citations.	Network technological diversity	Firm's exploratory innovation Increases as its technological diversity of alliance partners increase			
	(Tsai, 2009)	Product innovation performance, which is measured by innovative sales productivity.	types of collaboration with different partners	more diverse partners allow access to broad knowledge networks, which increase firms' product innovation			
	(Laursen and Salter, 2006)	Product innovation (radical/incremental/ significantly improved) As a fraction of the firm's turnover for each type	Breadth which is constructed as a combination of the 16 sources of knowledge or information for innovation	Firms that use a higher number of knowledge sources have access to a greater breadth of information for product innovation. however, too much diversity has a negative implication on firms' product innovation			
	(Sampson, 2007)	New product using Post-alliance patents	diversity of partner technological capabilities	Diversity between partners leads to better innovation performance. Nevertheless, when partners are highly diverse, firms' learning and knowledge sharing is less valuable and might hinder their innovation			

Table 6.2: Summary of thesis discussion- impact of relational network embeddedness on firm's innovation in the context of emerging economies

Network construct	The discussed Literature				This thesis (the context of emerging economies)		
	Authors	**Innovation performance measures**	**Operationalization of Network construct**	**Key findings**	**Innovation performance measures**	**Operationalization of Network construct**	**Key Findings**
Network density	(Rowley et al., 2000).	Firms performance (net income and return on assets)	Network Density	In an exploitation context, dense network ties could be a source of competitive advantage	Product/ process innovation	Network density	• An increase in network density has a positive effect on product innovation and process innovation • There is a negative effect of 2-way interaction between an increase in network density and repeated collaboration (continuity) on firms' product innovation
	(Phelps, 2010).	Exploratory innovation (patents count)	Network Density	Network density positively influence technological diversity, hence increases firms exploratory innovation			
	(Soh, 2003).	New product performance	Network Density (as a control variable)	Density is positively associated with new product performance			
	(Karamanos, 2016)	Exploratory/exploitative innovation (patents count)	Network density	Network density is positive and statistically significant for Exploratory/exploitative innovation. Furthermore, whole network density is consistently important for exploitative and exploratory innovation			
	(Zaheer and Bell, 2005)	Firm's performance (firm's market share)	Network closure/ structural-holes	Innovative firms that bridge structural holes have better performance			
	(Ahuja, 2000)	Innovation output (patents count)	structural-holes	Structural holes have both positive and negative (inverse-U shaped) influences on innovation (increasing structural holes has a negative effect on innovation). network closure increased the likelihood of firm innovation			
	(Gilsing et al., 2008),	Explorative innovation performance (patents count)	Network Density	Density has an inverse-U shaped impact on Exploration (innovation performance)			

	(Bae and Gargiulo, 2004)	Organizational profitability (return on investment and return on assets)	Network Density	negative effect of network density on organizational profitability			
Centrality	(Powell et al., 1996).	Firms performance (net income and return on assets)	degree centrality	central connectedness (degree centrality) positively influence firms exploration activities	Product/process innovation	betweenness centrality	• There is a positive and significant effect of an increase in network betweenness centrality and firms' product innovation and process innovation • There is a significant and positive 2-way interaction effect between betweenness centrality and strong ties on firm's product innovation
	(Soh, 2003).	New product performance	Closeness centrality	Firm's central position improves its new product performance			
	(Gilsing et al., 2008)	Explorative innovation performance (patents count)	betweenness centrality	explorative innovation performance is highly improved for firms occupying a highly central position			
	(Ibarra, 1993)	Administrative and technical innovation	Network centrality	centrality is one of the main influncial aspects for the creation and difussion of firm's innovation			
	(Tsai, 2001)	number of new products introduced	Network Centrality	occupying central position shows a positive impact on units innovation performance			
	(Liu, 2011)	Innovation performance (patents count)	betweenness centrality	betweenness centrality of a firm puts it in a place where it can access the network's flow of information, which is likely to positively contribute towards firms' innovation performance in networks			
	(Karamanos, 2016)	Exploratory/exploitative innovation (patents count)	betweenness centrality	alliance ego–network centrality supports exploitative innovation			
	(Gay and	firm innovation capability	betweenness	Central position is likely to positively			

	Dousset, 2005)	(number of patent)	centrality/degree centrality	contribute towards firms' innovation performance in networks			

Table 6.3: Summary of thesis discussion- impact of relational and structural network embeddedness on firm's innovation outcome in the context of emerging economies (Structural characteristics)

Chapter 7

Conclusion

7.1: Introduction:

This final chapter summarises the main discussions and findings of this thesis. The research aim and objectives are reviewed first, including how this study addresses them. The following section will discuss the theoretical contributions and practical implications of this study. In the final part, the research limitations are discussed and avenues for future research are suggested.

7.2: Overview of aim and objectives

This dissertation attempts to advance our knowledge and understanding of the key role that firms' network embeddedness in terms of structural and relational characteristics plays in their innovation (i.e. product and process innovation) in the context of medium and high technology sectors in emerging economies. This has been achieved by adopting an ego-network concept commonly used in social network analysis to analyse innovation research at the firm level. Moreover, through conceptually identifying and developing the main aspects of a focal-firm's network embeddedness allowed the assessment of how they impact upon product and process innovation.

In relation to the above aim and objectives, this study attempted to investigate the following research question:

To what extent do firms' network embeddedness characteristics (i.e. relational and structural embeddedness characteristics) impact their innovation outcomes (i.e. product and process innovation)?

To be able to provide evidence to answering this research question, a theoretical framework consisting of the main concepts (innovation types, network relational embeddedness characteristics, and network structural embeddedness characteristics) was developed following a review of the existing literature. The central structural construct in the model were the different types of innovation outcomes (i.e. product and process innovation). The two network embeddedness characteristics; 1) relational embeddedness aspects in terms of strong/weak ties, strengthen the ties, repeated collaboration (continuity), and network partners' diversity. 2) Structural embeddedness aspects, in terms of network density, and betweenness centrality. In addition, cross-sectional primary data were collected from the M&H technology sectors in Saudi Arabia by means of a structured questionnaire. Then the data were empirically tested in order to explore and determine the effect of different network embeddedness configurations and the conditions under which they possibly stimulate or hamper firms' innovation output.

This study was motivated by its overall primary objective, which was to examine the impact of networking on firms' innovation. A number of objectives were set up and met in this study. First, a review of the literature was conducted to examine the current stream of research, relevant theories and debates in the field of innovation, social capital, network embeddedness and social network. This systematic review of the literature led to the identification of knowledge gaps. Second, the study set out to develop and test the conceptual research model and to derive the study hypotheses linking network embeddedness characteristics to firms' innovation. The second aim was accomplished by providing the theoretical foundation of the study model and hypotheses based on the current literature. Ten hypotheses were developed and primary data were collected from M&H technology sectors in Saudi Arabia in order to empirically test these hypotheses. Third, using social capital, network embeddedness and social network perspectives to understand firms' network characteristics and their potential impact on firms' types of innovation output. This was achieved through a thorough review of social capital, network embeddedness and social network literature and by depicting the key network relational and structural embeddedness aspects that possibly contribute to shaping firms' innovation. The research analysis and results have directly contributed to this aim. The final objective was to provide theoretical and practical implications on which the scientific community might expand or build on for further understanding of the phenomena in hand. Furthermore, practical implications were introduced and recommended for professional managers in the M&H technology sectors in the emerging economies in general, and in Saudi Arabia in particular.

7.3: Contribution to the field: theoretical contributions and implications:

This study provides theoretical contributions to the literature and offers practical implications for medium and high technology sectors in the emerging economies context and examines the main effect of firms' network embeddedness characteristics on its product and process innovation. The study is distinctive because it presents research informed by a theoretical understanding of innovation management perspectives and three complimentary theoretical viewpoints (i.e. social capital, social network, and network embeddedness). The value of this research lies in the belief that the economic actions and outcomes of firms are influenced by the pairwise relationships in which they are embedded in and that outcomes can be affected by the structure of the overall network of relations (i.e. the network embeddedness characteristics of a firm). Moreover, firms' innovation performance can be affected by its embedded network of relational and structural configurations (Rogers, 2004; Ahuja, 2000; Powell et al.; 1996, Rowley et al., 2000; Gulati et al., 2000; Gilsing et al., 2008).

