

IMPACTS OF INTER-ORGANISATIONAL
KNOWLEDGE TRANSFER NETWORKS ON
DIFFERENT TYPES OF INNOVATIONS IN SMES

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Impacts of Inter-organisational Knowledge Transfer
Networks on Different Types of Innovations in SMEs

by

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Abstract

This research aims to understand the contributions of inter-organisational knowledge transfer to innovation in SMEs from a social network perspective. The main objective is to identify the impact of the network characteristics on company's innovation performance. Organisations are embedded in a network of relationships with other companies. They must make the best use of all available resources in order to survive and thrive in today's competitive environment. However, most of the previous network studies focus on large organisations and studying network effects in the context of SMEs is not well explored. This study sheds light on the relationships between different network characteristics and two different types of innovation performance in High Tech SMEs.

In this study inter-organisational knowledge transfer networks were investigated from ego-network perspective. Radical and incremental innovation was identified as specific types of innovation. More specifically this research studied the impact of the structural, relational and nodal properties of inter-organisational knowledge transfer network on radical and incremental innovation performance. In addition to network characteristics, internal capabilities of companies were also identified important. Pentathlon framework was used to capture firms' innovation management capabilities.

A survey instrument was used to collect data from a sample of UK Small to Medium size Enterprises (SMEs). A new innovation measurement instrument was developed to measure different types of innovation from companies' and customers' perspectives. The SMEs were chosen randomly from IT and Chemical industry. Inter-organisational relationships were mapped using social network techniques. Path analysis techniques including PLS were used to test the hypotheses of the study. In addition to the statistical method, Fuzzy set Qualitative Comparative Analysis was used to shed light on different combinations (various configurations) of factors that impact on radical and incremental innovation.

This study has made theoretical contributions by identifying research gaps through review and synthesis of literature in innovation and inter-organisational relationships and social network theories. Moreover, a new framework was developed based on the concepts identified in social network and innovation literature. The integration of theories and concepts regarding inter-organisational relationships, innovation and social networks with a view of better understanding of the impact of network characteristics on specific types of innovation is another contribution of this study.

This research shows how different network properties can help companies to achieve ambidextrousness, which is vital for organisations' competitive advantages and long term survival. Moreover, this study reveals that the internal capabilities (innovation management practices) of a firm play a significant role in enabling the company to benefit from its network resources. It shows how different configuration of the internal capabilities and network resources can lead to a better radical/incremental innovation performance. Findings from this research can help managers to adapt their network resources according to their strategies and the level of the innovation that they want to achieve.

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Glossary

AVE	Average Variance Extracted
CFA	Confirmatory Factor Analysis
EM	Expectation Maximisation
FsQCA	Fuzzy set Qualitative Comparative Analysis
ICT	Information and Communications Technology
IT	Information Technology
MCAR	Missing Completely At Random
PLS	Partial Least Squares
R&D	Research and Development
RFID	Radio Frequency Identification
SEM	Structural Equation Modelling
SMEs	Small to Medium Size Enterprises
SNA	Social Network Analysis
SPSS	Statistical Package for the Social Sciences

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1. Chapter 1: Introduction

1.1. Introduction

In this introductory chapter the context of the study is examined including social network and innovation contexts. Moreover, the importance of the research, the gaps in the literature addressed by this study, boundaries, aims and objectives of the work have been explained. Next, the method that was adopted to achieve the aim of the study is introduced. Finally the structure of the thesis is outlined.

1.2. Background

Organisations' competitive environment has changed over the last decades due to globalisation and it is vital for organisations to look for strategies that provide them with sustainable competitive advantages. Among the factors that are important in organisations' success, the ability to innovate is widely recognised as the most critical factor that helps the company to stay ahead of its competitors and to have more chance to survive in the fast changing environment. Innovation can change the entire shape of an industry and influence the life and death of firms. The history of business is littered with the graveyards of businesses that were destroyed due to the lack of innovation and failing to adapt to their changing environment (Chandy and Tellis 2000). Therefore, it is vital for managers to know how to manage and initiate innovation in their company.

During the last two decades, there has been a significant increase in research on inter-organisational relationships and its impacts on firms. Researchers have focused on

different types of inter-organisational networks that occur between organisations (e.g. R&D, Alliance, Joint venture). Some of them have analysed the co-operations according to the properties of knowledge being transferred such as tacit-explicit and individual-social (Amin and Cohendet 2004). The positive role of the networks on different aspects of organisations has already been confirmed (e.g. Ahuja 2000, Barringer and Harrison 2000, Gulati *et al.* 2002). Some of these aspects are the effects of inter-organisational networks on firms' innovation, performance, learning and survival rate (Ahuja 2000, Combs and Ketchen 1999, Gulati *et al.* 2002, Mitchell and Singh 1996, Powell *et al.* 1996, Stuart 2000). Innovation for firms and society has received great attention from scholars in different areas such as strategic management (Abernathy and Clark 1985, Ahuja and Katila 2001), economics (Teece 1992) and geography (Powell *et al.* 1996). Previous studies have addressed the role of both internal (e.g. strategy, human resources) and external factors (e.g. inter-organisational relationship, social network characteristics) on innovation performance. Most of the studies on inter-organisational relationships and innovation have studied innovation as a general concept and only some of them considered different categories of innovation.

In the following sections a brief background on each of the main concepts of the study is provided.

1.3. Innovation and Categories of Innovation

Innovation is more than having a research and development team (R&D) or employing bright people in a company. Innovation is defined as “the development and implementation of new ideas and knowledge into a socially and economically successful product, process or service” (Van de Ven *et al.* 1999, p. 13). According to this definition, innovation is an economic concept as much as a technological one.

There are different classifications for innovation but the use of radical and incremental is the most established one (Subramaniam and Youndt 2005). Incremental innovation is defined as minor changes or extensions to the current products, existing services or processes of the organisations (Dewar and Dutton 1986) and radical innovation is the development of new products that requires significantly new technology or ideas that had not existed in the market before or requires fundamental changes to the existing market (McDermott and O'Connor 2002). Companies to develop incremental innovation use their established capabilities, but for radical innovations they question their current methods of doing things or current products/services.

Innovation happens by using new technical and commercial skills and adopting different problem solving approaches (Henderson and Clark 1990, Tushman and Anderson 1986). These classifications will be discussed in detail in the next chapter. Being a radical innovator is an important factor for firms' long-term survival. This type of innovation is an engine of economic growth and makes the foundation for other new product development (McDermott and O'Connor 2002). Firms that are mainly focused on one product development cannot keep their leadership after a new technology shift (Abernathy and Clark 1985, Anderson and Tushman 1990), so they need to make changes to their products, processes or services to be able to survive in the current competitive environment. O'Reilly and Tushman (2004) argued that companies in order to be successful need to perform well in both types of innovation. They call this kind of organisation an ambidextrous organisation. An ambidextrous organisation is able to do both radical and incremental innovations and switch between these two based on their current situation. Moreover, literature on innovation has emphasised the importance of the balance between different innovation categories in a firm's innovation strategy (Booz-Allen and Hamilton 1980, Muzyka and Churchill 1997).

Radical and incremental innovations are similar in some aspects and vary in others. Both require resources such as funds, knowledge, human resource, strategy and both of them have consequences for companies. However, they are different in competitive outcomes (Henderson and Clark 1990), types of resources that they draw upon (Todtling *et al.* 2009) and organisational capabilities (Henderson and Clark 1990). Previous studies in large organisations revealed that the management requirements for incremental innovations and radical innovations are different (Oke *et al.* 2007). Therefore, investigating the requirements of each type of innovation will help managers in their strategy development and adopting the resources that reside inside and outside the company for innovation.

1.4. Small to Medium Size Organisations

Small to Medium Size Enterprises are an important part of most economic structures and a large number of people are employed by these enterprises (Hausman 2005). They play a significant role in most national economies (Wolff and Pett 2006) and there are programs by governments to stimulate innovation in this type of enterprise. Many governments recognise SMEs as a potential job creator which directly influences employment and economic growth. Previous research acknowledged the importance of SMEs in knowledge generation and exploring new business fields (Acs and Audretsch 1990). One of the main concerns of the policy makers is encouraging innovation in SMEs which will energise economic development at the local, regional, national and European level (Tilley and Tonge 2003). Given that SMEs represent 99.9 per cent of enterprises in the UK, 58.8 per cent of private sector employment and 48.8 per cent of private sector turnover (BIS 2011), there is no doubt that they play a significant role in the UK economy. In Chapter 3, it is highlighted that previous studies on types of innovation and their impacts on firm performance are mainly about large organisations. However, there is a link between

innovation and business performance in SMEs that could contribute to economic growth (Oke *et al.* 2007).

SMEs have strengths and weaknesses compared to large organisations. Strengths include management dynamism, organisational flexibility, rapid internal communication and a high degree of adaptability (Rothwell and Dodgson 1991). Some of the weaknesses include lack of some resources (e.g. capital, distribution and servicing facilities, scaling economies) that are associated with large organisations. SMEs in order to survive in the current competitive environment need to find a solution to this shortcoming.

1.5. Social Network, Innovation and SMEs

Network perspective is based on the idea that economic activities are embedded in a social network of relationships (Gulati *et al.* 2002). Laumann *et al.* (1987 p. 458) defined a social network as a “set of nodes (e.g., persons, organisations) linked by a set of social relationships (e.g., friendship, transfer of funds, overlapping membership) of a specified type”. These relations vary from different perspectives (this has been explained in detail in Chapter 3), but they all link actors of the network and it is through these social ties that social network structures are formed. At the inter-organisational level, organisations are the actors and customer supplier relationships, resource flows, trade association memberships, interlocking directorates, or prior strategic alliances are the relationships between them. It is necessary to distinguish between inter-firm relationships and inter-organisational relationships. Former refers only to the relationships between companies while later includes all the relationships between different types of organisations such as companies, universities, laboratories. In this study, because of the importance of the knowledge transfer with universities and other similar organisations the term ‘inter-organisational relationship’ has been used throughout this text to include all those relationships.

The main benefit of networking with other organisations is sharing different kinds of resources (Barringer and Harrison 2000, Gulati *et al.* 2002). Different scholars in their studies reported that these resources may include financial (Ingram and Inman 1996), institutional (Baum and Oliver 1991), knowledge and information resources, as well as a host of other resources in the network (Ingram and Inman 1996). Among the different potential benefits that an efficient and effective inter-organisational network can provide for an organisation, Burt (1992) suggested that three of them are specifically important. First is the access to information. Information that companies can access through their network is beyond what they can achieve alone. Second is the timing of the information. Information provided early (or at the right time) can be a great advantage for the recipient company. The last benefit is the referrals. Using their network partners, companies can represent their interests to third parties in a positive way.

Companies, in order to be innovative, need to access different types of resources (e.g. fund and knowledge). SMEs, because of their limited resources, do not have access to all the necessary resources that they require for innovation. Therefore they need to find a solution to overcome these barriers. Establishing relations with other companies and exchanging resources with partners is one of the ways that can help them to address this issue. Many studies have investigated and confirmed the positive impact of networking with other companies on innovation performance (Ahuja 2000, Ahuja and Katila 2001, Boschma and Wal 2007, De Propris 2002). SMEs, in order to be innovative and increase the novelty of their innovation, must improve their learning capabilities (Amara *et al.* 2008). Learning capabilities refers to their ability to generate new knowledge internally as well as exploiting resources that lie outside the firm (e.g. clients, suppliers, universities). Other researchers also confirmed the importance of internal capabilities (Hakansson 1989, Hippel 1988) together with networking and knowledge exchange between partners on the innovative performance of companies. Therefore, to study innovation in SMEs it is

vital to consider both internal and external factors. Adopting a social network perspective will help to better understand the effect of the factors that fall outside the firms' boundaries. To address the internal capabilities of firms for innovation generation, innovation management practices adopted by the companies were studied.

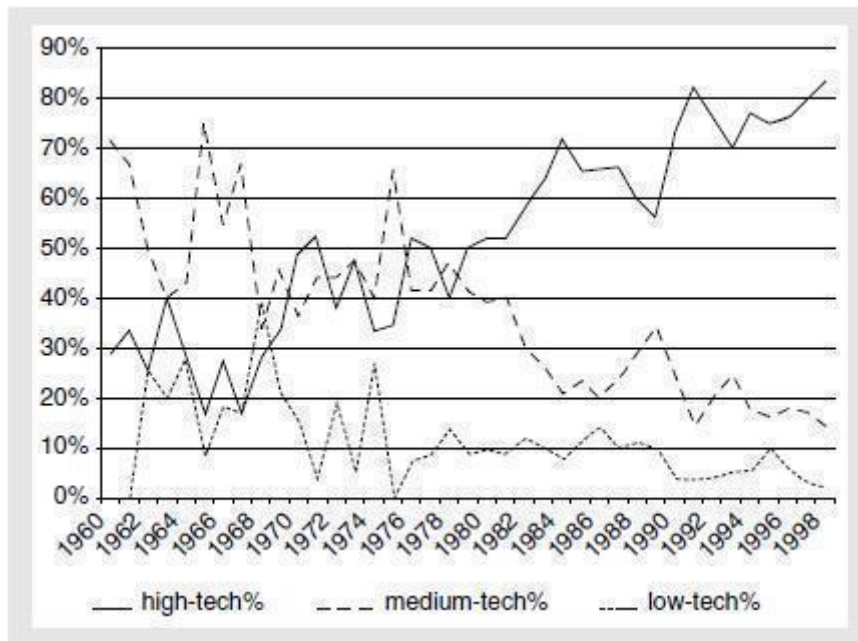


Figure 1.1: The share (%) of high-tech, medium-tech, and low-tech industries in established R&D partnerships (Hagedoorn 2002)

There are two main streams of research in innovation studies. One stream is about the innovation performance of companies. This stream focuses on the presence and absence of innovation and makes it possible to differentiate between innovative and non-innovative companies. The second stream of innovation research is about the novelty of the innovation that organisations develop. This body of literature studies the degree of novelty from either the customers or firms' perspective. In the former, most studies are focused on large or science-based firms (Amara *et al.* 2008). Considering those studies that used social network method to investigate this issue there are limited studies about SMEs in this stream of research. Specifically this research is focused on the high-tech sector, because companies in this sector rely more on alliances and inter-organisational

knowledge transfer (as shown in Figure 1.1) rather than companies in medium or low-tech sectors (Hagedoorn 2002). Another reason is that knowledge creation is a fundamental factor to achieve competitive advantages for the companies in this sector (Hagedoorn 2002). Therefore this study is focused on UK SMEs in the high-tech sector.

1.6. Research Problem

There are studies on inter-organisational networks and their effects on innovation (Ahuja 2000, Boschma and Wal 2007, Julien *et al.* 2004, Moller *et al.* 2007, Powell *et al.* 1996, Rodan and Galunic 2004, Rothwell 1991, Stuart 2000). Literature review in this area revealed that most of them have studied network effects on innovation performance and there are a few articles about the effects of inter-organisational networks on each type of innovation (De Propris 2002, Gilsing *et al.* 2008). Moreover, most studies on the degree of novelty of innovation focused on large firms (Amara *et al.* 2008) that appear to have ignored the fact that findings derived from large firms cannot normally be applicable to SMEs because they are simply not a smaller version of large companies (Hausman 2005, Moller *et al.* 2007). Therefore, the main focus of this research is studying the relation between inter-organisational knowledge transfer and types of innovation in SMEs. According to the above arguments, the main research question of this study is:

- **How and to what extent are inter-organisational networks impacting on different types of innovation in SMEs?**

1.7. Aims and Objectives of the study

Based on the literature on knowledge transfer, innovation and social networks, the aim of this research is: **to examine the relationships of the inter-organisational knowledge transfer networks on different types of innovation in SMEs.**

The following objectives have been developed to address the aim of the research:

1. Identifying gaps in the literature, understanding the current research, relevant theories and debates on inter-organisational knowledge transfer, social networks and organisational innovation through selective literature review and critical reflections.
2. Developing and testing a conceptual model and hypotheses underpinned by social network and innovation theories.
3. Using social network theories to understand the inter-organisational networks, knowledge transfer and the impact on innovation by investigating how and to what extent ego network characteristics are influencing different types of innovation.
4. Providing implications for future research and practices.