Through employing social capital theory, the network embeddedness and social network perspective, this research contributes to the expanding body of knowledge by uncovering the essential network configuration of firms' relational and structural embeddedness aspects; these result in better innovation outputs, which contribute to both short and long-term competitiveness, profitability (Mol and Birkinshaw, 2009; Freeman, 1991), long term survival, and growth (Faems et al., 2005; Rothwell, 1991; Gopalakrishnan and Damanpour, 1997). In summary, this dissertation contributes to academic research in several ways: first, by employing social network analysis (SNA) and the ego-network approach, the study underlines the main constructs of network embeddedness that have potential effects on firms' innovation outcomes, in terms of product and process innovation. Secondly, this research contributes to the literature by investigating the effects of network embeddedness on firms' product and process innovation. The current literature mainly deals with product innovation (e.g. exploration, exploitation, new product development) and falls far short of examining such effects on firms' process innovation.

The third contribution of this study to the literature is by generating empirical evidence on the impact of network relational and structural embeddedness on firm's product and process innovations. The research focuses on innovation and network embeddedness characteristics in the medium and high technology sectors of emerging economies by considering two types of innovation (i.e. product innovation and process innovation). The existing innovation literature has largely ignored this context. This research conceptualizes the framework model from previous studies and further assesses the central structure constructs in the model, following Hosmer et al. (2013) logistic regression modelling approach. This study clearly established that the two main network embeddedness properties and their elements: relational embeddedness characteristics (strong/weak ties, strengthen the ties, repeated collaboration, and network partner diversity), and structural embeddedness characteristics (network density and betweenness centrality), have an influence on the product and process innovation at the firm level. According to the research findings, this effect is different for each type of innovation (product or process). In addition, the focal-firm's network embeddedness configuration plays an essential part on this effect. It was empirically demonstrated that this effect leads to different firm innovation outcomes and depends largely on different network relational and structural embeddedness configurations. Therefore, in order to fully assess this effect on firms' innovation, network relational and structural embeddedness configuration should be looked into in combination (i.e. interaction effect among different settings).

Fourth, the theoretical framework model developed in this study further suggests the main and joint effects that firms' relational and structural network embeddedness characteristics play in shaping ego-firms' product and process innovations. This approach has advanced our understanding of the effect of different network embeddedness configurations on different innovation types. For instance, for product innovation, the findings of this research suggest that repeated collaboration (continuity) and an increase in network density characteristics show positive effects on firms' product innovation when considered individually (model-3 in table 5.17). However, considering the joint effect of both aspects (2-way interaction between the two, model-4 in table 5.18) indicates a negative impact on firms' product innovation. In a similar approach, firms' process innovation is positively impacted by the 3-way interaction between relational and structural network embeddedness characteristics in terms of strong ties, an increase in network density, and an increase in betweenness centrality (model-10 in table 5.28). Whereas, this effect remains positive for network density and betweenness centrality in the main effect direct model, but strong ties showed a negative effect on process innovation (model-8 in table 5.28). These findings suggest that each type of innovation requires a different set of network embeddedness properties. Furthermore, it shows the different effects of network embeddedness of relational and structural characteristics on each type of firms' innovation when they are jointly considered, as suggested by previous literature (e.g. Gilsing et al., 2008; Rowley et al., 2000).

Fifth, the results of this study contribute to the literature of the innovation, social capital, network embeddedness, inter-firm and strategic alliance fields, where most existing studies focus mainly on an exploration of the relationship between network characteristics and innovation based on a direct effect. However, firm network embeddedness characteristics cannot be fully evaluated based on strong/weak ties only, for instance, in isolation of network structure (e.g. network density or centrality position). The most interesting result of this study is the suggestion that the interactive effects of both relational and structural embeddedness characteristics are central and can hopefully create a greater understanding into the role that network embeddedness properties play in shaping firms' innovation output. Overall, this study contributes to the innovation, social capital, network embeddedness, and social network literature in three important ways:

a) First, in exploring two types of firms' network embeddedness characteristics in the medium and high technology sectors in the context of emerging economies, this study introduces direct, 2-way interaction, and 3-way interaction conceptual models for future work to build on in investigating product innovation and process innovation at a firms' level.
b) Second, differentiation between two types of firms' innovation outcomes (i.e. product innovation and process innovation) and in arguing that firms' network embeddedness characteristics can have boosting or hampering effects on these types of innovation depending on a firm's network embeddedness configuration.
c) Third, this study makes an initial attempt towards consolidating our understanding of the effect of network embeddedness on firms' product and process innovation by proposing a social network analysis (SNA) approach and by empirically distinguishing between direct and interactive effects of network relational and structural embeddedness characteristics.

7.4: Managerial implications:

In addition to contributing to research, this dissertation also contributes to practice by highlighting the key aspects of firms' network embeddedness that could in part constrain or create opportunities for innovation. Foremost, focusing on the ego-network of a focal firm provides a concrete basis for professional managers strategically aiming for high innovation performance to reconsider and re-evaluate their organization's network embeddedness configurations. As the findings of this study show, the implications for firms in the medium and high technology sectors in emerging economies differ depending on their strategic goals for product or process innovation. This research also provides awareness of the crucial role that firms' network configuration, in terms of relational and structural embeddedness characteristics, plays in achieving or hindering these goals. Essentially, this study finding suggests that:

This study proposes that network relational and structural characteristics that firms are embedded in are aligned with the firm's strategic goals. Different network embeddedness configurations yield different innovation outputs, hence, managers need to first specify and clearly define their innovation strategic goals and re-assess their network embeddedness characteristics. Moreover, the methodology of measuring the focal-firm's network (ego-network perspective) in this research provides a solid foundation for professional managers to evaluate their existing network configuration and plan accordingly for their product innovation or process innovation. In addition, managers are now more aware of the significance that firms' relational and structural embeddedness characteristics play in product and process innovation. They are able, based on the findings of this study, to distinguish between the two types of network embeddedness characteristics effects on firms' innovation. First, the direct effect of different firms' network embeddedness characteristics showed a positive and significant effect on firms' product innovation when related to relational aspects (strengthen the ties, repeated collaboration, and diversity of partners). Similarly, network embeddedness in terms of structural characteristics (network density and betweenness centrality also exerts a positive and significant effect on firms' product innovation (models 1-3 in table 5.17). For process innovation, the network structural embeddedness characteristics show a positive and significant effect, whereas none of the relational embeddedness properties have a significant impact except for strong ties, which negatively and significantly affected firms' process innovation (models 6-8 in table 5.28).

The second type of effect is the interactive effect between firms' relational and structural network embeddedness characteristics. The 2-way and 3-way interaction effect shown in this study can be a great help for managerial implications, as suggested in previous studies (e.g. Gilsing et al., 2008; Rowley et al., 2000). The results of this study contribute to this stream of research and suggest joint consideration should be given to relational and structural network embeddedness aspects when evaluating a firm's network embeddedness impact on its innovation outcomes. For instance, professional managers are recommended to take into account the following:

a) For firms' product innovation strategies, even though strong ties showed no significant impact on product innovation when considering the direct effect in isolation (model-3 in table 5.17), it is highly beneficial when considered jointly with a central position (i.e. 2-way interaction between strong ties and betweenness centrality) (model-4 in table 5.18). Besides, it could be a source of better product innovation performance when a firm has strong ties type of relations and is strategically embedded in a dense and central network position (i.e. 3-way interaction between strong ties, network density, and betweenness centrality) (model-5 in table 5.19). Another important implication was the advantages that a firm achieves from repeated collaboration with its network partners, as suggested in many literature (e.g. (Nieto and Santamaria, 2007; Soh, 2003). Although the findings suggest only a weak support of the positive impact of repeated collaboration on product innovation when the direct effect was considered (model-3 in table 5.17), an interesting result emerges from the 2-way interaction effect between repeated collaboration and firms' network density structure. It was found that if a firm embedded in a dense network and exercises repeated collaboration with its network members, the firm is constrained by such a network embeddedness configuration (model-4 in table 5.18). Hence, its product innovation was negatively impacted. This implies that firms are expected to find themselves in a strategic locked-in situation in a network, potentially where they will receive overlapping information hindering their product innovation opportunities. Therefore, firms with similar network embeddedness characteristics are encouraged to look outside their closed network circle and aim to establish new contacts so they can access new and diverse information and knowledge sources, fostering product innovation. In addition, this can be seen from the interaction effect plots (Figure 6.2) showing that with sparse network embeddedness, firms that conducted continuous collaboration with its partners outperformed the ones with low density and do not practice repeated collaboration with other actors in the network.

b) With respect to firms aiming for better process innovation strategies, the research results suggest that strong ties have a significant and negative effect on process innovation in the direct main effect model (model-8 in table 5.28). However, this negative influence of strong ties is diminishing when in concert with a strategic network position in terms of density and betweenness centrality. Firms that enjoy strong ties type of relation and are characterized as having dense networks, centrally positioned in a network are predicted to be better process innovators (model-10 in table 5.28). Consequently, firms are highly recommended to strategically aim towards this type of network embeddedness configuration in order to perform well in terms of process innovation.

c) For both product and process innovation, it was apparent from the findings that looking critically at firms' embeddedness in a network has important practical implications. Leaders seeking to improve their firms' innovation performance can find appealing insights from this study. By looking into their relational as well as structural network embeddedness characteristics in combination, firms can recognise the potential improvement in both product and process innovation outputs. This is clearly indicated by the interactive effect between network embeddedness relational aspects (strong/weak ties) and structural properties (dense/sparse network and peripheral/central position). For instance, it is suggested that complementing a firm's dense and central structural embeddedness configuration with strong ties type of relations will have a positive impact. Whereas, firms with a structure characterized as sparse and peripherally embedded in a network, are encouraged to develop links and relationships with other organizations in terms of weak type of ties.

7.5: Limitations and avenues for future research

For all its contributions, this research is not without limitations that may provide an avenue for future research. Thus, the interpretation of the outcome of the study should be undertaken in light of its limitations. The first limitation is that the present research only focused on two types of innovation (i.e. product and process innovation). Therefore, the outcome of this study is only related to these types of innovation. Future research could be extended to other types of innovation, such as organization, marketing, incremental, and radical innovation. Moreover, the measures of product and process innovation were based on respondents' perceptions. Future research possibly uses other objective measures, such as profit, return on sales, return on profits, and patents. In addition, future researches are recommended to control for other factors such as R&D intensity.

Second, another limitation of this research is related to the unit of analysis; the firm level of analysis and the adopted network level (i.e. ego-network). The study results suggest very insightful implications from the focal firm's perspective. However, it does not capture the aspects of the whole network, which might have an effect on a firm's ego-network and innovation. This can be a great opportunity for future work to incorporate and examine various levels of analysis at the whole network and industry level.

Third, this study finding is limited by focusing on the effect of firms' exogenous network characteristics on its innovation outcomes. Internal factors were not include, which are, in much of the literature, considered significant to its innovation. Therefore, future study is encouraged to comprehend the conceptual model used in this study and in order to integrate network embeddedness aspects external to the firm and monitor their effect relative to the characteristics of its internal capabilities (e.g. innovation management practice, absorptive capacity).

Fourth, as explained in methodology chapter, this study employs a cross-sectional and survey based design, which means it could not tap into exploring firms' network dynamics and their accumulative effect on innovation. To overcome this limitation, future research could employ a longitudinal approach and in-depth case studies to examine time lags between constructs; this would further advance our understanding of the nature and mechanism of the long-term effect.

Fifth, this study relies on the developed conceptual model, which has not been tested beyond the aforementioned survey. Self-reports employed in this study might not be entirely accurate as they rely mostly on the respondents' experience and memory of their firms' related innovation and network data. However, the study tried to remedy this limitation by employing reliable innovation questions, such as OECD's community innovation survey, providing adequate definitions for network questions and consulting available firms and public archival data, but it might not be sufficient to claim perfect reliability.

Sixth, to ensure validity of the research instrument, the guidelines by Bearden et al. (2011) were followed. For example, the measurements of network characteristics were built up based on relevant literature and previous empirical works. Furthermore, the research instrument was sent to experts from academia and industry to pre-test to ensure appropriateness and validity of the research instrument. However, the adopted network characteristics measures, which were developed from the social network literature, are mostly concerned with network data at the individual level. This research adopted those types of measurements at the firm level. Given the limited time and resources available, it was difficult to perform further validation steps. To overcome this limitation, this study recommends additional validation to measurements at the firm level in future research.

The seventh limitation is concerned with the relatively small sample size of 121 firms. Although sufficient for accomplishing the objective of this research, larger samples may be useful to strengthen the results. Having larger sample sizes could also allow controlling for other specific effects, such as type of industry and network collaboration partners. In addition, the study was restricted to the context of the medium and high technology sectors in Saudi Arabia. Hence, future research could aim to expand on this study by testing its conceptual model in other research contexts.

Eighth, the fact that the sample was limited to Saudi Arabian firms might have limited the interpretation of the findings of this research. The study adopted OECD's community innovation survey methodology to gather innovation data from respondents. This approach, when combined with the network part of the survey, would allow further investigation of the effect of network embeddedness characteristics on firms' innovation and enable comparative empirical studies among different OECD and non-OECD countries.

In spite of these limitations, this study was able to contribute not only to theory and practice, but also to provide a new insight into ways of investigating the extent to which firms' network relational and structural embeddedness characteristics impact their types of innovation.

7.6: Conclusion:

This chapter summarizes the work presented in this dissertation and implications for M&H technology sectors in Saudi Arabia were discussed. It also highlights the key findings and main arguments underpinning this research. Moreover, it addresses the study's contribution to the fields of innovation, social capital, network embeddedness, and social networks. Finally, limitations and directions for future research were presented.

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APPENDICES

Appendix A

Product innovation logistic regression analysis

Identification of potential confounders from the removed insignificance variables:

Testing for confounders depends on the change of logistic regression coefficient in the model that include the removed variables and the model without that variable. It can be calculated per the formula (Hosmer et al., 2013):

Δ β % = 100 [regression coefficient (β) without the removed variable in model - regression coefficient (β) with the removed variable model]/ regression coefficient (β) with the removed variable in model

Using the definition provided by Hosmer et al. (2013), variables whose removal from the model resulted in a 20% or greater change in β for any of the independent variables in the main effects model are considered confounders and should be included in the main effects model for the proceeding analysis.

Variables assessment for confounding		Regression coefficient (β) with the removed variable	Regression coefficient (β) without the removed variable	Δ β %
Firm_Size	Sector_Type (Service)	1.284	1.443	12%
	Firm_Export (Export)	1.127	1.032	-8%
	Strengthen the Ties (Strengthen)	1.042	1.033	-1%
	Ties Strength (Strong Ties)	-0.692	-0.747	8%
	Continuity	0.955	0.959	0%
	Partners _Diversity	1.137	1.062	-7%
	Network Density	0.028	0.026	-8%
	Betweenness Centrality	0.154	0.149	-3%
Firm_Age	Sector_Type (Service)	1.55	1.443	-7%
	Firm_Export (Export)	1.024	1.032	1%
	Strengthen the Ties (Strengthen)	1.042	1.033	-1%
	Ties Strength (Strong Ties)	-0.74	-0.747	1%
	Continuity	0.876	0.959	9%
	Partners _Diversity	1.125	1.062	-6%
	Network Density	0.026	0.026	-1%
	Betweenness Centrality	0.152	0.149	-2%
Firm_Group	Sector_Type (Service)	1.498	1.443	-4%
	Firm_Export (Export)	1.189	1.032	-13%
	Strengthen the Ties (Strengthen)	1.096	1.033	-6%
	Ties Strength (Strong Ties)	-0.64	-0.747	17%
	Continuity	1.074	0.959	-11%
	Partners _Diversity	1.037	1.062	2%
	Network Density	0.029	0.026	-11%
	Betweenness Centrality	0.163	0.149	-8%