1.8. Departure Points of the Study

This study follows calls by researchers (Gilsing *et al.* 2008 p. 1729) to study more specific types of innovation such as “new to the industry” or “new to the world”. The departure points of this research from previous studies are as follows:

Social network studies in the context of SMEs: Studies that investigated the role of partners’ relationships in small firm innovation are limited. Small firms are not simply smaller versions of larger organisations (Hausman 2005, Moller *et al.* 2007). The main reason for this phenomenon is lack of financial resources, human capital and differences in their governance and reward structure. Thus the appropriateness of large firm theories for SMEs remains doubtful. Although there are many studies with the focus on social networks and innovation, most of them are about large organisations and studying this topic in the context of SMEs is not well developed. Therefore, studying the relation between innovation performance of the SMEs and their access to external resources is necessary (Rizzoni 1991).

Social network characteristics and different types of innovation: Previous studies investigated the network effects on innovation as a general concept and examining social network and different types of innovation has not been researched extensively. This research will help to understand which network characteristics influence specific types of innovation. In addition to that, studying networks together with firms' internal capabilities sheds more light on different requirements of each type of innovation.

Developing a tool to measure radical and incremental innovation: Another departure point of this study is developing a tool to measure different innovation types from both companies' and customers' perspectives. Previous attempts have only measured innovation from one perspective (usually firms' perspective) and they did not consider customers' perspective in this regard. The importance of considering both perspectives is that an innovation might be radical to an organisation but incremental to customers or vice versa. An example is a company using a new technology to add an extra functionality to one of its products. For customers this is an incremental innovation since it is just an improvement on the previous product. However, for the organisation it could be a radical innovation because they have used a technology that is new to their industry. Therefore, understanding this issue from different perspective is necessary.

Measuring innovation performance using primary data collected from companies directly: In this study innovation is measured directly by asking questions to company managers. Other researchers (Ahuja 2000, Gilsing *et al.* 2008, Srivastava 2007, Stuart 2000) have studied the relation between network characteristics and innovation by analysing secondary data. Their studies mainly used patent citation as a substitute for innovative activities. The main issue with this measure is the underpinning definition which is very restrictive. Using this approach will exclude modification and improvements to products, services and processes (Kalantaridis and Pheby 1999). Another shortcoming of using patent data is that it undermines the innovation output of

the SMEs since these are smaller units compared to large organisations and it may not be possible for them to afford the resources (e.g. time, money) required in the process of patenting. A detailed review of different methods for measuring innovation and their advantages and disadvantages is provided in Chapter 2. This study will address all these issues by developing a new measure and using a survey to collect the innovation data.

Measuring real network relations: There are some criticisms of measures that have been used in network studies. Meeus and Faber (2006) argue that researchers have rarely used real networks as indicators at the inter-organisational level. For example, patent citation does not necessarily reflect network interaction since they can be interaction independent (Meeus and Faber 2006). Another example is alliance which usually has been measured by announcements and it has never been confirmed that all these alliances have been implemented in reality. This research, by employing a different method in collecting innovation and network data, has addressed these issues.

Internal factors and external factors: Innovation literature has mostly focused on either internal or external factors that influence the innovation performance of a company. Studies covering both areas together are limited. In the social network and innovation literature researchers considered internal factors (e.g. company size, absorptive capacity, company age, R&D intensity) as well as external factors. But previous studies did not include some important factors such as innovation management practices which play an important role in companies' innovation performance. Companies with effective network structures but without these internal capabilities in place will not be able to use the transferred resources effectively and generate innovation. In this research, social network characteristics together with internal factors (innovation management practices) have been studied which provides a better understanding of the organisations and network settings that are more beneficial for different types of innovation.

1.9. Research Boundaries

The boundaries of the study were set as follows:

Broad area of study: This research is underpinned by the theoretical foundations in the following areas: Innovation, inter-organisational relationships and social network analysis.

Level of respondent: Given that the research is at inter-organisational level, insights at a senior management level were required to address the need for data about companies' strategy, structure and performance. Moreover the managing director of an SME is more likely to have reasonable insights into business operations that are required for this study.

Type of relationship: As explained in this chapter and Chapter 3 there are different types of relationships between organisations. But this study focuses on knowledge transfer relationships. The reason behind this is that access to knowledge is the fundamental part of every innovation and without this, companies would not be able to innovate. Therefore, this study focuses on knowledge transfer relationships between organisations.

Firm size: Small to medium size organisations were the target populations for this research and provided the required sample for the empirical data.

Industry: Both types of innovations include product, service and process innovations. Also given that the research is in the high-tech sector, the industry selection has to be made based on these criteria. Chemical and IT industries have been selected as the target industries to collect the empirical data. Both chemical and IT industries are in the high-tech sector which addresses the requirements of product and process innovations. Companies in the IT industry, also because of the nature of their business (customer support), are appropriate for service innovation data. Other reasons for selecting these two industries are discussed in more detail in Chapter 5.

Geographical limits: The sample is drawn from all the SMEs in the UK due to the sample size requirements.

1.10. Research Methodology and Process

Survey questionnaire was adopted to generate primary data. A questionnaire was designed based on the theoretical framework developed in Chapter 4. The questionnaire was revised and improved following a pilot study (semi structured interview). A new innovation measurement tool was developed and tested to measure different types of innovations and included in the final version of the questionnaire. The empirical data was collected by sending the questionnaire through mail and online to a sample of SMEs in the chemical and IT industry in the UK.

Figure 1.2 illustrates an overview of the research and how different phases of the study are linked to each other and contributed toward the outcome of the research. As shown in the figure the literature review informed all the conceptual, empirical and analytical phases of the study.

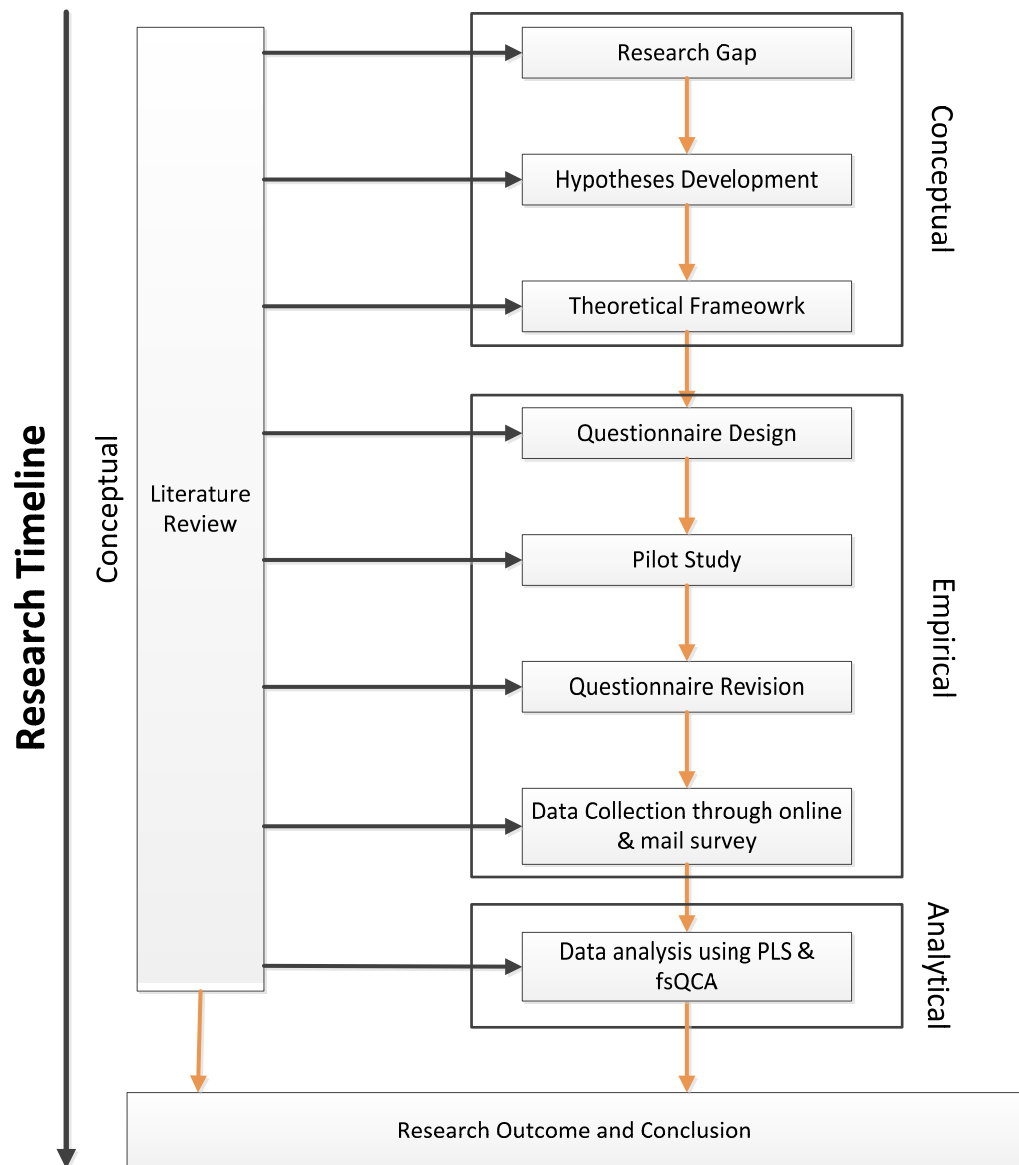


Figure 1.2: Research Process of the Thesis

1.11. Thesis Structure

To address the research question, the thesis is set-out in five parts over nine chapters:

1.11.1. Part One: Introduction

Chapter 1 introduced the research by providing background information related to the need to examine the relation between inter-organisational knowledge transfer and

different types of innovations. The significance of studying internal capabilities of companies in this context was also highlighted. In addition to this, it was explained why studying these relationships is important for small and medium sized enterprises. The academic significance of the research question in terms of studying network characteristics and innovation management practices together, and studying different types of innovation and developing a rigorous measure for different types of innovation was also emphasised. Moreover, the aims and objectives of the study were drawn in this chapter.

1.11.2. Part Two: Review of Literature and Development of a Theoretical Framework

In Chapter 2 the concept of innovation and its different paradigms, specifically open innovation, are explained. Innovation management practices, Pentathlon framework and how they are developed based on the open innovation paradigm are reviewed. Different types of innovations in terms of dimensions of innovation and degree of innovativeness are explained in the last part of the chapter. Moreover, a taxonomy for different types of innovations is introduced in this chapter.

Chapter 3 starts by explaining social network and different approaches that have been used to study this concept. Next structural, relational and nodal properties of networks are reviewed. A definition for inter-organisational relationship in this study is introduced. All the theories that have been used in inter-organisational network studies are reviewed in the last part of the chapter.

Chapter 4 of the thesis uses the concepts provided in the previous chapters as a foundation to develop the theoretical framework of the study. Twelve hypotheses are developed using the network characteristics and the Pentathlon framework. The theoretical model of the study is based on these hypotheses. The chapter concludes by

describing the detail of the methods used to measure dependent, independent, and control variables.

1.11.3. Part Three: Primary Methodology

The primary research methodology is dealt with in Chapter 5. Following a justification of the positivist paradigm and survey method, questionnaire design method is carefully considered. Then, the pilot study to test designed questionnaire and steps for designing the different types of innovation measure are explained. The survey was administered by mail and online to the managing directors of a sample of UK SMEs drawn from two industry sectors. An overview of the methods used for data analysis is explained in the last part of the chapter.

1.11.4. Part Four: Analysis of Results

In Chapter 6, first the appropriateness of data for further analysis is examined. Partial Least Square and soft modelling was used as the methods of analysis. In the first step the measurement model was examined and was approved for the next steps of the analysis. In the next part of the chapter the structural model and the hypotheses test are explained. The last part of the chapter examines the adequacy of the sample using power analysis.

Chapter 7 of the thesis is about analysing data using the Fuzzy set Qualitative Comparative Analysis (FsQCA) method to provide a better understanding of the factors that impact on radical and incremental innovation performance. First a brief introduction of the method and its different steps is given. The chapter continues with preparing the variables for analysis (calibration) and construction of the truth tables. The chapter concludes with explaining different configurations that lead to higher radical and incremental innovation performance.

1.11.5. Part Five: Discussion and Conclusion

The findings of the study are discussed in Chapter 8. Findings are also discussed in terms of their relation and contradiction to previous studies. First the findings of the statistical method are discussed in detail and then the chapter continues with the discussion of the FsQCA findings and how the findings of these two methods are related to each other.

In Chapter 9, conclusions regarding the research question, hypotheses, research aim and the objectives are discussed. Subsequently, contribution to theory and practice and finally limitations and suggestions for future research are explained.

Finally, the appendices include additional material and more details on innovation management practices questionnaire items (Appendix A), pre-notification, cover letter and reminders (Appendix B), pilot questionnaire, final questionnaire and online questionnaire (Appendix C), interview protocol (Appendix D) and details of the FsQCA analysis (Appendix E) . Figure 1.3 illustrates the thesis structure and content.

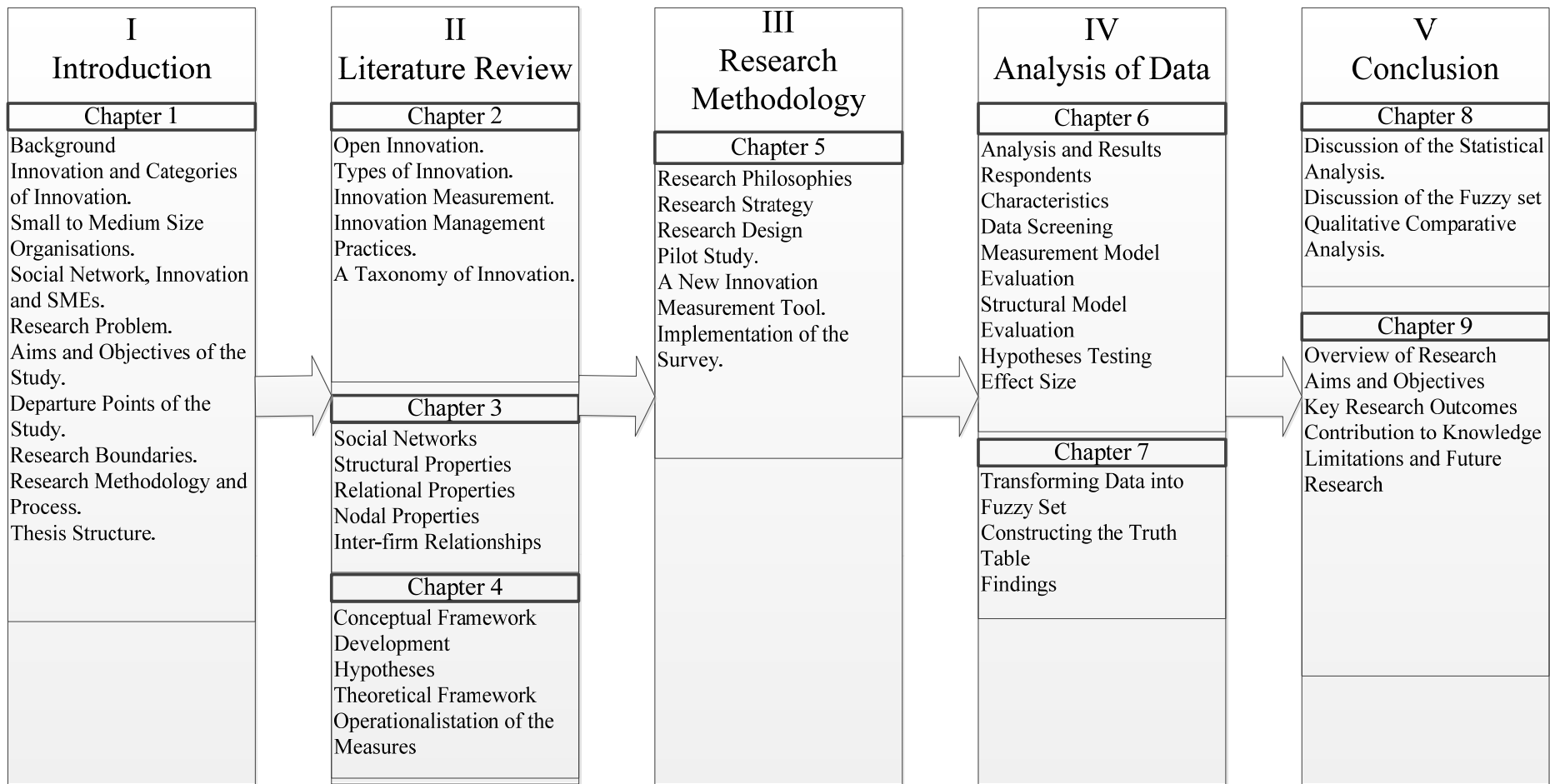


Figure 1.3: Structure of the thesis and content

2. Chapter 2: Innovation, Types of Innovations and Innovation Management Practices

2.1. Introduction

The aim of this chapter and next chapter is to provide the theoretical foundation that underpins this research by reviewing literature in innovation, social networks and inter-organisational relations streams. The review identifies gaps in the current research which motivate this research.

This chapter begins by providing a definition for innovation and reviews different approaches of innovation. It continues by explaining how open innovation approach changed the view of innovation from a final product of internal activities of a company to a product of internal and external activities of an organisation. Next, literature on different types of innovation is studied and a taxonomy to categories these innovations in different groups is introduced. Finally, innovation management frameworks have been appraised and an appropriate framework for innovation management practices has been chosen for the study.

2.2. Innovation

Innovation is the most fundamental activity for every company that aims for survival and long term competitiveness (Hamel 1998, Roberts 1998). Schumpeter (1930) defines innovation as “the introduction of new goods, new methods of production, the opening of new markets, the conquest of new sources of supply and the carrying out of a new organisation of any industry”. This definition addresses five important aspects of

innovation. These aspects include a) product (either new to consumers or with improved quality for those that have already been available), b) process (methods of production either new to the world or new to the industry), c) new market, d) new sources of supply, and e) new forms of competition. This definition, although very comprehensive, fails to address innovation in service sector (Goffin and Mitchell 2010). One reason might be the economic situation of that time that was more focused on manufacturing. The service sector started to emerge in the last 30 years and there has been a substantial shift from manufacturing to service sector. Van de ven *et al.* (1999, p. 13) in their definition of innovation address this sector and define innovation as “the development and implementation of new ideas and knowledge into a socially and economically successful product, process or service innovation”. Considering the importance of service sector in the current economy, the definition by Van de ven *et al.* (1999) is more appropriate (comparing to previous definitions) and addresses the main aspects of innovation that are significant in firms’ survival.

The importance of innovation in firm growth, profitability (Roberts 1999) and survival (Greve 2003) is well established in the literature. Moreover, surveys by government and consultancy organisations on innovation show the importance of innovation in both manufacturing and service sector companies. The study on the importance of innovation goes back to 1930 by Joseph Schumpeter. His study of innovation had a considerable effect on the field of economy (Goffin and Mitchell 2010). Schumpeter (1950), regarding the significance of innovation in companies, points out that innovation not only affect current profit and output of the firms but also makes fundamental changes in the organisations’ lives. Innovation can change the entire shape of an industry and influence life and death of companies.

There are many reasons that drive companies to be innovative. Goffin and Mitchell (2010) categorise them in four main drivers. Figure 2-1 illustrates these drivers.

Technological advances is the first driver which involves using new technologies in product and activities (such as using RFID in logistics) and application of the established technologies in a new context (such as using internet to track parcels) (Goffin and Mitchell 2010). Companies are required to respond to the technological advances quickly to be able to employ them in their products/services and stay ahead of their competitors. This will also offer the potential for them to open a new market. The second driver that demands innovation in companies is the changes in customers, such as their age or behaviour, and their requirements. For example the ageing population of a country is a different market compared to a country with young population. Also over the time and by increasing the competition, there is more demand for environmental friendly products with more features that address more than basic requirements of customers.

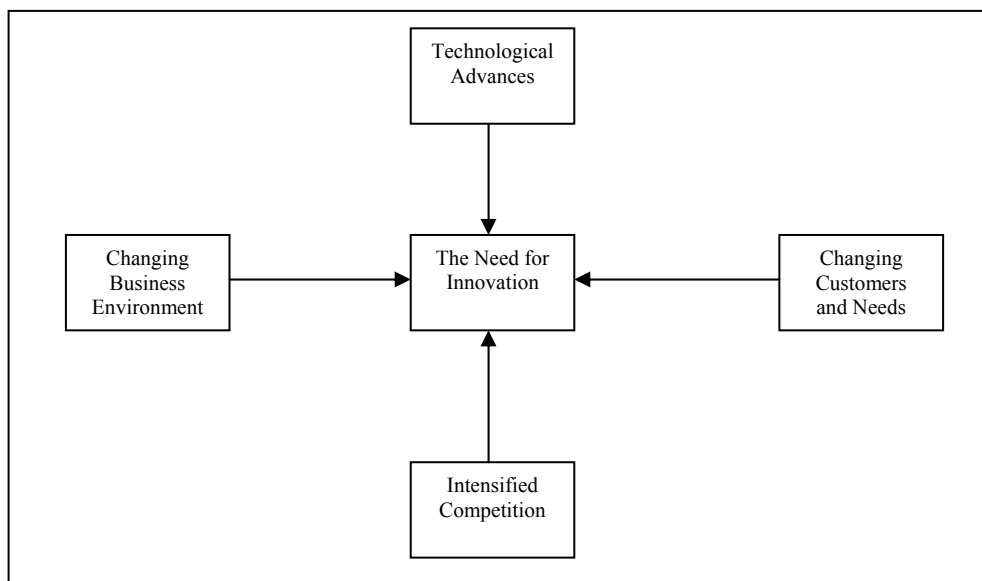


Figure 2.1: Driving forces for companies to be innovative (Source: Goffin and Mitchell (2010, p. 2))

The third driver for innovation is the intensified competition. Previously companies had to deal with their local or national competitors. However, with the increasing logistics and production cost, companies need to compete with international competitors. For example companies in China can produce a product much cheaper than Western countries and

export their products there. Overseas call centres is another example in the service sector. The last driver is the changing business environment. Changes in rules and regulations will affect the economy by opening new markets which are easier to access compared to the previous situation (trade grouping such as European Union). Another change in the business environment can be changes in the economic situation. For example, during a financial crisis companies may decide to cut their investments on innovation.

2.3. Open Innovation

Like other concepts in business studies, scholars developed the innovation concept from different perspectives. Open innovation paradigm is opposed to the traditional models of innovation that view innovation as a final product of internal activities (e.g. R&D) of an organisation. Open innovation has been developed following earlier models of innovation. Vanhaverbeke (2006) indicates that post-war innovation models are known as closed innovation paradigm in which companies only employ their internal capabilities and resources to innovate. In the early models, innovation is known as sequential activities (e.g. design, production and marketing) with sequential interaction between stages and low requirement of knowledge integration (Rothwell 1992). The 'Technology-Driven model' (Technology Push model) was developed in 1950's which innovation was mainly based on the knowledge and technology that was being developed in research and development (R&D) (Sammorra and Biggiero 2008). The 'Need-Pull' model is the second innovation model which is based on the exploitation of the market knowledge as a source of innovation (Rothwell 1992). The third model is the coupling model which emphasises on the interaction between R&D, manufacturing and marketing in the innovation process. The next model is the 'integration model' which for the first time identified innovation as a parallel process (Rothwell 1992). In this model innovation is the result of the interaction between marketplace, science base and organisational capabilities (Trott 2002). The fifth model of innovation is the 'system and networking'

model which stress that IT-based networking enhances the accelerating process of innovation. Table 2-1 summarises the five generations of innovation model.

Table 2.1: Rothwell's five generations of innovation models (Source: Tidd *et al.* (2005, p. 67))

Generation	Key features
First and Second	The linear models – need pull and technology push
Third	Interaction between different elements and feedback loops between them – the coupling model
Fourth	The parallel lines model, integration within the firm, 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

Although inter-organisational relationships had existed for a long period, scholars did not question the closed innovation paradigm. One reason for this phenomenon was companies' reliance on their internal capabilities for innovation and that they were not able to leverage the resources that reside outside the organisations. The closed innovation paradigm fails to address the changes in organisational environments such as the increasing cost of R&D, the pace of the new technologies coming to the market or the new knowledge that is being developed in universities (Vanhaverbeke 2006). Open innovation paradigm has been developed to address these changes in companies' innovation. Chesbrough (2006, p. 2) defines 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”. According to this paradigm, useful knowledge is widely dispersed and firms need to synthesise their external resources with

the internal activities in order to be successful and innovative. In this approach to innovation, R&D is considered as an open system and great ideas come from external sources outside the organisation as well as internal ones (Chesbrough 2006).

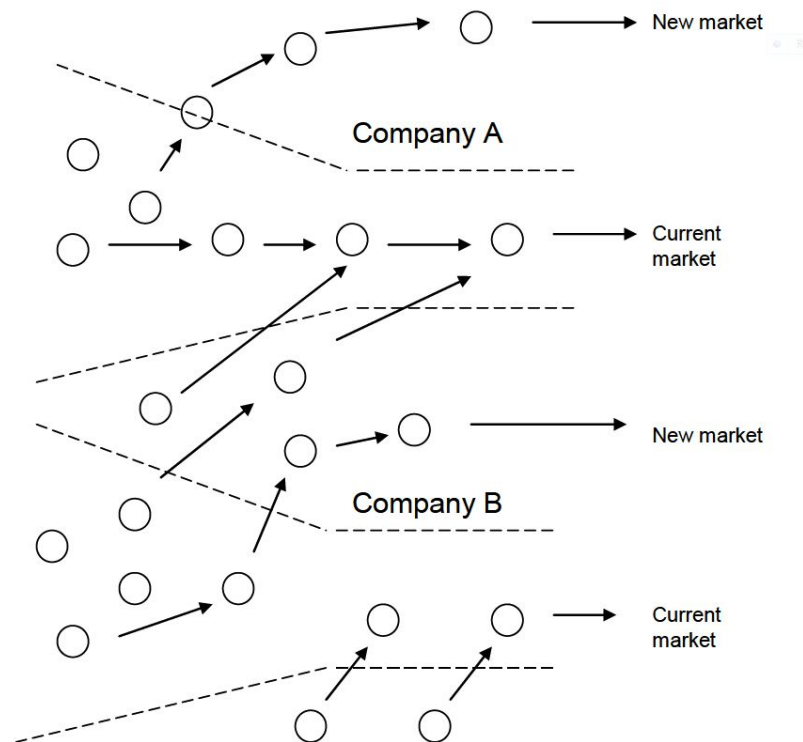


Figure 2.2: Knowledge flow in an open innovation paradigm (Chesbrough 2006, p. 3)

Figure 2.2 illustrates the knowledge flow in an open innovation paradigm. The circles in the figure are projects and they can be launched from both internal and external sources. Projects can go to a company's current market or open a new market for the company. In addition to that they can provide an opportunity for out-licensing or a spin-off venture company (Chesbrough 2006).

In the open innovation paradigm, internal R&D helps to identify and absorb the appropriate knowledge from the external resources and fill the knowledge gap in the organisation (Chesbrough 2003). Inter-organisational relations are an essential part of the open innovation paradigm and provide access to complementary knowledge, technologies

and skills that contribute to the innovation development of the company. Open innovation addresses inter-organisational relationships by considering external knowledge as a complement with the current business capabilities or when firms' internal ideas go outside the firm boundaries through external knowledge (Vanhaverbeke 2006).

In summary, open innovation paradigm is different and more comprehensive compared to the previous models of innovation. This paradigm is more relevant to this study for two reasons. First, in this paradigm the same level of importance has been given to both external knowledge and internal knowledge. Second, the open innovation paradigm justifies the significance of studying external resources together with internal capabilities of the company in innovation studies. The next point is that open innovation supports the purposive outbound flows of knowledge and technology. This will open up new market opportunities that have been neglected or were not known to the company (Chesbrough 2006).

2.3.1. Innovation in SMEs

SMEs are different from large organisations in terms of access to resources for innovation. Two significant differences in this regard include larger research resources and broader knowledge that is available to large organisations (Gibb 2000). Mosey (2005) studied SMEs in building capabilities to develop new to market products. His findings show that empowering cross functional teams helps innovation performance of SMEs through increasing number of partnerships. This will help companies to gather technical and market knowledge that they require for their innovation.

SMEs feature some characteristics that increase their abilities in generating innovation. One of these characteristics is the closeness between customers and managers (Hausman 2005). This provides managers with information about customers' unmet requirements which is an opportunity for innovation. Moreover, there is less bureaucracy in SMEs

which improves inter-organisational trust and communication that are important for innovation (Olson *et al.* 1995). Kanter (1985) and Simon *et al.* (2002) point out that SMEs are more predominant in radical innovations. The reason is that it is easier for SMEs to provide the appropriate environment for radical innovation and make the required adjustments compared to larger organisations (Kanter 1985).

Oke *et al.* (2007) study the types of innovation that are predominant in the UK SMEs as well as the effect of focusing on a specific type of innovation and firm's performance. In contrast to previous findings (Kanter (1985) and Simon *et al.*(2002)), this study shows that SMEs tend to do more incremental innovation which also increases the business performance of the company. However, their finding is limited to those companies that participated in the Business Growth Program in one of the UK universities. Therefore the sample is limited to those companies that are more ambitious for being innovative and does not present the average UK SMEs.

In a similar theme Oke (2007) studied predominant types of innovation in service sector companies. He also studied the relation between types of innovation and innovation management practices employed by a company. His findings show that service companies are more focused on incremental product innovation, incremental service innovation and me-too innovations. Another finding of this study is the relation between radical product innovation and radical service innovation with innovation performance of a company. Moreover he found that innovation management practices are biased toward radical innovations. Therefore he suggest that service companies have to consider incremental innovations in their innovation management practices.

In the next section, literature on different types of innovation is reviewed which provides a better understanding of the resources that they draw upon, and the similarities and differences between them.

2.4. Types of Innovation

Innovations are not all similar; previous studies show that innovation reflects the strategic objectives pursued by a company (Anderson and Tushman 1990, Teece 1996). Innovations are heterogeneous and a distinction between different types of innovation is necessary (Moller *et al.* 2007). Based on the Oslo Manual (OECD 1992) two main bodies of literature on innovation can be identified. The first body focuses on presence or absence of innovation e.g. product or process innovation. The literature in this area investigates the differences between innovative and non-innovative companies and factors affecting innovation performance of the companies (Becheikh *et al.* 2006). The second body of literature focuses on the innovation itself and explains the degree of novelty of innovation. This stream of research investigates the difference between innovation in terms of newness and how they are different in the resources that they draw upon.

There are different classifications for innovation. In this study two aspects of innovation have been used to categories different types of innovation: Dimensions of innovation and Degree of innovation.