Table A1: Testing for potential confounders from the removed insignificance variables

Network Structural Characteristics (Model2 -Product): ***Tests for goodness of model fit***

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	41.336	4	0.000
	Block	41.336	4	0.000
	Model	**41.336**	**4**	**0.000**

Table A2: Chi-Square test (Omnibus Tests of Model Coefficients) - model-2

2- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	6.927	8	**0.544**

Table A3: Hosmer and Lemeshow goodness-of-fit test for Model-2

3- Classification Tables

Classification Table[a,b]					
			Predicted		
			Prod_Innov		
Observed			Not-Innovator	Product-Innovator	Percentage Correct
Step 0	Prod_Innov	Not-Innovator	0	51	0.0
		Product-Innovator	0	70	100.0
	Overall Percentage				57.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]					
			Predicted		
			Prod_Innov		
Observed			Not-Innovator	Product-Innovator	Percentage Correct
Step 1	Prod_Innov	Not-Innovator	35	16	68.6
		Product-Innovator	12	58	82.9
	Overall Percentage				76.9

a. The cut value is .500

Table A4, a & b: The results of Network Structural Characteristics (Model-2) classification tables

1- Receiver Operating Characteristic Curve (ROC)

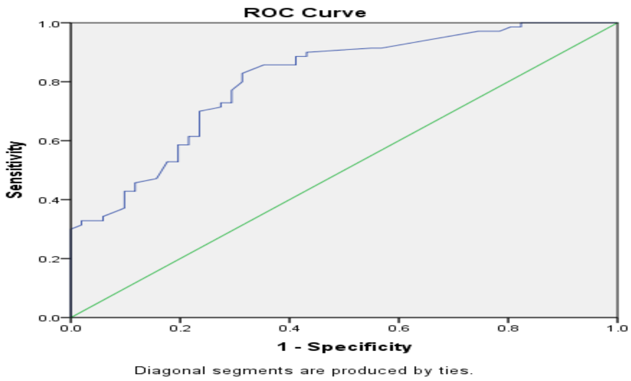

Figure A1: ROC plot for Network Structural Characteristics (Model-2)

Area Under the Curve				
Test Result Variable(s):				
			Confidence Interval	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
0.806	0.040	0.000	0.728	0.883

The test result variable(s): Predicted probability has at least one tie

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Table A5: Area under the curve (AUC) statistics in model-2

Network Relational and Structural Characteristics "Main effects Model" (Model-3-Product): *Tests for goodness of model fit*

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	53.273	8	0.000
	Block	53.273	8	0.000
	Model	**53.273**	**8**	**0.000**

Table A6: Chi-Square test (Omnibus Tests of Model Coefficients) model-3

2- Hosmer and Lemeshow Test

3-

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	7.457	8	0.488

Table A7: Hosmer and Lemeshow goodness-of-fit test for Model-3

4- Classification Tables

Classification Table[a,b]

Observed			Predicted: Prod_Innov Not-Innovator	Predicted: Prod_Innov Product-Innovator	Percentage Correct
Step 0	Prod_Innov	Not-Innovator	0	51	0.0
		Product-Innovator	0	70	100.0
	Overall Percentage				57.9

a. Constant is included in the model.

b. The cut value is .500

Classification Table[a]

Observed			Predicted: Prod_Innov Not-Innovator	Predicted: Prod_Innov Product-Innovator	Percentage Correct
Step 1	Prod_Innov	Not-Innovator	36	15	70.6
		Product-Innovator	13	57	81.4
	Overall Percentage				76.9

a. The cut value is .500

Table A8, a & b: The results of Network Relational and Structural Characteristics (Model-3) classification tables

5- Receiver Operating Characteristic Curve (ROC)

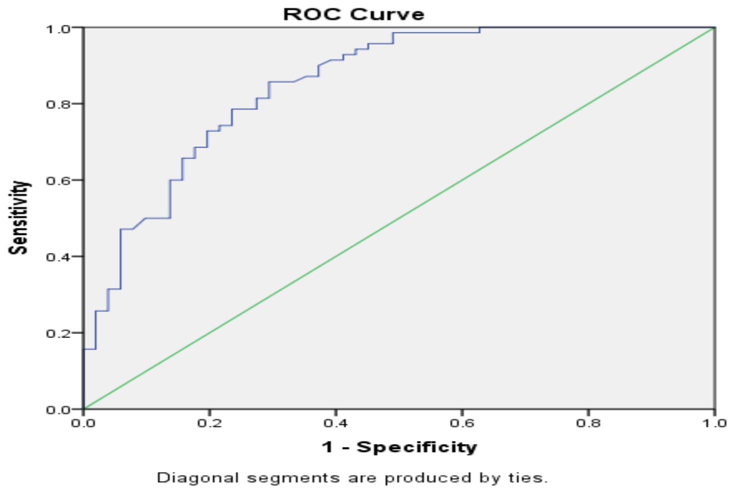

Figure A2: ROC plot for Network Structural Characteristics (Model-3)

Area Under the Curve

Test Result Variable(s):

Area	Std. Error[a]	Asymptotic Sig.[b]	Confidence Interval Lower Bound	Confidence Interval Upper Bound
0.852	0.035	0.000	0.782	0.921

The test result variable(s): Predicted probability has at least one tie

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Table A9: Area under the curve (AUC) statistics in model-3

Testing Interaction between Network Relational and Structural characteristics:

2-way interactions (model-4):

Tests for goodness of model fit

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	65.261	11	0.000
	Block	65.261	11	0.000
	Model	**65.261**	**11**	**0.000**

Table A10: Chi-Square test (Omnibus Tests of Model Coefficients) - model-4

2- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	6.119	8	0.634

Table A11: Hosmer and Lemeshow goodness-of-fit test for Model-4

3- Classification Tables

Classification Table[a,b]

Observed			Predicted: Prod_Innov: Not-Innovator	Predicted: Prod_Innov: Product-Innovator	Predicted: Percentage Correct
Step 0	Prod_Innov	Not-Innovator	0	51	0.0
		Product-Innovator	0	70	100.0
	Overall Percentage				57.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]

Observed			Predicted: Prod_Innov: Not-Innovator	Predicted: Prod_Innov: Product-Innovator	Predicted: Percentage Correct
Step 1	Prod_Innov	Not-Innovator	38	13	74.5
		Product-Innovator	11	59	84.3
	Overall Percentage				80.2

a. The cut value is .500

Table A12, a & b: The results of 2-way interactions (Model-4) classification tables

4- Receiver Operating Characteristic Curve (ROC)

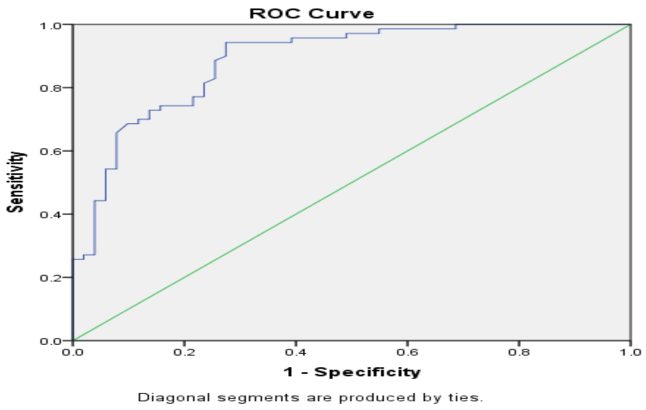

Figure A3: ROC plot for 2-way interactions (Model-4)

Area Under the Curve

Test Result Variable(s):

Area	Std. Error[a]	Asymptotic Sig.[b]	Confidence Interval Lower Bound	Confidence Interval Upper Bound
0.888	0.030	0.000	0.828	0.947

The test result variable(s): Predicted probability has at least one tie

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Table A13: Area under the curve (AUC) statistics in model-4

3-way interactions (model-5):