2.4.1. Dimensions of Innovation

The first aspect is the dimension of innovation (Goffin and Mitchell 2010) which categorises innovation based on its final outcome. Figure 2.3 illustrates different dimensions of innovation. This model also applies to the service sector companies. In manufacturing sector product innovation refers to a new or improved product introduced to the market and it is one of the most common forms of innovation (Oke *et al.* 2007). Service innovations in the manufacturing sector are new services that are introduced by an organisation as an additional feature of their products to make it more interesting to their customers. In the service sector, service innovation is the changes in the core of the

current services or new services that bring new profits to companies (Oke 2007). An example of service innovation in the financial sector is new repayment options to the customers or some insurance products e.g. building or travel insurance. Process innovations are the changes and improvements that companies make in their manufacturing processes or administrative operations (Khazanchi *et al.* 2007). Reichstein and Salter’s (2006) empirical study shows that in the UK manufacturing sector process innovation involves the following activities: introduction of new machinery, changes to the production process, use of ICT or new management practices (e.g. lean production) in the production process. Business process and business model innovations include the changes in processes such as ordering goods or the way that a company makes profit.

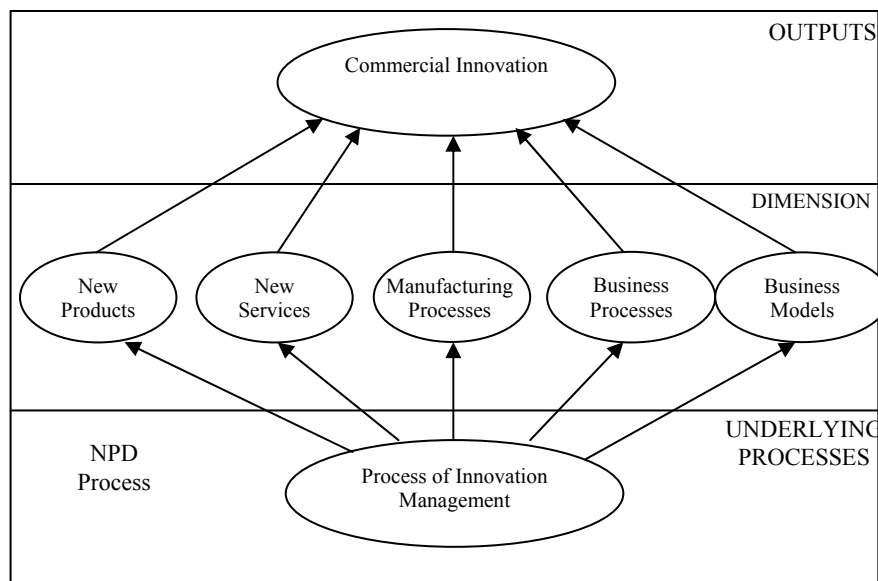


Figure 2.3: The Dimensions of Innovation in the Manufacturing Sector (Source: Goffin and Mitchell (2010, p. 9))

2.4.2. Degree of Innovation

The second aspect of innovation that is important for classification is degree of innovation. Degree of innovation refers to the newness of the innovation as innovation can be something simple like improving the performance of a product or be more complex like introducing something completely new to the world. Degree of innovation is important since increasing the degree of novelty of innovation can help a company to

increase competitive advantage and opens avenues to new market (McDermott and Handfield 2000). Although there are vast amounts of research on the degree of novelty of innovation researchers have not agreed on a formal definition for radical innovation (McDermott and O'Connor 2002). Researchers agree that innovation is about changes and improvement in the products, services or processes. Scholars used different names and classification to address this aspect of innovation e.g. radical and incremental (Dewar and Dutton 1986), regular, niche, revolutionary and architectural innovation (Abernathy and Clark 1985) and incremental, radical and breakthrough innovation (Chandy and Tellis 1998). Following the work of other researchers (Dewar and Dutton 1986, Oke *et al.* 2007, Stamm 2003, Subramaniam and Youndt 2005) the terms *radical* and *incremental* have been employed for the purpose of this study. Another reason for using these two types of innovation is that they are the most established classification for innovation (Subramaniam and Youndt 2005).

Incremental innovation: Incremental innovation is minor and continuing changes that companies make on their existing products by utilising the established design (Dewar and Dutton 1986, Tushman and Anderson 1986). Although it is not based on a new science or technology, it requires knowledge and resources in company (Henderson and Clark 1990). Tushman and Anderson (1986) recognise this type of innovation as competence enhancing since, for example, it improves the performance or price of a product by using the existing knowledge (Tushman and Anderson 1986). This type of innovation makes no obsolete skills, reinforces the current design in company and requires a deep knowledge in the current technologies that are being used in the product.

Radical innovation: Radical innovation is about significant changes and makes the current practices obsolete. It makes fundamental changes in the current products or services and often opens up a new market to the organisation (Dewar and Dutton 1986). Radical innovation is also known as competence destroying and creates, for example, a

new product class or replaces an existing product or service. Uncertainty, knowledge intensity and boundary crossing are the characteristics of this type of innovation.

Table 2.2: Differences between radical and incremental innovation (Source: Stamm (2003, p. 272))

Focus	Incremental	Radical
Time frame	Short term – 6 to 24 months	Long term-usually 10 year plus
Development trajectory	Step after step from conception to commercialisation, high levels of certainty	Discontinuous, iterative, setbacks, high levels of uncertainty
Idea generation and opportunity recognition	Continuous stream of incremental improvement; critical events large anticipated	Ideas often pop up unexpectedly, and from unexpected sources, slack tends to be required; focus and purpose might change over the course of the development
Process	Formal, established, generally with stages and gates	A formal, structured process might hinder
Business case	A complete business case can be produced at the outset, customer reaction can be anticipated	The business case evolves throughout the development, and might change; predicting customer reaction is difficult
Players	Can be assigned to a cross-functional team with clearly assigned and understood roles; skill emphasis is on making things happen	Skill areas required; key players may come and go; finding the right skills often relies on informal networks; flexibility, persistence and willingness to experiment are required
Development structure	Typically, a cross-functional team operates within an existing business unit	Tends to originate in R&D; tends to be driven by the determination of one individual who pursues it wherever he or she is
Resource and skill requirements	All skills and competences necessary tend to be within the project team; resource allocation follows a standardised process	It is difficult to predict skill and competence requirements; additional expertise from outside might be required; informal networks; flexibility is required
Operating unit involvement	Operating units are involved from the beginning	Involving operating units too early can again lead to great ideas becoming small

In addition to that, radical innovation demands for flexibility in organisation and capabilities to manage the requirements (Oke *et al.* 2007).

Difference between the outcomes of radical and incremental innovation is because of the different organisational capabilities that they require. It is difficult and costly to create organisational capabilities and adjusting them (Henderson and Clark 1990) with strategies of organisation. Table 2.2 summarises the differences between these two types of innovation from different perspectives. Radical and incremental innovations address two ends of the theoretical continuum of degree of new knowledge in innovation. It is hard to capture the middle values of this continuum (Dewar and Dutton 1986) and for this reason this research only focuses on the two end of this range.

In the following section, literature with focus on radical and incremental innovation is reviewed.

2.4.3. Incremental and Radical Innovation

Based on the definitions and the outcome in the industry and market, each type of innovation demands variety of resources and capabilities. In the context of SMEs, Chandy and Tellis (1998) indicate that SMEs have two options for developing and introducing radical innovations: 1. use research spillovers from more resource-rich firms and 2. actively partner with organisations with technological capabilities and financial resources they do not have themselves. In the former option, companies will focus on the development part of the R&D and address their requirements, for example for new technologies, by components developed by other companies in different industries. They also emphasise that the latter option is more sustainable and inimitable resource in many industries.

In a related theme, in order to understand the diversity of resources that is required for different types of innovation, Todtling *et al.* (2009) study specific types of knowledge

interaction and its relation with radical and incremental innovation. This study shows that those companies that perform better in terms of radical innovation rely more on their links with universities and research organisations. On the other hand incremental innovator companies rely more on their links with business services. In another attempt De Propriis (2002) investigates the relation between inter-organisational cooperation and product, process, radical and incremental innovations. This research shows that, for any of the four types of innovation, companies' capacity for innovation is substantially improved by co-operating with other firms. Particularly all the four types of innovation benefit from the co-operation with suppliers. However, for radical and product innovation, co-operation with customers and R&D expenditure play a significant role.

Although the literature so far was about the differences between the relationships that companies use for different types of innovation, this is not the only resource that they differ on. McDermott and O'Connor (2002) investigate the different resources that radical and incremental innovation require by examining the management practices. They identify similar management practices in 12 radical innovation projects. They group their findings in three high level strategic themes. The first theme is about the market scope. Companies must distinguish the situation if there is a market for the innovation or not. In a situation with existing market, a company develop an innovation for a familiar market which strengthens the firm's position (McDermott and O'Connor 2002). When there is not clear market for the innovation or market is not developed enough, although the situation is more risky, but it can provide the company with the opportunity to move into a new direction which causes a higher growth. The second theme is competency management. In addition to Tushman and Anderson's (1986) competence enhancing and competence destroying, they introduced competence stretching which is about moving to a new direction through market or technology. The last theme is about people side (both

individual and project teams) issues of the radical innovation in organisations that are not designed to support such uncertainty.

Another difference between radical and incremental innovation is based on the knowledge management practices that are required for radical and incremental innovation. Darroch and McNaughton (2002) examine the link between knowledge management practices and different types of innovation. They conduct the study on medium and large size companies in New Zealand. In this research, innovation has been categorised as incremental innovation, innovation that changes consumer behaviour (they used the term radical innovation for this category interchangeably) and innovation that destroys competencies. Although none of their hypotheses have been supported their findings show that incremental innovation is linked to being flexible and opportunistic, being sensitive to information about changes in market place and responding to knowledge about technology.

Subramaniam and Youndt (2005) investigate the link between different aspects of intellectual capital and types of innovation capabilities in a longitudinal study. This study shows that both human capital and social capital positively influence incremental innovation capabilities. They also indicated that human and social capital together influence radical innovation capabilities positively. Moreover they argue that organisational capital is important in incremental innovation capabilities. To summarise this section, the differences between resources that are required for radical and incremental innovation are inter-organisational relationships with different types of partner (De Propriis 2002, Todtling *et al.* 2009) and different management practices (McDermott and O'Connor 2002).

Next section is an evaluation of measurement tools that have been used in previous studies to measure different types of innovation. The instruments are reviewed here to

shed light on limitations of these measures and build the necessary knowledge for developing a new instrument.

2.5. Innovation Measurement

Measuring innovation is one of the major problems of the innovation research (Koberg *et al.* 2003). Researchers have used a variety of methods to measure innovative activities. Kalantaridis and Pheby (1999) identify four main methods that have been adapted by researchers to measure innovation.

The first method focuses on collecting innovation data based on patents. Although this measure has been used by many researchers (Ahuja 2000, Gilsing *et al.* 2008, Stuart 2000) it has two main limitations. First this measure is based on a restrictive definition and excludes the modification on the products and processes. The second problem is that SMEs usually do not have enough resources to go through the patenting process; therefore, using this measure underestimates SMEs.

The second method to measure innovation is collecting data by monitoring all the innovations reported in industry-specific trade journals, research periodical, conferences and exhibitions (Acs *et al.* 1994). This is a reliable method but requires a lot of resources to monitor all the materials.

The third method is based on industry specific benchmarks designed by the researcher from the beginning of the process (Smallbone and North 1999). This method is very attractive because of its accuracy but it involves significant practical problems.

The last measure is using survey and asking owner or manager of the company about their innovation performance (Keeble 1997). This measure is very subjective and is based on the respondent's judgment; it therefore should be dealt with caution.

Chandy and Tellis (1998), in their study of the required resources for radical innovation measured radical innovation using the following two dimensions of radical innovation: (1) significantly different core technology and (2) higher customer benefit. Three experts rated these dimensions relative to previous products in the same category. De Propris (2002) measures each type of innovation by counting the number of firms' new products, new processes, improved products and improved processes. To be more specific, firms are product innovators if they have new or improved product and radical innovator if they have new product or process over the period of the study. The same logic has been used with incremental and process innovation. In another study, McDermott and O'Connor (2002) ask R&D management in companies to identify radical innovation as those projects that have a formal budget, have an assigned team to the project and affect the market in at least one of the following ways: by offering a better performance, offering new performance and offering substantial cost reduction.

Subramaniam and Youndt (2005) adopted the approach by Tushman and Anderson (1986) and Henderson and Clarks (1990) to measure different types of innovation capabilities in organisations. They use a three item scale to measure companies' capabilities to reinforce current expertise and product/service lines for incremental capabilities and companies capabilities to obsolete current products/service lines. Oke *et al.* (2007) measured innovation by asking managers of the companies about the number of products that they made minor/major improvement or adaptations. Similar question has been used for other types of innovations in their study. Todtling *et al.* (2009) use a similar approach to measure radical and incremental innovation. They asked companies whether they have introduced any product new to the firm (incremental) or new to the market (radical).

Darroch and McNaughton (2002) adopt a different approach comparing to the previous studies. Previous studies identify radical and incremental innovation only from

companies' perspective. In this study Darroch and McNaughton develop a new measure that identifies different types of innovation from companies' and customers' perspectives. They have developed the measure mainly based on a typology introduced by Booz-Allen and Hamilton (1980). Table 2.3 shows the Booz-Allen and Hamilton's typology of innovations. They classify the first two (new to the world, new to the firm) as radical innovation and the other four as incremental innovation. The reason for classifying the first two as radical innovation is that the company might lack the experience and knowledge in dealing with the innovation (Ettlie and Rubenstein 1987).

Table 2.3: Typology of innovation (Booz-Allen and Hamilton 1980)

	Innovation
1	New to the world
2	New products to the firm
3	Additions to one of the firm's existing lines
4	Improvements or revision to the firm's existing lines
5	Cost reductions to company's existing products
6	Repositioning company's existing products

To address the aim of the research they added questions to include consumers' perspective as well as the managers (Appendix C.1, section B shows the final developed and tested measure).

2.6. Innovation Management Practices

To innovate effectively, all stakeholders of an organisation have to participate actively in the innovation process. For example, innovation should not only come from the R&D department in a manufacturing company or the strategic planning group of a service company (Goffin and Mitchell 2010). Different functional areas in an organisation can contribute significantly to its innovation activities. Goffin and Mitchell (2010) indicate that the functional areas that need to be involved are: research and development,

marketing, operations, finance and accounting, human resource management, and outside resources such as suppliers, customers or universities. It is the responsibility of the general managers to motivate different parts of an organisation to work on innovation.

Innovation management practices refer to the solutions that companies use to manage the process of developing an innovation (Oke 2002). There is a number of innovation management frameworks developed for managing innovation process but they are mainly in manufacturing companies. Drew (1995) uses the McKinsey 7-S model (Peters and Waterman 1982, Song *et al.* 1999) as a framework to compare innovation management practices in various Canadian financial service firms. Oke (2007, p. 568) explains the elements in the 7 S framework as “Strategic planning practices relating to innovation, barriers to product innovation, organisation changes to promote innovation, drivers of new product development strategy, structures and systems for innovation, approaches to new product development and human resource strategies for innovation”. Cooper (1999), using a stage-gate approach, develops another framework for innovation management practices. It is stated that this approach has been adopted by many companies and it enables them to manage, direct and control their innovation activities (Oke 2007). The main limitation of Cooper’s approach is its focus on process factors. There are other organisational factors that impact on innovation performance and they have to be taken into account.

Goffin and Mitchell (2010) have introduced an innovation management framework which illustrates the main elements of innovation management and their relationships. They call the framework the Pentathlon framework which addresses a number of soft organisational and process issues. Open innovation is the heart of this framework. They based their framework on different elements that have been used in innovation management practices by previous scholars (de Brentani 2001, Drew 1995, Griffin 1997). This framework addresses the limitations of previous frameworks.

The framework covers five areas where companies need to perform well to be able to achieve successful business management (Goffin and Pfeiffer 1999): Innovation strategy, creativity and idea management, selection of the ideas, portfolio management (selection), implementation management and human resource management (see figure 2.4).

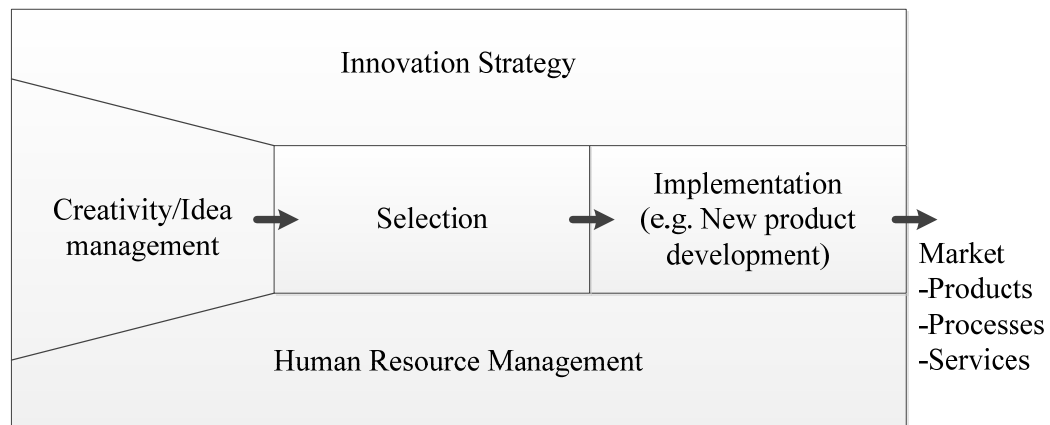


Figure 2.4: Innovation Pentathlon framework (Source: Goffin and Mitchell (2010, p. 33))

Innovation Strategy: it is vital for companies that aim for innovation to have a clear strategy for new products/services which guides companies during their innovation process (Cooper *et al.* 1999, Griffin 1997). Innovation strategy helps the entire organisation to focus on the same innovation goal and provides it with a clear path through its innovation process. The top management team of a company is responsible for developing an innovation strategy that fits these purposes. In order to develop an effective strategy they have to assess market trends, consider how to use technology and how to acquire the required resources for the strategy (Goffin and Mitchell 2010). In developing innovation strategy, managers first have to define what innovation means to the company and what are the areas that they need to focus on in terms of innovation (Oke 2002). By knowing the areas of innovation they can better address the requirements. An innovation strategy should outline how employees of a firm will be aware of the innovation importance which reveals the importance of the innovation for the management team and success of a company. Kuczarski & Associates (1994) indicate that those companies

that the management team shows more commitment and support for new product development are more successful compared to other companies.

Creativity/Idea Management: Idea generation is an important part of the innovation development process. Ideas are the raw material of innovation and have to be generated from both inside and outside a firm. Managers are responsible for creating an environment which encourages creativity at different levels. Responding to customers' new requirements in the generated ideas is very important (Goffin and Mitchell 2010). Particularly companies should keep the scope of ideas wide and use external resources for this purpose as well as the internal ones.

Selection / Portfolio Management: Managers are responsible for investing the company's resources for innovation in feasible ideas that are in line with the innovation strategy of firm. It is important to have an efficient process in place to choose the ideas for development that meet these requirements. Managers also have to collect information from individual projects to monitor the risks and returns of each project. Selection, or portfolio management, and prioritisation of R&D projects and new products is a key factor to improve companies performance (Cooper *et al.* 1999). One reason for this is the fact that portfolio management is about assigning scarce resources (e.g. finance, R&D, marketing) to a project at a time that will dominate the business's future in next five years (Cooper *et al.* 1999).

Implementation: This phase requires fundamental capabilities to quickly and efficiently develop and commercialise an idea into a new product, process or service innovation. Goffin and Mitchell (2010) suggest methods such as cross-functional teams, prototyping and testing.

The last three phases (idea management, selection and implementation) are the main processes that are necessary for innovation. Many studies have confirmed that there is a

formal process for developing product and service innovation in high performance companies (Cooper *et al.* 1994, Griffin 1997, Shaw *et al.* 2001, Tatikonda and Rosenthal 2000). This formal process includes idea management, selection and implementation.

Human Resource Management: This element of the framework is concerned about people and organisation climate issues. Goffin and Mitchell (2010) suggest that there are many issues related to the human resource management of a company e.g. training policies, job design, creating an effective organisational structure. One of the most significant parts of this element is creating a cultural environment that encourages employees to be innovative. In this regard O'Reilly and Tushman (1997) argue that innovative culture can be created by supporting creativity and implementation. Another way of supporting innovative culture is rewarding employees (both financial and non-financial rewards) (Griffin 1997, Kuczarski & Associates 1994).

It is important to bear in mind that being good in one area of the Pentathlon framework is not enough for successful innovation and performing well in all five areas is often more significant (Goffin and Mitchell 2010).

2.7. A Taxonomy of Innovation

According to the literature, product, service and process innovations are the most studied types of innovation. In addition to these, according to previous studies, these innovations can be categorised as a subcategory for radical and incremental innovations. For example a company can have both radical product innovation and incremental product innovation. This is the same with process and service innovations. Figure 2.5 illustrates a taxonomy for innovation according to this classification. Since products, services and processes in SMEs are limited and do not have the variety in these innovations compared to larger organisations, the study is only limited on radical and incremental innovation and not on the very specific type for product, service and process. Although specific types of

innovation are being measured they will be presented in their parent category (radical and incremental). It is possible to argue that Figure 2.5 can be drawn differently, which is swapping the place between radical and incremental with product, process and service innovation. Although this is acceptable, as is mentioned before, considering the focus of this study this taxonomy is more appropriate and comprehensive.

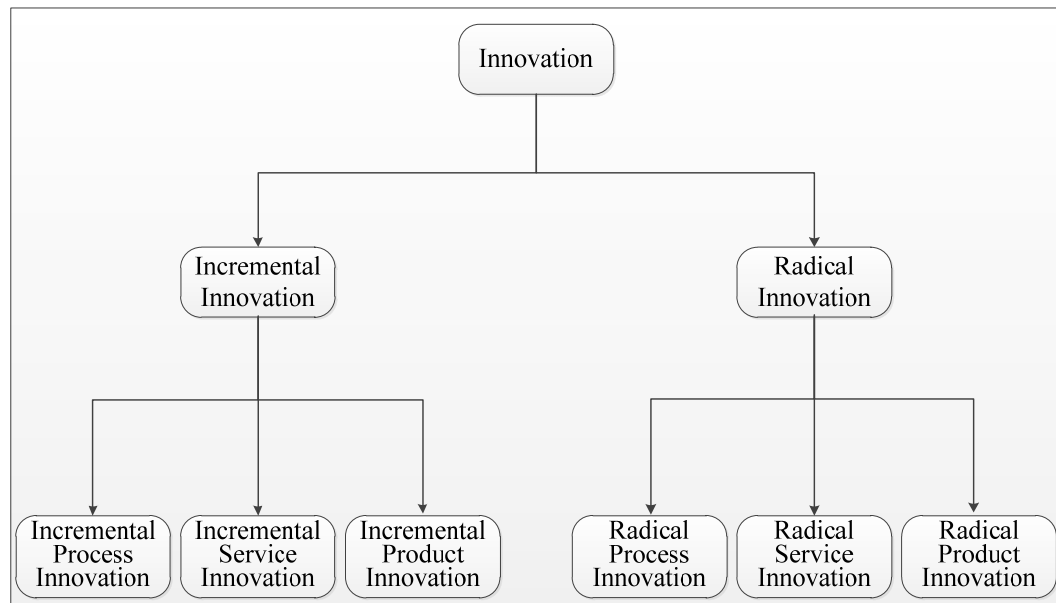


Figure 2.5: Taxonomy of Innovation

2.8. Critique

The literature analysis revealed that there are two main streams in the innovation studies. The first stream is about the presence and absence of innovation and the second stream is on the degree of novelty of innovation. Innovation studies in each stream can be grouped in two main categories. The first category is the studies that are focused on internal factors that impact on innovation. The second category is the studies that look at the external factors that are important in innovation performance. Although these studies have identified important factors in these two main categories they failed to look at them at the same time. Studying both internal and external factors that impact on innovation is important as the reviewed studies show that both of them play a significant role in the

innovation performance of companies. Therefore researchers focusing on one area fail to address the complementary role that these two groups have in innovation performance. This is more important in terms of radical and incremental innovation as they require different types of resources. There are specific internal factors that impact on radical innovation performance as well as external factors. This is same with incremental innovation. Therefore, studying both internal and external factors that impact on radical and incremental innovation is important and has not been investigated in previous studies. In addition to that, another shortcoming that was identified through this chapter was measuring radical and incremental innovation performance from customers and companies' perspectives. There was only one study (Darroch and Jardine 2002) that made an effort to measure them from two perspectives and all the other studies only looked at innovation from companies' perspective. According to the literature review, innovation might be radical from companies' perspective and incremental from customers' perspective. Therefore it is important to look at them from both perspectives. These two main gaps in the innovation literature were identified and addressed by this research.

2.9. Summary

The concept of innovation was defined and factors that demand companies to be innovative were explained. Different generations of innovation were studied and the open innovation, which has been used in this research, was explained. Next, different types of innovation, their similarity and differences were identified and discussed. A taxonomy for different types of innovation was introduced which will be used to categorise different types of innovation in this study. In the last part of the chapter, using the open innovation concept different innovation management capabilities were identified and described

In summary, innovation is important for competitive advantage of companies. It can open a new market, make a fundamental change to the current situation of a company or can

destroy the whole business. Open innovation shows that it is very important to consider resources outside the firms' boundaries for innovation as well as those inside the organisation. Moreover, innovations are different and scholars have classified them from different approaches. Literature shows that each type requires different types of resources and knowledge so it is important to study the requirement for each of them. Also it is important for companies to work toward both types of innovation in order to survive. Table 2.4 summarises the literatures in this chapter and their key findings.

In the next chapter the social network concept, which is the main pillar of this study, is explained in details. The chapter includes explanation for different network properties, relevant literatures and theories.

Table 2.4: Summary of key literature on different types of innovation

No	Author	Year	Key Findings	Instrument
1	Chandy and Tellis	1998	Two options for SMEs to introduce radical innovations are: 1. use research spillovers from more resource-rich firms and 2. actively partner with organisations with technological capabilities and financial resources they do not have themselves.	The following two dimensions of radical innovation were used: (1) significantly different core technology and (2) higher customer benefit.
3	De Propris	2002	All the four types of innovation benefit from the co-operation with suppliers. However, for radical and product innovation co-operation with customers and R&D expenditure play a significant role.	The number of firms' new products, new processes, improved products and improved processes has been counted.
4	McDermott and O'Connor	2002	Investigated the management practices that are similar in 12 radical innovation projects. They grouped their findings in three high level strategic themes: 1. Market scope, 2. Competency management, 3. People side (individual and project teams)	Radical innovation is measured as projects that have a formal budget, have an assigned team to the project and affect the market in at least one of the following ways: by offering a better performance, offering new performance and offering substantial cost reduction.
5	Darroch and McNaughton	2002	Incremental innovation is linked to being flexible and opportunistic, being sensitive to information about changes in market place and responding to knowledge about technology.	They used a measure that has been developed based on Booz-Allen and Hamilton (1980) and Green <i>et al.</i> 's (1995) typology of innovation
6	Subramaniam and Youndt	2005	Both human capital and social capital positively influence incremental innovation capabilities. They also indicated that human and social capital together influence radical innovation capabilities positively. Organisational capital is also important in incremental innovation	A three item scale was used to measure companies' capabilities to reinforce current expertise and product/service lines for incremental capabilities and companies' capabilities to obsolete current products/service lines.

			capabilities.	
7	Oke <i>et al.</i>	2007	SMEs tend to do more incremental innovation which will also increase the business performance of the company.	Different types of innovation have been measured by asking the managers of the companies the number of, for example, products that they made minor/major improvement or adaptations. Similar question has been used for other types of innovations.
8	Oke	2007	Service companies are more focused on incremental product innovation, incremental service innovation and me-too innovations. Another finding of this study was the relation between radical product innovation and radical service innovation with innovation performance of a company. He also found that innovation management practices are biased toward radical innovations.	A multi-item, 1-5 Likert scale was developed to measure radical and incremental. Respondents were asked to rate the extent to which the activity is being pursued in their organisation.
2	Todtling <i>et al.</i>	2009	Those companies that perform better in terms of radical innovation rely more on their links with universities and research organisations. Incremental innovator companies rely more on their links with business services.	They measured radical and incremental innovation by asking companies if they had introduced any product new to the firm (incremental) or new to the market (radical)

3. Chapter 3: Social Networks

3.1. Introduction

The concept of open innovation was explained in the previous chapter. According to the reviewed literature, what makes the open innovation strategy different from previous innovation strategies is its ability to address the importance of leveraging the external knowledge that flows between organisations. Companies adopting this perspective are more successful compared to those that are not using these resources. Chesbrough (2003) suggests that new ideas for innovation usually arise from outside the organisations. This argument resonates with the literature on innovation and inter-organisational social networks that companies with access to network resources are more successful in their innovation activities. Moreover, Chesbrough (2003) suggests that the backbone of open innovation strategy is utilising the knowledge across firm boundaries. Inter-organisational networks are the channels for these knowledge flows. Therefore, studying inter-organisational networks is highly related to open innovation.

In this chapter the fundamental concepts of social networks are reviewed. The chapter begins with an introduction to social network analysis and different approaches that have been adopted in this method. Next, different properties of social networks including structural, relational and nodal properties are discussed. The chapter continues by introducing a definition for inter-organisational relationships in the context of this study which later will be used in questionnaire and hypotheses development. The chapter finishes by reviewing theories that have been used in inter-organisational network studies.

3.2. Social Network

During the last two decades there has been a growing interest in the field of social networks. The reason for this growing body of literature was the changes that happened in the nature of the competition between organisations. Nohria (1992) indicated that previously, there were single organisations competing with each other but now it has changed and a group of organisations together compete with other groups of organisations. As discussed in the previous chapter, innovation requires a variety of resources and establishing relations with people who already have these resources is one of the solutions to address this issue. The relation between people, groups and organisations is the fundamental part of social networks. Liebowitz (2007 p. 3) defined social networks as “a set of relationships between a group of ‘actors’ (the ‘actors’ could be individuals, departments, and so on) who usually have similar interests”. According to this definition actors and the relations between them are the two main elements of all networks. Networks are in fact an important medium to transfer knowledge and provide access to resources in different contexts. However, just having relations with others is not sufficient for the actors to be able to benefit from the relationship. Other elements such as the abilities of the actor, the characteristics of the partners, the characteristics of the relationship itself and other factors need to be considered in order to make a profitable relationship.

There are two main approaches in social network studies: Sociocentric and Egocentric. In the sociocentric approach data is collected from all the actors in a network and the relation between them. In the egocentric approach the data is collected about the focal firm and all the actors in the first order neighbourhood. Ego networks are defined as networks consisting of one focal actor (ego) together with all partners in the first order neighbourhood (alters) of the ego and all the links among the partners (Everett and Borgatti 2005). At the inter-organisational level the ego network approach is more

appropriate as, in the organisation's environment, other organisations are the important elements that the focal firm must interact with (Nohria 1992). Moreover, adopting an ego network approach helps to explain how being part of a network affects firm actions and outcomes (Provan *et al.* 2007).

A network is more than a set of actors that are connected with a set of ties. In network studies actors are seen in a structure of connections in which the actor is embedded and relations are as important as the actor itself (Hanneman and Riddle 2005). In fact actors are explained by the relations between them and not their attributes (Hanneman and Riddle 2005). Different characteristics are identified in social network studies. In this research these characteristics have been reviewed under three broad categories: 1) structural properties which address the potential for resources and the context for the flow of resources (Burt 1992), 2), relational properties which reflect the quality of resource flows (Gulati *et al.* 2002, Rowley *et al.* 2000) and 3) nodal properties which is about the quality and variety of resources and capabilities of the ego partners (Beckman and Haunschild 2002, Laursen and Salter 2006). In the following sections each of these categories, the characteristics of each category and related studies in each area will be reviewed in detail.