Tests for goodness of model fit

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	72.251	18	0.000
	Block	72.251	18	0.000
	Model	**72.251**	**18**	**0.000**

Table A14: Chi-Square test (Omnibus Tests of Model Coefficients) model-5

2- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	5.236	8	0.732

Table A15: Hosmer and Lemeshow goodness-of-fit test for Model-5

3- Classification Tables

Classification Table[a,b]

Observed			Predicted: Prod_Innov Not-Innovator	Predicted: Prod_Innov Product-Innovator	Predicted: Percentage Correct
Step 0	Prod_Innov	Not-Innovator	0	51	0.0
		Product-Innovator	0	70	100.0
	Overall Percentage				57.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]

Observed			Predicted: Prod_Innov Not-Innovator	Predicted: Prod_Innov Product-Innovator	Predicted: Percentage Correct
Step 1	Prod_Innov	Not-Innovator	41	10	80.4
		Product-Innovator	10	60	85.7
	Overall Percentage				83.5

a. The cut value is .500

Table A16, a & b: The results of 3-way interactions (Model-5) classification tables

4- Receiver Operating Characteristic Curve (ROC)

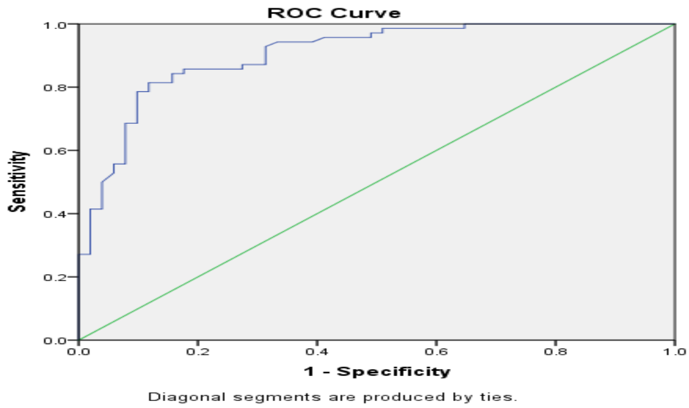

Figure A4: ROC plot for 3-way interactions (Model-5)

Area Under the Curve

Test Result Variable(s):

Area	Std. Error[a]	Asymptotic Sig.[b]	Confidence Interval Lower Bound	Confidence Interval Upper Bound
0.905	0.027	0.000	0.851	0.958

The test result variable(s): Predicted probability has at

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Table A17: Area under the curve (AUC) statistics in model-5

Appendix B

Process innovation logistic regression analysis

Identification of potential confounders from the removed insignificance variables:

Variables assessment for confounding		Regression coefficient (β) with the removed variable	Regression coefficient (β) without the removed variable	Δ β %
Sector_Type (Service)	Strengthen the Ties (Strengthen)	0.509	0.4219	-17%
	Ties Strength (Strong Ties)	-1.218	-1.1825	-3%
	Continuity	0.495	0.5387	9%
	Partners _Diversity	0.625	0.6051	-3%
	Network Density	0.018	0.0194	8%
	Betweenness Centrality	0.071	0.0705	-1%
Firm_Age				
	Strengthen the Ties (Strengthen)	0.433	0.4219	-3%
	Ties Strength (Strong Ties)	-1.209	-1.1825	-2%
	Continuity	0.6	0.5387	-10%
	Partners _Diversity	0.577	0.6051	5%
	Network Density	0.02	0.0194	-3%
	Betweenness Centrality	0.069	0.0705	2%
Firm_Size (Medium)				
	Strengthen the Ties (Strengthen)	0.448	0.4219	-6%
	Ties Strength (Strong Ties)	-1.158	-1.1825	2%
	Continuity	0.529	0.5387	2%
	Partners _Diversity	0.638	0.6051	-5%
	Network Density	0.02	0.0194	-3%
	Betweenness Centrality	0.074	0.0705	-5%
Firm_Group (Part of Group)				
	Strengthen the Ties (Strengthen)	0.405	0.4219	4%
	Ties Strength (Strong Ties)	-1.214	-1.1825	-3%
	Continuity	0.511	0.5387	5%
	Partners _Diversity	0.618	0.6051	-2%
	Network Density	0.019	0.0194	2%
	Betweenness Centrality	0.068	0.0705	4%
Firm_Export (Export)				
	Strengthen the Ties (Strengthen)	0.455	0.4219	-7%
	Ties Strength (Strong Ties)	-1.218	-1.1825	-3%
	Continuity	0.574	0.5387	-6%
	Partners _Diversity	0.657	0.6051	-8%
	Network Density	0.019	0.0194	2%
	Betweenness Centrality	0.069	0.0705	2%

Figure B1: Testing for potential confounders from the removed insignificance variables

Network Relational Characteristics (Model 6-Process): *Tests for Goodness of Model fit*

2- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	15.234	4	0.004
	Block	15.234	4	0.004
	Model	**15.234**	**4**	**0.004**

Table B2: Chi Square test (Omnibus Tests of Model Coefficients), Model-6

3- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	5.244	7	0.630

Table B3: Hosmer and Lemeshow goodness-of-fit test for Model-6

4- Classification Tables

Classification Table[a,b]					
			Predicted		
			ProcInnov		Percentage Correct
Observed			NotProcInnov	ProcInno	
Step 0	ProcInnov	NotProcInnov	0	40	0.0
		ProcInno	0	81	100.0
	Overall Percentage				66.9
a. Constant is included in the model.					
b. The cut value is .500					

Classification Table[a]					
			Predicted		
			ProcInnov		Percentage Correct
Observed			NotProcInnov	ProcInno	
Step 1	ProcInnov	NotProcInnov	13	27	32.5
		ProcInno	6	75	92.6
	Overall Percentage				72.7
a. The cut value is .500					

Table B4, a & b: The results of Network Relational Characteristics (Model-6) classification tables

5- Receiver Operating Characteristic Curve (ROC)

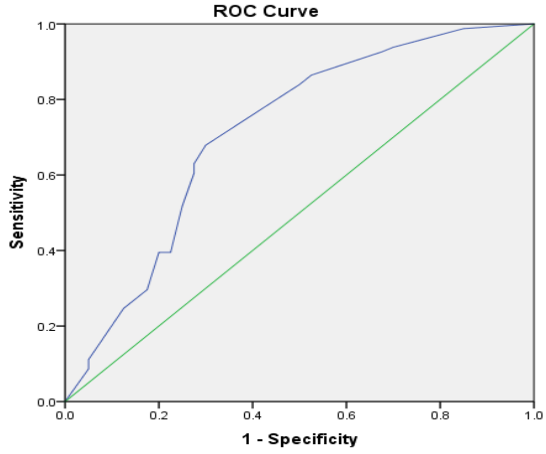

Figure B1: ROC plot of Network Relational Characteristics (Model-6)

Area Under the Curve				
Test Result Variable(s):				
			Asymptotic 95% Confidence Interval	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
0.714	0.053	0.000	0.609	0.818

The test result variable(s): Predicted probability has at least one tie
a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Table B5: Area under the curve (AUC) statistics in model-6

Network Structural Characteristics (Model 7-Process): *Tests for Goodness of Model fit:*

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	15.397	2	0.000
	Block	15.397	2	0.000
	Model	**15.397**	**2**	**0.000**

Table B6: Chi Square test (Omnibus Tests of Model Coefficients), Model-7

2- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	4.377	7	0.735

Table B7: Hosmer and Lemeshow goodness-of-fit test for Model-7

3- Classification Tables

Classification Table[a,b]

Observed			Predicted: ProcInnov NotProcInnov	Predicted: ProcInnov ProcInno	Predicted: Percentage Correct
Step 0	ProcInnov	NotProcInnov	0	40	0.0
		ProcInno	0	81	100.0
	Overall Percentage				66.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]

Observed			Predicted: ProcInnov NotProcInnov	Predicted: ProcInnov ProcInno	Predicted: Percentage Correct
Step 1	ProcInnov	NotProcInnov	18	22	45.0
		ProcInno	12	69	85.2
	Overall Percentage				71.9

a. The cut value is .500

Table B8, a & b: The results of Network Structural Characteristics (Model-7) classification tables