3.3. Structural Properties

Studying networks from a structural point of view is the dominant perspective in network studies. The main argument of this perspective is that the best way to explain the actions and behaviours of a node is studying its position in the overall network (Burt 1992, Wellman 1988). Gulati *et al.* (2000), on the importance of structural patterns, argue that the structural patterns that exist in company networks are significant resources not available to other companies and not imitable. The structure of the relationships is the main focus in this perspective of network studies. Some scholars suggest that studying

individuals in an isolated level is not appropriate and sociologists have to study the structural nature of social systems (Mayhew 1980, Wellman 1988). Since this structuralism approach was the main focus of the researchers other aspects of networks such as relational and nodal properties have been neglected. Only recently some scholars have paid attention to the importance of these features of the network in addition to the structural patterns (Laursen and Salter 2006, Wellman and Frank 2001), which helps to better understand the social network effects. In the following sections key network constructs and related empirical research in inter-organisational network literature are reviewed. For each construct a definition is provided, then the literature on how it relates to firm innovation and performance outcome is reviewed.

3.3.1. Centrality

Centrality of a node is one of the oldest and most widely used network constructs in social network studies. Centrality refers to the strategically important position of an actor in a network (Freeman 1979). In other words, centrality is the degree to which a firm is involved with other firms in its network (Wasserman and Faust 1994). Being central in a network of relationships between organisations provides the focal firm with a wide range from access to control of different types of resources (Gulati 1999). Using centrality measures goes back to the 1950s with the work of Katz (1953). Since that time researchers have developed different types of measures for this construct. Freeman (1979) in his seminal paper categorised all these measures in three main types of centralities and provided a measure for each of them. These three categories are 1) degree centrality, 2) closeness centrality and 3) betweenness centrality. In addition to Freeman's work, Bonacich (1972) also proposed an eigenvector-based measure for centrality. Although attempts have been made in developing other measures for centrality, these four measures have kept their dominance in the empirical works.

Degree centrality is mainly concerned with the firm's involvement in a network and is measured by the number of immediate partners that an actor has in their network (Freeman 1979). Degree centrality provides the focal firm with more growth opportunities and access to resources. Based on the previous studies this network construct increases the visibility of the focal firm in the network and makes it more desirable for networking by other companies (Gulati *et al.* 2002). Another benefit of the degree centrality is the experience that they gain in firm cooperation. It will increase both the cooperative experience and the abilities of the focal firm to extract value from the alliances (Gulati 1999).

Closeness centrality refers to the focal firm's distance to the rest of the network members directly and indirectly. A firm with higher closeness centrality can quickly interact with firms and access important information such as new business opportunities or information about valuable innovation (Gulati *et al.* 2002). Moreover, it can help companies 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).

Betweenness centrality is concerned with the position of a firm which lies between other firms in the network. This is calculated by the number of times that a firm falls in two other firms' shortest path. The main argument in betweenness centrality is that a firm that lies between two other firms that are not connected to each other directly has control of the information and resource flow (Freeman 1979). It is argued that high betweenness centrality may enable a firm to extract more value from the network because of its strategic position (Gulati *et al.* 2002).

Degree centrality is one of the centrality measures that has been used primarily in inter-organisational network literature. One of the early works that studied the effect of network size on firms' innovation is by Shan *et al.* (1994). In their study they found that

inter-organisational cooperation affects innovation performance. They studied start-up companies in the biotechnology industry and pointed out that the number of cooperative relationships is positively related to the innovation performance of the start-up companies. Similarly, Deeds and Hill (1996) indicated that there is a non-linear positive relationship between the number of alliances that a company joins and the rate of the new product development. The reason for the nonlinear relationship could be the resources that companies need to spend when they enter a new alliance. Therefore, the benefit of entering a new alliance will diminish after a certain number of alliances. But this number of alliances is varied between organisations based on the company's resources. On a related theme, Ahuja (2000) found that the number of direct and indirect ties influence a company's patenting rate. He argues that a higher number of directed ties will increase the patent rate of companies. This is the same with indirect ties, which means the number of indirect ties will increase the patenting rate of a company. However, the effect of indirect ties will diminish by increasing the number of direct ties. In a similar study Salman and Saives (2005) studied the effects of the immediate indirect ties (second order neighbourhood). They conducted their study on Quebec biotechnology firms and found that being central in a network of indirect ties provides the focal firm with more chance of accessing complementary knowledge from their direct partners and increases innovation.

Powell *et al.* (1996) in a longitudinal study on organisational learning, developed hypotheses that link network position, research and development alliances, network management experiences, firms' growth and portfolios of collaborative activities. They tested these hypotheses with a sample of biotechnology firms and the results supported a learning view. Although all these studies support the idea that a network will increase the innovation outcome of a company, there are some studies that indicate companies are different in their ability to benefit from their network. Soh and Roberts (2005), in their research in the U.S. computer networking market sector, find that firms with a higher

level of research capabilities benefit more from their centrality in their innovation performance. In this study, similar to previous studies, they used centrality and direct ties as the network construct and examined the relation between these constructs and innovation performance of the company. But their departure point is that they have considered the research capabilities of the focal firm in addition to the network factors. In their findings they argue that companies' research capabilities play a key role in their abilities to exploit their centrality in their innovation. The main reason for this can be the improvement in the absorptive capacity of the company. Having internal R&D in a company enables them to realise the opportunities and makes it easier for them to adopt the new technology or knowledge in their current product development, and therefore the shorter product development cycle.

Ouimet *et al.* (2004) have taken a more specific approach about innovation and examined the link between network positions of a firm and radical innovation. They conducted research in a small industrial cluster in the optic and photonic sector. Their findings suggest that degree centrality and effective size are positively correlated with radical innovation. However, they could not find any relation for betweenness centrality and radical innovation. In a related theme, Gilsing *et al.* (2008) studied network effects on firms' exploration and exploitation activities. They conducted a longitudinal study in the chemical, automotive and pharmaceutical industries. Their findings indicate that betweenness centrality, technological distance and density have an inverse U shape relation with the exploration activities of the company. They also suggest that the interaction between technological distance and betweenness centrality as well as betweenness centrality and density have a positive effect on exploration. Although the findings are very interesting and practical, they failed to consider the role of companies' internal capabilities in their studies. As already mentioned, companies' internal

capabilities play a key role in their abilities to benefit from their network positions and enable them to use the available resources.

Therefore, according to the literature, network centrality has a positive impact on a firm's innovation performance. Moreover, those who have higher absorptive capacities can benefit more from this network characteristic. In addition to that, network centrality has a positive impact on radical innovation but studying this impact together with companies' internal capabilities is not well developed.

3.3.2. Density

Network density is defined as the extent to which network members are connected to each other (Gilsing *et al.* 2008). In other words, density is the proportion of the existing ties over all possible ties in the network. There are two streams of literature in density. The first stream is in favour of sparse networks (Burt 1992) and argues that the number of non-redundant contacts is more important than the size of the network (Hagedoorn and Duysters 2002). This stream of literature is based on control, dependence and efficient flow of information. As shown in Figure 3.1 (on the left) actors are connected to each other and all the actors potentially receive the same information. However in b (on the right) B and C are not connected which makes a structural hole. This means that in theory they are using different information resources and A is receiving different information from each of its partners.

The second stream supports dense network idea and suggests that a network with redundant contacts is more effective as it will help with the development of trust and norms between the network members and contribute to the coordination of the network members (Uzzi 1996). This approach of density or closure argument, first introduced by Coleman (1988), is based on the emergence of trust, enforcement of norms and effective coordination. This argument, which states that high density networks are better for actors,

is in contrast to Burt's (1992) structural holes approach, which is about being embedded in a sparse network of disconnected partners. Burt (1992, p. 18) argues that "non-redundant contacts are connected by structural holes". With these two opposite arguments it is hard to examine how firms should be embedded in their network. However, Burt (2000, p. 409) shed some light on this problem by supporting both perspective and argues that "the closure and hole arguments are not as contradictory as they might seem ... the ambiguity stems in large part from different roles that social capital plays in the study populations with which each is justified". According to this argument both Coleman's closure and Burt's structural hole arguments are beneficial but for different strategic purposes (Rowley *et al.* 2000). Because of these two perspectives the findings of the network studies for density are diverse and in order to understand and adapt them correctly it is necessary to consider the context of the study.

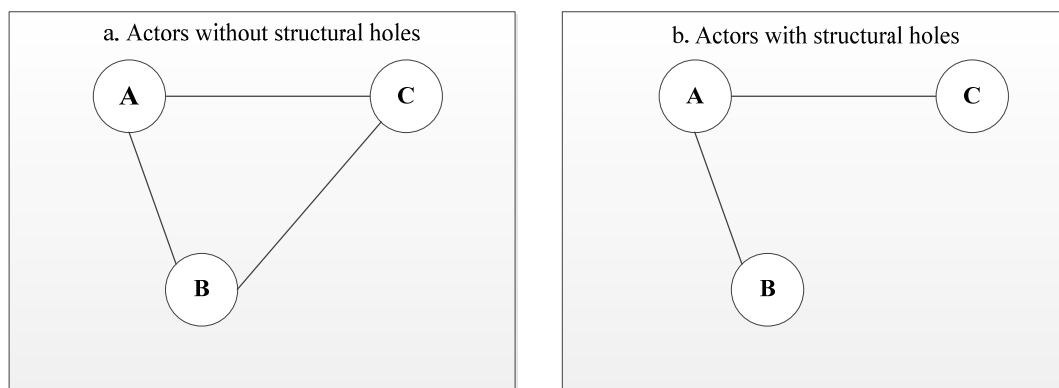


Figure 3.1: An example of structural holes (Source: Hanneman and Riddle (2005, p.136))

Gilsing *et al.* (2008) suggest that the network density of a firm has an inverse U-shaped relation with the exploration activities of the company. In their research they adopted Colman's (1988) closure perspective and examined the global network density of the firms. In global network density they have taken the effects of both direct and indirect ties into account, rather than studying the density of ties surrounding a focal firm (local density). They found that having a dense network is beneficial up to a threshold point and

a very dense network will cause undesired spillovers, redundant knowledge and loyalty to their current partners (Gulati *et al.* 2000, Nooteboom 1999) which are not useful for novelty creation. In a study of firms in the chemical industry, Ahuja (2000) claimed that the presence of structural holes has a negative effect on the companies' patenting rate. Local density is about the interconnectedness of the direct partners of the focal firm. Rowley *et al.* (2000) investigated the effects of local density of the strategic alliance networks on organisations' performance in the semiconductor and steel industry. It was mentioned before that each of the closure and structural holes arguments has to be adopted in the right context. Since they were studying companies in the exploration environment, they have chosen Burt's (1992) approach and their findings show that in an exploration environment high local density of an organisation is negatively related to its performance. Zaheer and Bell (2005) examined the effects of both structural holes and closure on firm performance on Canadian fund companies. They suggest that spanning structural holes will enhance the performance of the companies. They also hypothesised that network closure will enhance firm performance but they did not find any evidence for this argument. These findings support Burt's (2000) argument that sparse network and closure are valuable in different contexts. In Zaheer and Bell's (2005) study, the research setting is an exploration environment in which rapid response to market movements is vital for companies, therefore spanning structural hole is more beneficial compared to network closure.

Reviewing literature on density of the network and analysing the empirical work on closure and structural holes show that the effect of density has to be studied with the context of the study taken into account. It seems where coordination and trust is more important having a dense network is more effective, but where novel information and speedy access to diverse information is required spanning structural holes is more beneficial for the companies.

3.4. Relational Properties

While previous constructs of the network deal with quantitative aspects of the network, relational properties are more about the qualitative aspects of a relation between a focal firm and its partners and refer to the nature and types of ties between them. Whereas structural properties are concerned with providing the setting for innovation resource flow, relational properties are about the nature and extent of resources flowing to the focal firm (Srivastava 2007).

3.4.1. Strength of Ties

Granovetter (1973) introduced the concept of strength of ties for the first time at the interpersonal level. According to this theory, strength of ties is characterised by the amount of time, emotional intensity, intimacy, and reciprocal services. Strong and weak ties are two types of ties that have been identified according to this theory. A simple example of strong ties at interpersonal level is friendship and familial relationships which requires more time and intimacy. In contrast, weak ties are those relationships that have limited investment in time and intimacy. Granovetter (1973) argues that weak ties are important channels to transfer resources and information since they tend to be a bridge tie (a tie that connects the focal firm to a partner that is not connected to any other partners of the focal firm). Since all the network members know other members and know the focal firm, strong ties are less efficient in terms of knowledge. All the bridge ties are weak ties but not all weak ties are bridge ties (Granovetter 1973). This means some weak ties have an additional characteristic which is connecting two unconnected networks. Although other researchers argue that a strong tie can also be a bridge tie (Burt 1992) they all agree about the redundancy of the information and resources being transferred through this type of tie.

At the inter-organisational level Rowley *et al.* (2000, p. 371) defined tie strength between firms as “frequency of interaction between partners and their level of resource commitment to the relationship”. Strong ties in an ego network connect a focal firm to another firm so they have intensive interaction. In contrast, weak ties in an ego network connect a focal firm to another partner so they have very few interactions. Strong ties are sources of private information and critical resources (Gulati *et al.* 2002). There are two main advantages with strong ties. First they can exchange high quality information and tacit knowledge and second they can provide governance on partnership behaviours (Rowley *et al.* 2000). Although strong ties are beneficial for companies, relying more on strong ties and less on weak ties will cause the focal firm to be dependent on the resources of their strong tie partners (Gulati *et al.* 2002). Another problem with having too many strong ties is that it may stop the information about the new opportunities in the market being transferred to the focal firm (Gulati *et al.* 2002). Weak ties are sources of novel information and opportunities in the market (Granovetter 1985) and it reduces the firm dependence on strong partners (Baker 1990). Therefore it is necessary for companies to configure their network according to their requirement for information and resources. There are conflicting results for the outcomes of strong and weak ties and in some cases there seems to be a disadvantage. For example, Julien *et al.* (2004) studied weak signal networks and technological innovation in SMEs in the land-based transportation equipment sector. Their findings show that more innovative companies use their weak ties more frequently and weak ties are more likely to trigger innovation than strong ties. Moreover, they argue that a firm’s absorptive capacity impacts on their ability to benefit from their weak ties. Thus it is not only the network setting that is important in technological innovation; the right internal environment is needed for the company to be able to benefit from its network's potential. In other research, Gargiulo and Benassi (1999) in their study on managers of a special unit of a high technology firm found that strong ties negatively affect managers’ capability to keep control of the composition of

their network. However, Burt (2000) argues that the findings are not conflicting but each of the ties play a different role, which are valuable in different situations. In line with Burt's argument Rowley *et al.* (2000) in their study found that in an explorative environment, which requires access to novel information, weak ties are more beneficial for companies' performance while in an exploitative environment strong ties are more important.

Capaldo (2007) studied the relation between strength of ties and innovation at the inter-organisational level on the furnishing industry in Italy. In this study he found the strengths and weaknesses of strong ties and the benefits of having a dual network (core strong ties with heterogeneous weak ties around it). His field work shows that strong ties can assist organisations to learn about their partners' resources and abilities, so they can choose the right partner for joint product development, reduce time to market the new product and increase the joint-design effectiveness. Another benefit of strong ties is the mutual trust between the partners which makes it possible to share their knowledge and assets with their partners without being concerned about opportunistic behaviours and unwanted knowledge spillovers to their competitors. The last positive outcome of the strong ties is on the partners that are connected with strong ties. The destinies of these partners depend on each other. Therefore, they know that all the investment and actions they are taking will affect both sides of the relation. His findings also include the weaknesses of strong ties. These weaknesses include constraining the firms' access to novel information and not being able to adopt themselves to the changing environment including social and economic changes. However he argues that a dual network, which includes both weak and strong ties, will eliminate the hazard of being locked in a closed network (which helps to foster learning process), increasing variance in the network (which contributes to the lead firm knowledge base) and opening a new market trend to the overall network and leading partners.

Reviewing literature on the strength of ties reveals that both strong and weak ties have advantages and disadvantages. Although the primitive research showed benefits of weak ties and negative effects of strong ties, scholars in recent studies found the strengths of strong ties. Having a network with only one of these ties is not beneficial and it is important to configure the network with a combination of these ties and change the balance between weak and strong ties based on the organisation's strategies.

3.4.2. Diversity of Ties

Diversity of ego network ties is about the different types of relationships that connect the focal firm to its partners. Tie diversity is high when the focal firm has different types of inter-organisational relationships (such as joint venture, alliance, consortia) or transfer different types of knowledge through these relationships (such as marketing, manufacturing or management knowledge). Powell *et al.* (1996) studied inter-organisational relations in the biotechnology industry. Their findings show that diversity of ties together with the number of R&D relations and the company's experience in managing these relations, increases the firm's central connectedness. Tie diversity is likely to provide the focal firm with complementary resources, opportunities and capabilities which can help the company to address the resource barriers and uncertainties related to innovation (Srivastava 2007). Access to diverse knowledge provides the company with new solutions for existing problems (Rosenkopf and Nerkar 2001). The importance of the access to diverse knowledge is well documented in the network and innovation literature (Baum *et al.* 2000, Katila 2002, Nooteboom 1999, Rosenkopf and Nerkar 2001, Subramaniam and Youndt 2005). Sammarra and Biggiero (2008) in their research found that in an inter-organisational relationship three different types of knowledge may be transferred (managerial, technological and market knowledge). They argued that all of these different types of knowledge are necessary for a successful innovation. Diverse ties bring complementary resources to the organisations and help

companies to reduce uncertainty during the innovation process. Baum *et al.* (2000) conducted their study on Canadian start-ups' performance and suggested that start-ups can enhance their early performance by configuring their network into an efficient network that provides access to diverse information and capabilities.

Compared to other network properties, research on diversity of ties is limited and only recently have scholars recognised the importance of this property of network. Overall, tie diversity improves companies' performance by providing the focal firm with a variety of resources that they can adapt in their innovation process.

3.5. Nodal Properties

Nodal properties refer to the partners' characteristics of the focal firm. These characteristics include resources of the partners, capabilities of the partners or the industry that they are performing in. Nodal factors affect the quality and variety of the resources available to the focal firm based on the partners' capabilities. There is a substantial body of literature which shows that focal firms are influenced by their partners in their decision making (Beckman and Haunschild 2002). Studies show that the experiences of the network partners are transferred to each other and influence different organisational practices (Beckman and Haunschild 2002). In the study of the nodal properties of the network, scholars studied the resourcefulness of the partners (Beckman and Haunschild 2002, Stuart 2000), which reflects quality of resources, capabilities and diversity of the partners (Beckman and Haunschild 2002, Goerzen and Beamish 2005) explained in the following section.

3.5.1. Diversity of Nodes

Diversity of nodes refers to the variety of resources, experiences and practices of the focal firm partners. Companies are different in their resources, capabilities, technological domains and the market that they are working on. Therefore, choosing partners from

different backgrounds will bring a variety of resources and knowledge to the ego network, which influences the performance of the network members.

The importance of diversity of network on innovativeness of the partners has been addressed in different studies (Kaufmann and Todtling 2000, Kaufmann and Todtling 2001, Rothwell 1991). Kaufmann and Todtling (2001) pointed out the importance of partners' diversity in innovation and their findings have been supported by Perez Perez and Sanchez's (2002) work on the Spanish automobile industry.

Beckman and Haunschild (2002) conducted longitudinal research about the diversity of network partners and the amount of premium that the focal firm pays for acquisition in the manufacturing industry. Their findings show that having a diverse network, partners with experience of acquisition of various sizes, partners who pay diverse premium and partners with diverse sizes aid the focal firms' learning. This helps them to pay a lower premium for the acquisitions. However, they could not find any evidence that supports the relation between industry diversity of partners and the premium that a focal firm pays for acquisition. Goerzen and Beamish (2005) studied alliance diversity on the performance of the multinational enterprises. Their findings show that higher diversity of alliance networks is negatively related to the performance of the large multinational enterprises. Although previous studies implied that diversity of alliance network will enable firms to access resources on a timely basis and therefore to be in a competitive position, Goerzen and Beamish's study shows that increasing the diversity will diminish the benefit of it by increasing the cost and resources required to manage these relationships in the MNE industry.

Reviewing literature on nodal properties revealed that this is a newer concept in network studies compared to other network properties and, although important in different aspects of organisational outcome, only recently have scholars started to address it in their

studies. Moreover, the findings are scattered and in some cases they are in contrast with each other which needs to be addressed in future studies. However, the findings show that it is important for the focal firm to find partners with different abilities and resources.

To summarise this section, according to the literature that has been reviewed here, inter-organisational relationships offer valuable resources for innovation performance. In order to be innovative, companies face some specific problems (such as sharing risks, reducing uncertainties and getting access to external knowledge or information) for which inter-organisational networks can provide the solutions. In addition to that, structural, relational and nodal properties all foster innovation and improve organisation performance which is important for their survival. Table 3.1 summarises the literature that has been reviewed here and the key findings.

Table 3.1: Summary of the reviewed network literature

#	Network Construct	Authors	Year	Dependent Variables	Independent Variables	Industry	Sample	Key Findings
1	Centrality	Shan <i>et al.</i>	1994	Innovation output	Commercial ties Research agreements	Biotechnology	85 start-up firms	Relationship with large firms will increase the innovation output of the start-up firms.
2		Deeds and Hill	1996	Rate of new product development	Number of strategic alliances	Biotechnology	132 entrepreneurial firms	The number of strategic alliances has an inverse U-shaped relationship with the amount of new product development.
3		Ahuja	2000	Innovation output	Direct ties	Chemical	97 chemical firms	The number of direct ties is positively related to the innovation output of the company.
4		Ahuja	2000	Innovation output	Indirect ties	Chemical	97 chemical firms	Higher number of indirect ties will positively influence innovation output.
5		Ahuja	2000	Innovation output	Indirect ties * Direct ties	Chemical	97 chemical firms	The number of direct ties will moderate the positive effect of indirect ties on innovation.
6		Ouimet <i>et al.</i>	2004	Radical innovation	Degree centrality Betweenness centrality Effective size	Optics and photonics	58 organisations	Degree and effective size are positively correlated with radical innovation.
6		Salman and Saives	2005	Innovation output	Indirect ties	Biotechnology	40 companies	The higher the centrality of the firm in a network of indirect ties, the more the access to useful knowledge and the higher the innovation of the company.
7		Soh and Robert	2005	Innovation performance	Number of partners Closeness centrality Research capabilities	Computer networking market	49 firms	Number of partners and closeness centrality is positively related to the firms' innovation performance. The higher the firm's research capabilities the higher the positive effects of betweenness centrality and direct ties.
8	Gilsing <i>et al.</i>	2008	Explorative innovation performance	Betweenness centrality	Pharmaceutical, chemical and automotive	116 companies	Centrality is positively related to exploration performance of the company up to a threshold point, after that it affects it negatively.	

						industry		
10	Density	Ahuja	2000	Innovation output	Structural holes	Chemical	97 chemical industry	Structural holes are negatively related to innovation output.
11		Rowley <i>et al.</i>	2000	Firm performance	Density	Semiconductor and steel	138 Semiconductor and 132 Steel	In an exploration environment density of ties among firm's direct partners is negatively related to its performance.
12		Zaheer and Bell	2005	Market share	Structural holes	Canadian mutual fund companies	77 firms	Innovative firms that span structural holes have a better performance
13		Gilsing <i>et al</i>	2008	Explorative innovation performance	Density	Pharmaceutical, chemical and automotive industry	116 companies	Density is positively related to exploration performance of the company up to a threshold point after that it affects it negatively.
14		Gilsing <i>et al</i>	2008	Explorative innovation performance	Density * Betweenness centrality	Pharmaceutical, chemical and automotive industry	116 Companies	Interaction between betweenness centrality and density is positively related to exploration.
15	Strength of Ties	Rowley <i>et al.</i>	2000	Firm performance	Strong Ties Weak Ties	Semiconductor and steel	138 Semiconductor and 132 Steel	Strong ties in a high density network negatively affect firm performance in the semiconductor industry. Strong ties and weak ties are positively related to firm performance in both sectors.
16		Julien <i>et al.</i>	2004	Technological innovation	Weak ties	Small to medium size land-based transportation equipment sector	147 SMEs	Innovative firms use their weak ties more frequently. Also weak ties comparing to strong ties are more likely to trigger technological innovation
18		Capaldo	2007	Innovative performance	Strong ties Dual networks	Furnishing industry	3 lead firms	Benefits of strong ties can help focal firms to learn about their partners, make mutual trust, partner's destinies depending on each other. Dual network will remove the hazard of being locked in a closed network, increases diversity and opens new market trends to the firms
19	Nodal	Kaufmann	2000	Innovation	Partners in	A broad range of	107 in Styria, 103	The findings show that companies partly rely

	Properties	and Todtling		activities	innovation process Innovation partners by types of firms	industries including automotive engineering, electronic engineering and healthcare.	in Wales, 142 in Tampere and 80 in the Basque country. (mostly medium and large organisations)	on their regional partners for innovation. They are mostly integrated into national and European networks.
20		Kaufmann and Todtling	2001	Product new to the market Product new to the firm	Partners from the business systems Partners from science	A broad range of industries including automotive engineering, electronic engineering and healthcare	107 in Styria, 103 in Wales, 142 in Tampere and 80 in the Basque country. (mostly medium and large organisations)	The results show that partners in science are more important than a firm's customer in their new product innovation.
21		Perez Perez and Sanchez	2002	Teamwork In-house training	Networking suppliers	Automotive industry	28 automotive suppliers	Those companies that participate in networking have more in-house training and teamwork compared to non-networking suppliers.
22		Beckman and Haunschild	2002	Acquisition decision	Network Diversity Network partner industry Network partner size Network multiplexity	Service and manufacturing US firms	300 large firms	Companies pay lower premiums for their acquisitions when they have partners with unique information, diverse sizes and multiplex relationships.
23		Goerzen and Beamish	2005	Economic performance	Alliance network diversity	-----	580 large MNEs	The higher the diversity of alliance network, the lower the economic performance compared with those with less diverse alliances
24		Laursen and Salter	2006	Innovation performance	External search breadth External search depth	UK manufacturing sector	2707 manufacturing firms	Search breadth and depth has an inverted U- shape relationship with innovation performance

3.6. Inter-Organisational Relationships

Previous literature has addressed a portfolio of reasons for the establishment of inter-organisational relationships e.g. spread the cost, share risks, learning and knowledge sharing. Among them acquisition of knowledge and capabilities from partner firms are the most cited reasons for inter-organisational collaboration (Hagedoorn 1993, Mowery *et al.* 1996). Table 3.2 shows a summary of the potential advantages of participating in inter-organisational relationships.

The desire for partnership formation is consistent with literature arguing that firms which establish relationships with other organisations are more innovative (Ahuja 2000, Powell *et al.* 1996). Grant and Baden-Fuller (2004) indicated that access to knowledge is another way that companies can benefit from their inter-organisational relationship in addition to knowledge acquisition. They argued that knowledge acquisition helps companies to increase their knowledge in specialised areas while knowledge access will help the growth of the knowledge base of a company. According to learning theory, firms form relationships to gain access to new sources of knowledge and create more opportunities for learning (Barringer and Harrison 2000, Mowery *et al.* 1996). Mowery *et al.* (1996) argued that since knowledge is often tacit and difficult to price it is rarely possible for a firm to buy it from the market. A firm that requires knowledge for a particular purpose, such as creating a new product, has a better chance of success by forming a relation with a partner which already has expertise in that area. So the focal firm is able to fill the gap in their knowledge base with the transferred knowledge from the partners.

Table 3.2 Potential benefits of forming inter-organisational relationships (Source: Barringer and Harrison (2000, p. 385))

Potential Advantage	Description
Gain access to a particular resource	Firms form inter-organisational relationships to gain access to a particular resource, such as capital, employees with specialised skills, intimate knowledge of a market, or a modern production facility.
Economies of scale	In many industries, high fixed costs require firms to find partners to expand production volume.
Risk and cost sharing	Inter-organisational relationships allow two or more firms to share the risk and cost of a particular business endeavour.
Gain access to a foreign market	Partnering with a local company is often the only practical way to gain access to a foreign market.
Product and/or service development	Inter-organisational relationships provide firms the opportunity to pool their skills to develop new products and/or services.
Learning	Inter-organisational relationships often provide the participants the opportunity to “learn” from their partners (e.g. lean manufacturing, product development, human resource management in an unfamiliar country).
Speed to market	Firms with complementary skills, such as one firm that is technologically strong and another that has strong market access, partner to increase speed to market in the hope of capturing first-mover advantages.
Flexibility	Inter-organisational relationships provide a valuable alternative to markets and hierarchies, and are subject to fewer regulatory concerns than acquisitions.
Collective lobbying	Organisations form inter-organisational relationships to increase their collective clout and pressure their governments into adopting policies favourable to their industries.
Neutralising or blocking competitors	Through an inter-organisational relationship, firms can gain the competencies and market power needed to neutralise or block the moves of a competitor.

The resource based view of the firm argues that resources are distributed heterogeneously across firms; they are not imitable, transferrable and cannot be bought in resource markets (Barney 1991). This approach focuses on firms’ skills and abilities in different areas which have been gained through organisational processes (Eisenhardt and Martin

2000). Resources consist of the physical, human, and intangible assets of a firm. These capabilities enable firms to coordinate their activities and make use of tangible and intangible assets (Eisenhardt and Martin 2000). The primitive focus of resource based theory was on internal capabilities and resources of the firm but this focus has been extended to demanding companies to exchange their resources, and particularly knowledge, with their partners (Burgers *et al.* 1993, Teece 1996). There is a growing body of literature about knowledge transfer through inter-organisational networking which suggests that firms' competitive advantages in many industries depend on using essential knowledge and the capabilities of other companies that are difficult to imitate (Gulati 1999, McEvily and Marcus 2005).

Organisations are embedded in formal and informal networks between organisations and people inside organisations. With regards to inter-organisational relationships, this thesis makes a clear distinction between formal and informal ties. Formal inter-organisational relationships are based on contractual obligations and they are means of planned knowledge exchange between organisations (Smith *et al.* 1995). It is argued that formal ties are more easily incorporated into an open innovation strategy (Simard and West 2006). On the other hand, informal inter-organisational ties are based on adaptable agreements rather than contractual obligations. To define inter-organisational relationships in the context of this study it is necessary to bear in mind that employees of an organisation are sources of informal inter-organisational relationships and capturing data for these relationships is hard and time consuming. Therefore this thesis only focuses on formal relationships between companies. An inter-organisational relationship in the context of this study is defined as: 'Inter-organisational relationships refer to all types of knowledge transfer relationships between companies. These relationships are formal and can be with any type of organisations, customers, suppliers, partners, universities or

laboratories'. This definition covers all the formal knowledge transfer relationships between a company and all of their partners.

Theories that have been used in network studies and their limitations are reviewed in the next section.

3.7. Theories Used in Inter-Organisational Social Network Studies

As mentioned earlier there are different motives for companies to establish inter-organisational relationships with others. Barringer and Harrison (2000) have reviewed six widely used theoretical paradigms and suggested combining different theoretical paradigms in order to provide a better understanding of the formation of inter-organisational relationships. The theories reviewed by Barringer and Harrison (2000) include transaction cost economics, resource dependence, strategic choice, stakeholder theory, learning theory, and institutional theory. These theories plus network theory and their shortcomings have been reviewed briefly to provide a better understanding of the motives behind inter-organisational relationships.