4- Receiver Operating Characteristic Curve (ROC)

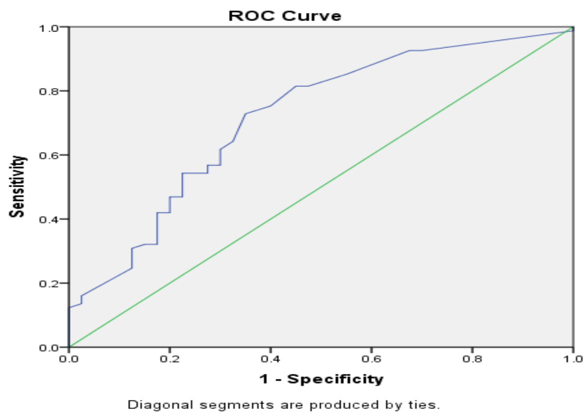

Figure B2: ROC plot of Network Structural Characteristics (Model-7)

Area Under the Curve				
Test Result Variable(s):				
			Confidence Interval	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
0.716	0.051	0.000	0.617	0.816
The test result variable(s): Predicted probability has at least one tie				
a. Under the nonparametric assumption				
b. Null hypothesis: true area = 0.5				

Table B9: Area under the curve (AUC) statistics in model-7

Network Relational and Structural Characteristics "main effects Model" (Model 8-Process):

Tests for goodness of model fit

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	26.812	6	0.000
	Block	26.812	6	0.000
	Model	**26.812**	**6**	**0.000**

Table B10: Chi Square test (Omnibus Tests of Model Coefficients), Model-8

1- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	15.268	8	0.054

Table B11: Hosmer and Lemeshow goodness-of-fit test for Model-8

1- Classification Tables

Classification Table[a,b]					
			Predicted		
			ProcInnov		
Observed			NotProcInnov	ProcInno	Percentage Correct
Step 0	ProcInnov	NotProcInnov	0	40	0.0
		ProcInno	0	81	100.0
	Overall Percentage				66.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]					
			Predicted		
			ProcInnov		
Observed			NotProcInnov	ProcInno	Percentage Correct
Step 1	ProcInnov	NotProcInnov	20	20	50.0
		ProcInno	7	74	91.4
	Overall Percentage				77.7

a. The cut value is .500

Table B12, a & b: The results of main effects model (Model-8) classification tables

4- Receiver Operating Characteristic Curve (ROC)

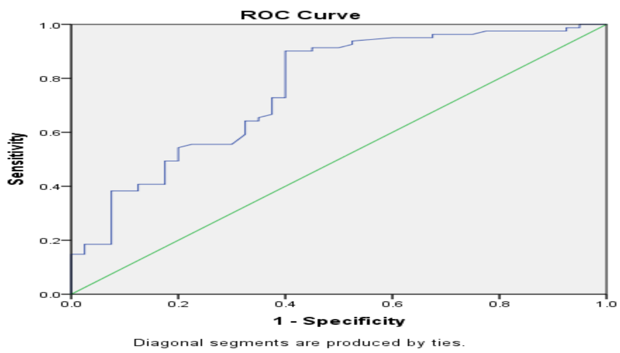

Figure B3: ROC plot of main effects model (Model-8)

Area Under the Curve				
Test Result Variable(s):				
			Asymptotic 95%	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
0.759	0.048	0.000	0.664	0.853

The test result variable(s): Predicted probability has at least one tie
a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Table B13: Area under the curve (AUC) statistics in model-8

The logit transformation of the LR model (main effects Model):

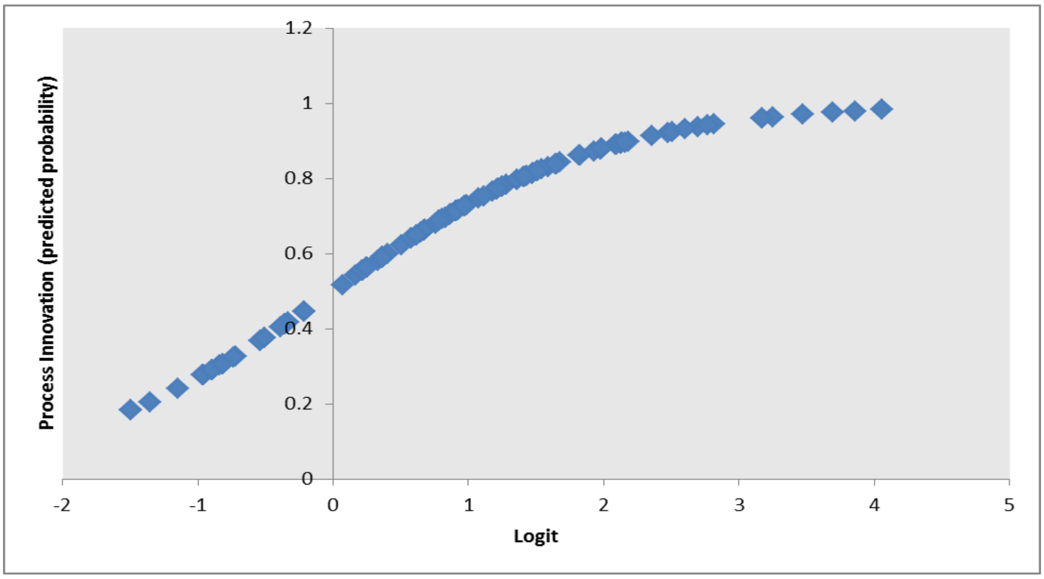

Figure B4: Logit plot against the predicted probability of process innovation in model 8 (main effects model)

Testing Interaction between Network Relational and Structural characteristics:

2-way interactions (model-9):

Tests for goodness of model fit

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	36.722	9	0.000
	Block	36.722	9	0.000
	Model	**36.722**	**9**	**0.000**

Table B14: Chi Square test (Omnibus Tests of Model Coefficients), Model-9

2- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	15.382	8	0.052

Table B15: Hosmer and Lemeshow goodness-of-fit test for Model-9

3- Classification Tables

Classification Table[a,b]

Observed			Predicted: ProcInnov: NotProcInnov	Predicted: ProcInnov: ProcInno	Predicted: Percentage Correct
Step 0	ProcInnov	NotProcInnov	0	40	0.0
		ProcInno	0	81	100.0
	Overall Percentage				66.9

a. Constant is included in the model.

b. The cut value is .500

Classification Table[a]

Observed			Predicted: ProcInnov: NotProcInnov	Predicted: ProcInnov: ProcInno	Predicted: Percentage Correct
Step 1	ProcInnov	NotProcInnov	22	18	55.0
		ProcInno	8	73	90.1
	Overall Percentage				78.5

a. The cut value is .500

Table B16, a & b: The results of 2-way interaction (Model-9) classification tables

4- Receiver Operating Characteristic Curve (ROC)

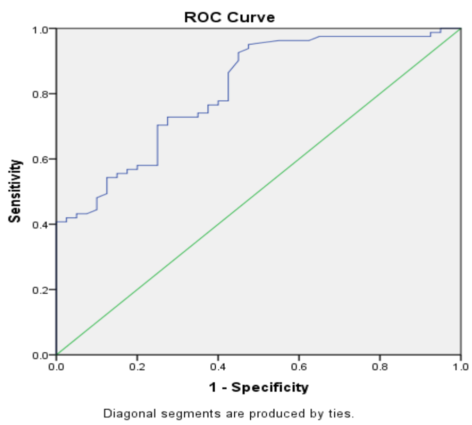

Figure B5: ROC plot of 2-way interaction (Model-9)

Area Under the Curve				
Test Result Variable(s):				
			Asymptotic 95% Confidence Interval	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
0.811	0.040	0.000	0.732	0.890

The test result variable(s): Predicted probability has at least one tie
a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Table B17: Area under the curve (AUC) statistics in model-9

The logit transformation of the 2-way interaction model (model-9)

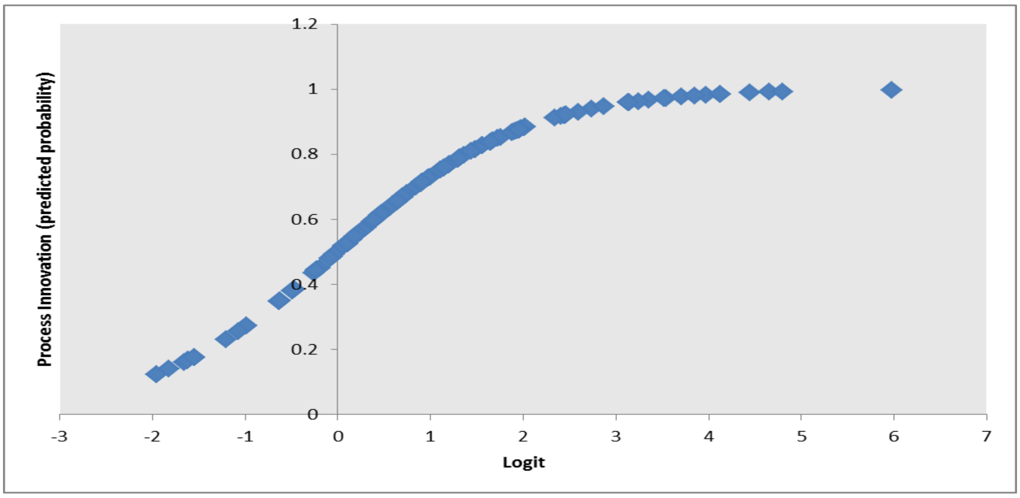

Fig B6: Logit plot against the predicted probability of process innovation in model 9 (2-way interaction model)

3-way interactions (model-10):

Tests for goodness of model fit

1- Chi Square test (Omnibus Tests of Model Coefficients)

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	47.059	17	0.000
	Block	47.059	17	0.000
	Model	**47.059**	**17**	**0.000**

Table B18: Chi Square test (Omnibus Tests of Model Coefficients), Model-10

2- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	10.599	8	0.225

Table B19: Hosmer and Lemeshow goodness-of-fit test for Model-10

3- Classification Tables

Classification Table[a,b]

Observed			Predicted: ProcInnov: NotProcInnov	Predicted: ProcInnov: ProcInno	Predicted: Percentage Correct
Step 0	ProcInnov	NotProcInnov	0	40	0.0
		ProcInno	0	81	100.0
	Overall Percentage				66.9

a. Constant is included in the model.
b. The cut value is .500

Classification Table[a]

Observed			Predicted: ProcInnov: NotProcInnov	Predicted: ProcInnov: ProcInno	Predicted: Percentage Correct
Step 1	ProcInnov	NotProcInnov	23	17	57.5
		ProcInno	8	73	90.1
	Overall Percentage				79.3

a. The cut value is .500

Table B20, a & b: The results of 3-way interaction (Model-10) classification tables

4- Receiver Operating Characteristic Curve (ROC)

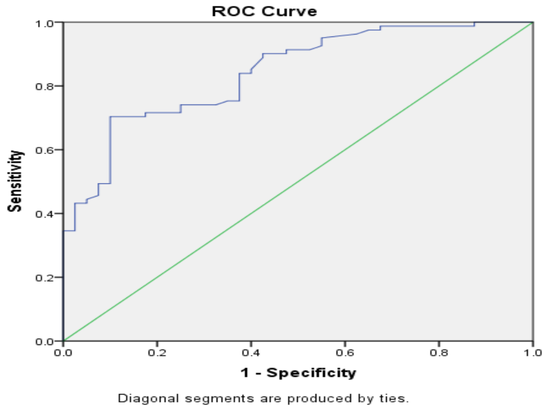

Figure B7: ROC plot of 3-way interaction (Model-10)

Area Under the Curve				
Test Result Variable(s):				
			Asymptotic 95% Confidence Interval	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
0.842	0.036	0.000	0.771	0.913
The test result variable(s): Predicted probability has at				
a. Under the nonparametric assumption				
b. Null hypothesis: true area = 0.5				

Table B21: Area under the curve (AUC) statistics in model-10

The logit transformation of the 3-way interaction model (model-10)

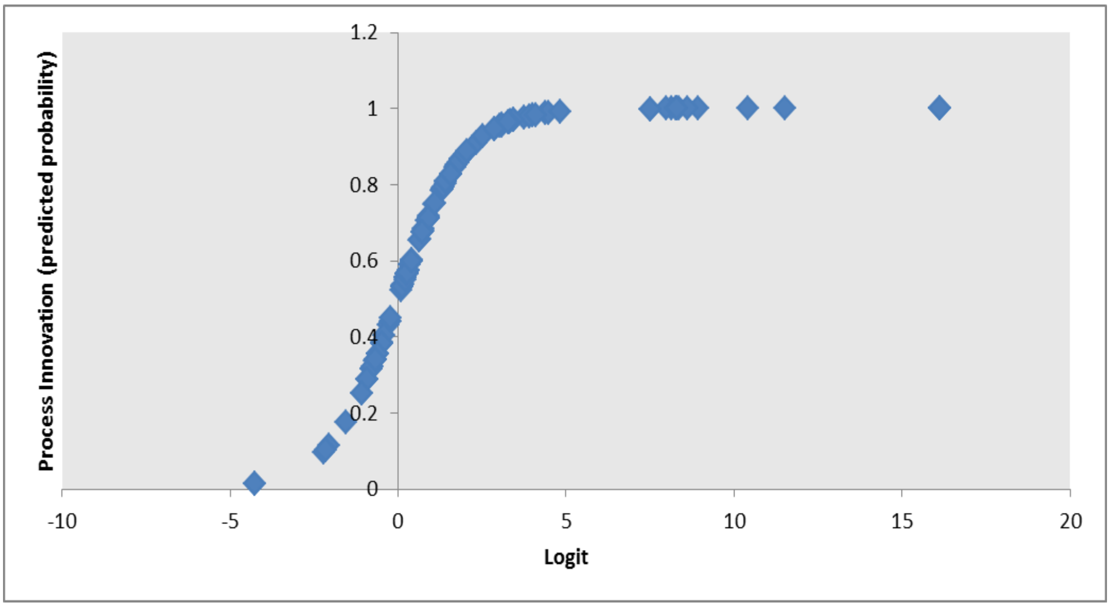

Fig B8: Logit plot against the predicted probability of process innovation in model 10 (3-way interaction model)

Appendix C:

Spearman's Correlation coefficient among variables

		Product _innovation	Process _innovation	Strengthen the Ties	Ties Strength	Network Density	Betweenness Centrality	Degree centrality	Continuity	Partners _Diversity	Firm_Age	Sector_ Type	Firm_Size	Firm_ Group	Firm_ Export
Spearman's rho	Product _innovation	1													
	Process _innovation	.432**	1												
	Strengthen the Ties	.189*	0.111	1											
	Ties Strength	-.194*	-.277**	-0.07	1										
	Network Density	.385**	.327**	0.019	-0.028	1									
	Betweenness Centrality	.202*	0.162	.201*	-.182*	-0.17	1								
	Degree centrality	.321**	.258**	.194*	-.224*	.227*	**0.849****	1							
	Continuity	0.163	0.117	0.062	-0.121	0.035	-0.071	-0.062	1						
	Partners _Diversity	.221*	0.152	0.019	0.044	.230*	0.027	0.106	-0.057	1					
	Firm_Age	0.009	-0.001	0.019	-0.084	-0.036	-0.086	-0.109	0.17	-0.051	1				
	Sector_Type	-.198*	-0.088	0.166	-0.043	-.198*	0.117	0.043	-0.077	0.046	.317**	1			
	Firm_Size	-0.021	0.007	0.086	0.052	0.062	.182*	.190*	-0.043	0.178	.233*		1		
	Firm_Group	0.085	0.09	0.041	0.116	.232*	0.172	.239**	0.067	-0.046	0.008	-0.052	0.097	1	
	Firm_Export	.247**	0.057	.185*	-0.161	0.044	0.09	0.048	0.148	.193*	-0.034	0	0.161	0.131	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix D

Networking and Firm's Innovation Survey

Please, indicate your Job Title

____

How long have you been working for this company: ______________Year

Section 0.0: General Information about the Company

Company Name:____

Address:____

Contact:_______________________ E-mail: ___________________________

Main Activity (Sector):____

Is your Company part of a larger Company group?

- ☐ **No**
- ☐ **Yes** (Name of Company group _______________________________)

If your company part of a larger group, please answer the next sections for your company only

When was your company established?

☐

Number of full time Employees

- 49 and below ☐
- 50-249 ☐
- 250 and above ☐

0.1 In which market/s did your Company sell products (goods or services) during 2013 & 2014
(Tick more than one, if applicable)

- National ☐ A
- GCC (Gulf Cooperation Council) ☐ B
- International ☐ C

Which was your most important market in terms of sales share
(Give the corresponding letter): _________

Section 1: Company Innovation Information

1 Product (Good or Service) Innovation:

Product innovation defined as: the market introduction of a new or a significantly improved good or service with respect to its capabilities.

Notes:

- Please exclude any minor changes or simple product customization, since they don't considered as product innovations.
- Product innovations must be at least **New to your Company**, but they don't need to be new to your market/s.

Q.1

1.1 Considering years **2013 & 2014**, and according to the above product innovation definition:

	Number of Product Innovations				
	0	**1**	**2-3**	**4-6**	**>6**
➢ How many new or significantly improved **Goods** did your company introduce?	☐	☐	☐	☐	☐
➢ How many new or significantly improved **Services** did your company introduce?	☐	☐	☐	☐	☐

If you select (0) to all options, please go to question 2; otherwise continue with the next question,

1.2 Who developed these product innovations? ***Please, Tick all that apply***

	Goods Innovations	**Services Innovations**
➢ Your company by itself or company group	☐	☐
➢ Your company in cooperation with other organizations (organizations could include, research centres or institutions (public or private), other companies)	☐	☐
➢ By other organizations	☐	☐

1.3 Were any of your product innovations during **2013 & 2014**?

	Yes	**No**
➢ **New to your market** (Introduced to your market/s before competitors)	☐	☐
➢ **Only new to your Company**? (Product innovations already available in your market/s)	☐	☐

Remarks:

2	**Process Innovation:**

Process innovation defined as: the implementation of a new or significantly improved production process, distribution method, or supporting activity.

Notes:

- Please exclude purely organizational innovations (i.e. TQM, Knowledge Management, etc.), since they will be covered in the next section - Organizational innovation.
- Process innovations must be at least **new to your company**, but they don't need to be new to your market/s.

Q.2		Number of Process Innovations				
		0	**1**	**2-3**	**4-6**	**>6**
2.1	Considering years **2013 & 2014**, and according to the above Process innovation definition: ➢ How many new or significantly improved production, or delivery process and methods did your company introduce? *(For example new or significantly improved logistics, purchasing, accounting methods, or techniques, equipment and software used to produce goods or services.)*	☐	☐	☐	☐	☐

If you select(0), please go to question 3; otherwise continue with the next question,

2.2	Who developed these Process innovations?	***Please, Tick all that apply***
	➢ Your company by itself	☐
	➢ Your company in cooperation with other organizations *(organizations could include, research centres or institutions (public or private), other companies)*	☐
	➢ By other organizations	☐

2.3	Were any of your Process innovations during **2013 & 2014**?	**Yes**	**No**
	➢ **New to your market/s** (Introduced to your market/s before competitors)	☐	☐

Remarks:

Section 2:	Networking (Business/Inter-organizational Relationships)

Definitions:

Partner definition:
In this research, **Partner** could be any organization that your company exchange business with, or had informal or formal relationships, alliance or collaboration with. Such as, another companies, universities, research centres (public or private), suppliers, etc.

Business/inter-organizational relationship:
Any kind of formal or informal relationship between your company and other organizations. For example, it could be in the form of Joint Ventures, alliance, R&D agreement, licensing, manufacturing agreement, etc.

Definition of different form of formal Business/inter-organizational relationships:

Equity alliance: a type of contract or agreements where a company acquires partial ownership of another company

Joint ventures: a type of contract or agreements where two or more organizations share their resources (i.e. costs, management, profit, etc.) to pursue specific opportunities (i.e. market opportunities, manufacturing opportunities, new product opportunities, etc.)

		Partner 1	Partner 2	Partner 3	Partner 4	Partner 5	Partner 6	Partner 7	Partner 8
Q3	**Looking back over the years 2012 & 2013, who were your company in business/inter-organizational relationship with** (for example, Joint ventures, R&D Agreements, Licensing Agreements, Distribution/marketing Agreements, etc.), **Please list your partner's name; or if you prefer just provide their initials.** **Important Note: If you have more than <u>8 partners</u>, please complete section 3 after you finish with this section, otherwise continue with this section and then go to Q4**								
3.1	**What type of business /inter-organizational relationship did you have with this partner in 2012 & 2013?** (Please, *Tick all that apply*)								
	➢ Equity alliances								
	➢ Joint ventures								
	➢ R&D Agreements								
	➢ Second Source Agreements (For example: SSA for components, subassemblies and fully assembled products								
	➢ Component Sourcing Agreements								
	➢ Know-how and Patent Licensing Agreements								
	➢ Distribution/marketing Agreements								
	➢ Informal relationship/interaction (i.e. Formation of social relationships and networks at conferences, trade fairs, exhibitions, Professional and industry associations, etc.)								
	➢ Other (please specify)								
3.2	**On average, how frequently did you communicate/ interact/contact with each partner in 2012 & 2013?** *(please, choose only one answer)*								
	➢ Daily								
	➢ Several times a week								
	➢ Several times a month								
	➢ Once a month								
	➢ Several times a year								
	➢ Once a year or less								
3.3	**During years 2012 & 2013, did your Co. frequency of interaction/contact with this partner:** *(please, choose only one answer)*								
	➢ Increased								
	➢ Remained the same								
	➢ Decreased								
3.4	**Up to the end of 2013, for how long have your Co. been in business/inter-organizational relationship with this partner?** *(please, choose only one answer)*								
	➢ Less than 1 year								
	➢ 1 to 3 years								
	➢ 4 to 6 years								
	➢ 7 to 9 years								
	➢ 10 or more years								
3.5	**What is the main type of your partners you mentioned?** (Please, *Tick all that apply*)								
	➢ Suppliers of equipment, materials, components, or software								
	➢ Clients or customers								
	➢ Competitors or other companies in your sector								
	➢ Consultants, commercial labs, or private R&D institutes								
	➢ Universities or other higher education institutions								
	➢ Government or public research institutes								
	➢ Other (please specify)								
3.6	**Where is the location of your partner's main business/headquarter?** *(please, choose only one answer)*								
	➢ National								
	➢ GCC (Gulf Cooperation Council)								
	➢ International								

Q4	**Please think about your partners you have just mentioned in Q3, and specify to the best of your knowledge if any of these partners have had business/inter-organizational relationship/knowledge or information transfer with each other in 2012 &/or 2013.** (for example: if you think (**partner 1**) and (**Partner 4**) have had business/inter-organizational relationship/knowledge or information transfer in 2012 &/or 2013, then mark cell **1D**)

Partners Names		A	B	C	D	E	F	G	H	I	G	K	L	M	N	O	P
		Partner 1	Partner 2	Partner 3	Partner 4	Partner 5	Partner 6	Partner 7	Partner 8	Partner 9	Partner 10	Partner 11	Partner 12	Partner 13	Partner 14	Partner 15	Partner 16
1	Partner 1																
2	Partner 2																
3	Partner 3																
4	Partner 4																
5	Partner 5																
6	Partner 6																
7	Partner 7																
8	Partner 8																
9	Partner 9																
10	Partner 10																
11	Partner 11																
12	Partner 12																
13	Partner 13																
14	Partner 14																
15	Partner 15																
16	Partner 16																