3.7.1. Transaction Cost Economics

The main focus in transaction cost economics (TCE) is keeping a firm's transaction and production costs to a minimum by managing the firm's boundary spanning activities (Barringer and Harrison 2000). Both transaction cost and production cost of an organisation depend on different factors such as expenses associated with arranging, managing, and monitoring transactions across the market scale of an operation, location of a firm and learning/experience effects (Kogut 1988).

A simple example for TCE is when a company has to make a decision between buying a product from another company that is already expert in the area or to internalise and

produce it in the organisation. According to the TCE, if the product is cheaper in the market then companies will buy it. Otherwise, if for some reason they are unable to get it from the market, they choose to produce it in the organisation. However, inter-organisational relationships provide a third option for this situation. Companies, by establishing relationships with other companies, can address their requirement with less cost and avoid problems that may occur in buying or in-house production e.g. cost of opportunism and monitoring (Osborn and Baughn 1990) or producing something that is not in line with companies competencies (Harrigan 1988). Research by Jarillo (1988), Hennart (1988) and Harrigan (1988) are some examples that used TCE as the logic behind establishing inter-organisational relationships in their studies.

TCE, despite addressing an important aspect of inter-organisational relationship formation, has been criticised for not being able to explain other reasons behind it. For example Faulkner (1995) conducted research to find the role of TCE in alliance formation. His interviews with managers whose companies were involved in alliance with other companies showed that TCE was not the rationale behind any of the alliances. TCE only addresses cost efficiency rationale and is not able to explain other reasons such as learning and legitimacy (Barringer and Harrison 2000).

3.7.2. Resource Dependence Theory

According to resource dependence theory, companies are required to participate in exchanging resource activities to be able to acquire their required resources (Barringer and Harrison 2000). The difference between this theory and the resource based view of the firm is that RBV is mainly focused on internal resources of an organisation but resource dependence theory focuses on resources that need to be obtained from outside an organisation.

There are different reasons for establishing inter-organisational relationships that fit resource dependence theory. One reason can be taking advantage of complementary assets (Barringer and Harrison 2000) such as big biotechnology companies making partnerships with small biotech companies to access their novel knowledge bases and small companies participating to benefit from their financial resources and distribution channels (Fisher 1996). Other examples for resource needs that bring companies together are special services at low cost, relevant industry information (Oliver 1990) or access to the latest technology in the field (Browning *et al.* 1995).

The limitations of resource dependency theory fall in two main areas. The first one is why organisations choose other alternatives to address their resource limitations (such as merger and acquisition or employment of a key member of a competitor company). The second area is that this theory does not consider the role of other variables (such as transaction cost or learning opportunities) establishing relations (Barringer and Harrison 2000).

3.7.3. Strategic Choice

In this perspective companies employ strategic reasoning to rationalise the logic behind their inter-organisational relationships. There are varieties of strategic reasons (such as short term efficiency, resource based rationales (Jarillo 1989, Kogut 1988) to increase efficiency, or to reduce costs (Harrigan 1988)) that motivates organisations to launch inter-organisational relationships. The emergence of this perspective was based on the rationale that the main reason for inter-organisational relationships is increasing competitiveness or market power (Barringer and Harrison 2000).

Although strategic choice addresses many different reasons behind forming inter-organisational relationships, it is very challenging for researchers who use this

perspective to categorise existing inter-organisational relationship strategies into a meaningful group (Barringer and Harrison 2000).

3.7.4. Stakeholder Theory

According to stakeholder theory companies are at the centre of a network of their stakeholders and they have to consider legitimate interests of all of their stakeholders in their important operational and strategic decision making (Phillips and Freeman 2003). Stakeholders are defined as individuals, groups or companies and are affected by organisations or will affect organisations (Freeman 1994) (e.g. customers, partners, competitors, suppliers, shareholders). Although all the stakeholders are important for a company, they are not equal. There is literature that advises on the significance of determining which stakeholder is more important (Donaldson and Preston 1995). This theory interprets the purpose of inter-organisational relationships as a way of aligning their interests with their stakeholders and reducing environmental uncertainty (Dickson and Weaver 1997).

Like other theories, there are some aspects of inter-organisational relationships that stakeholder theory cannot address. One of the limitations is using this theory in large organisations with a lot of stakeholders which is not practical (Barringer and Harrison 2000). Another limitation is although this theory advises on using alliance for goal homogeneity between the company and its stakeholders, it does not provide any assistance about the form of the alliance (Barringer and Harrison 2000).

3.7.5. Learning Theory

Organisational learning is another reason for companies to establish inter-organisational relationships with other organisations. Access to knowledge and learning opportunities is important for a firm's competitive advantage. Companies can benefit from their relationship with other organisations to increase their learning opportunities and enrich

their organisational learning (Kogut 1988, Mowery *et al.* 1996). There is an extensive body of literature that confirms learning and acquisition of knowledge as a rationale for inter-organisational relationships (Mody 1993, Powell *et al.* 1996, Shan 1990).

March (1991) recognised exploration and exploitation as two types of learning activities that take place in inter-organisations relationships. Exploration is defined as finding new ways of doing things and experimenting with new alternatives or a new line of business which, if successful, may cause innovation and invention in a company (Hagedoorn and Duysters 2002). Exploitation on the other hand is about using and improving the existing capabilities of an organisation to make the firm more productive (Barringer and Harrison 2000). Hagedoorn and Duysters (2002) indicate that explorative activities are important for companies in a dynamic environment and help them to improve their knowledge about those partners where the relevance of their knowledge is not clear in advance. In contrast, exploitative activities are important in a static environment in which they have clear information of the capability of their partners and they can adopt this knowledge for different purposes such as improving their performance or decreasing their costs.

Although inter-organisational relationships can facilitate organisational learning, inter-organisational relationships alone are not enough. It is important to understand how much a firm is able to learn from the inter-organisational relationship. For this purpose, absorptive capacity is defined as the ‘ability of firms to identify, assimilate, transform and exploit knowledge’ (Hagedoorn and Duysters 2002). The absorptive capacity of firms is different and depends on factors such as firms’ prior experience, knowledge base, organisational culture and prior preparation (Kumar and Nti 1998).

Although learning as a rationale for inter-organisational relationships is well developed there are some limitations. Barringer and Harrison (2000) indicated the two main limitations as ignoring cost and unwanted spillover. The first limitation is ignoring the

cost of the training and skill development which is necessary to increase the absorptive capacity. Another limitation is an unwanted knowledge transfer which is not in the scope of the alliance.

3.7.6. Institutional Theory

Institutional theory suggests that organisations are under pressure from the environment to appear legitimate and follow dominant social norms (DiMaggio and Powell 1983). According to this theory institutional pressure is the motive behind companies activities to increase their legitimacy and shows that they are in agreement with predominant rules and norms in their business environment (Oliver 1990). One way of doing this is establishing inter-organisational relationships with other companies. For example small companies can gain reputation, visibility and image by establishing partnerships with larger organisations. In this way they will be more visible and legitimate compared to their competitors and this may open new avenues for the company to establish new relationships that give them access to critical resources (Barringer and Harrison 2000). Another reason for inter-organisational relationships that can be explained using institutional theory is to improve a company's image. Schermerhorn and Shirland (1981) linked inter-organisational relationships to institutional theory and found inter-organisational coordination between hospitals and concern for image are related to each other.

Next, the behaviour of organisations that institutional theory helps to explain is using inter-organisational relationships as a means of acceptance and survival (1991). One method of acceptance and survival is imitating industry norms such as mimicking successful organisations. As a result of this, many organisations may get involved in inter-organisational relationships because other successful companies are doing the same (Barringer and Harrison 2000).

Like other theories that have been reviewed here institutional theory has its own limitations. One of the limitations is that this theory is mainly focused on the behavioural aspect of inter-organisational relations (Barringer and Harrison 2000). For example institutional theory is not able to explain the existence of some forms of inter-organisational relationships that vary from the status quo. Another limitation is based on the resource-based view of the firm: if all companies imitate each other's behaviour then the possibility for creating a sustainable competitive advantage through inter-organisational relationships is very limited (Barringer and Harrison 2000).

3.7.7. Network Theory

Scholars of organisational studies have become interested in using the network concept in organisations studies during the last two decades. The main argument in network theory is that, among the potential benefits that organisations gain through an efficient and effective network, access to information, timing and referrals are significantly important (Burt 1992). Access to information provides the opportunity for an organisation to improve its knowledge base beyond what they could achieve alone. An organisation alone, due to the limited resources, can possess knowledge in limited areas. However, establishing relations with other organisations can help them to expand their domains of knowledge and expertise. The timing of the accessed information is also important since companies' early access to information can be a great advantage over their competitors; for example, information about a market niche which opens a new market for a company. Another example of timing is the access to a new technology before other companies, which is a great opportunity for them to adapt the technology in their products and improve their performance. Referral is the third benefit of inter-organisational networks according to this theory, which involves representation of a focal firm's interests to third parties through its partners in a positive manner. This might open new development opportunities for the focal firms through its indirect partners.

Table 3.3: Summary of the theory for inter-organisational relationships (the first six theories are from Barringer and Harrison (2000))

Theoretical Paradigm	Description	Rationale for Inter-organisational Relationships
Transaction Costs Economics	Focuses on how an organisation should organise its boundary-spanning activities so as to minimise the sum of its production and transaction costs.	Minimisation of the sum of production and transaction costs. IRs can reduce uncertainty caused by market failure and reduce costs associated with establishing a hierarchy.
Resource Dependence	A theory rooted in an open system framework that argues that all organisations must engage in exchanges with their environment to obtain resources.	Organisations form IRs to exert power or control over organisations that possess scarce resources. Alternatively, an organisation may enter an IR in an effort to fill a perceived resource need.
Strategic Choice	Study of factors that provide opportunities for firms to increase in competitiveness or market power. Profit and growth are typically the major firm objectives that drive strategic behavior.	An organisation will enter into an IR if the financial benefits of doing so exceed the costs. IR strategies may increase the ability of a firm to deliver superior products and services efficiently or work to decrease competition in an industry.
Stakeholder Theory of the Firm	Organisations are at the centre of an interdependent web of stakeholders and have a responsibility to consider the legitimate claims of their stakeholder when making decisions and carrying out business transactions.	Organisations form alliances, also called networks or constellations, to align their own interests with the interests of stakeholders and also to reduce environmental uncertainty.
Organisational Learning	Concerned with the processes that lead to organisational learning. A key factor is absorptive capacity, which is defined as a firm's ability to recognise the value of new knowledge, assimilate it, and apply it in a business setting.	Absorb as much knowledge as possible from IR partners, thus increasing organisational competencies and ultimately adding value to the organisation.
Institutional Theory	Suggests that institutional environments impose pressures on organisations to appear legitimate and conform to prevailing social norms.	Organisations form IRs to obtain legitimacy or as a result of succumbing to isomorphic pressures by mimicking firms that have established IRs.
Network Theory	Focuses on the quantity and quality of the relationships between entities. Quantity includes structure of the networks (number of partners, connectedness of the partners etc.) and quality is about the frequency of the relations or the resources being transferred through the relations.	Among different benefits of an efficient and effective inter-organisational network, access to information, timing of access to information and referrals have a significant economic benefit for organisations.

There are a number of studies that support these arguments (Ahuja 2000, Burt 1992, Gilsing *et al.* 2008). However, this theory has some limitations. For example Goerzen and Beamish (2005) adopted this theory in their study and examined an inverse U-shaped relationship between alliance diversity and company performance. The outcome of their study did not support the relationship and was in favour of TCE theory. The relation between alliance diversity and organisation performance was negative due to the cost of establishing and maintaining these relationships. Therefore, like other reviewed theories, this theory is not able to explain all the outcomes of the inter-organisational relationships.

Table 3.3 provides a summary of the reviewed theories. A brief description for each theory and how inter-organisational relationships have been explained in the context of each theory is provided. Reviewing different theories behind inter-organisational relationships helped to understand the different logic behind them. Each of these theories offers a unique perspective in understanding the formation of the relationships.

3.8. Critique

This chapter revealed a number of gaps in the innovation and social network literature.

First, social network studies are mainly focused on large organisations and studying network effects on innovation in the context of SMEs is not well developed. SMEs and large companies are different in terms of both the internal and external resources available to them. Therefore studying network characteristics in the context of SMEs is vital for understanding the impact of networks on this type of company.

Second, previous network studies are mainly focused on the presence and absence of innovation and there are limited studies that address the network effects on the degree of innovation novelty. Previous findings show that network characteristics play an important role in affecting a company's innovation performance. As explained in the last chapter, radical and incremental innovations require different types of resources. Therefore it is

necessary to study the effect of network resources on different types of innovation performance.

Third, studies so far have mainly used secondary resources to collect network and innovation performance data and they have rarely used real network data as the indicators at the inter-organisational level (Meeus and Faber 2006). An example is alliances that in previous studies have mainly been measured by announcements but it has never been confirmed whether all these alliances have been established in reality. Therefore, studying the impact of network resources on innovation using real network and innovation performance data is another gap in the network and innovation literature.

Fourth, the literature review revealed that network studies are mainly focused on the impact of network characteristics on innovation performance and there are very few studies looking at the internal factors and network resources at the same time. In addition to that, studies that investigated the external and internal factors were only about the presence and absence of innovation and did not focus on degree of innovation novelty. As reviewed in the last chapter, both internal and external factors are important and play a significant role in the innovation performance of companies. Therefore investigating the impact of external resources as well as internal resources of a company on different types of innovation is another gap identified through the literature review in this chapter. This research attempts to address these gaps identified in this chapter.

3.9. Summary

The concept of social networks was introduced and explained for the purpose of this study. The distinction between the sociocentric and egocentric approach was pointed out and the significance of using each approach was explained. Next structural, nodal and relational properties of social networks were explained and relevant literature was reviewed. In each of the properties, the constructs that were used for developing the

conceptual framework were explained in detail. Next, the concept of an inter-organisational relationship was defined for the purpose of this study and the differences between informal and formal relationships were explained. Then, different theories that have been used in inter-organisational relationship studies and their shortcomings were reviewed. The last part of the chapter was about the gaps that have been identified in the literature through the literature review.

In the next chapter, the theoretical framework of the study is developed based on the concepts reviewed in this chapter. Twelve hypotheses are developed and the theoretical model of the study is introduced based on the developed hypotheses.

4. Chapter 4: Conceptual Framework Development

4.1. Introduction

In this chapter a conceptual model for the study is proposed. To answer the research question, a number of hypotheses are developed based on the literature reviewed in chapters 2 and 3. Next a conceptual model is proposed based on the developed hypotheses.

4.2. Overview of the Theoretical Framework Underpinning the Study

Reviewing the innovation and network literature in the last two chapters confirms the importance of these concepts in the success of organisations. Innovation is a source of sustainable competitive advantage that transforms organisations' lives and futures. Also each type of innovation has its own advantages and demands different types of resources.

In addition to innovation, since organisations are not isolated entities and interact with their environment, the importance of inter-organisational relationships and its significance on different aspects of organisational outcome is identified. It is argued that the quantity and quality of the relationships and types of partners are important in providing the right environment and resources for innovation and improving company performance.

The literature analysis reveals that, although there is much research on network and innovation, investigating this relationship at a more specific level of innovation is not

well developed. In addition prior research failed to include firms' internal capabilities in their studies as well as external resources. Both internal and external related factors are important in innovation performance. Also innovations are not similar and different types of innovations require different types of resources. Internal resources in an organisation that impact on different types of innovation are identified as absorptive capacity, R&D and innovation management practices. Resources that reside outside a company that are important in innovation performance are identified as knowledge transfer networks with companies, customers, universities and other partners outside the company. This study argues that both internal and external factors need to be investigated at the same time to provide a better picture of their impact on different types of innovation.

Therefore, investigating the relation between network properties and a firm's internal capabilities with different types of innovation seems necessary. Figure 4.1 illustrates an overview of the theoretical framework of the study which is based on the three main concepts: innovation, inter-organisational knowledge transfer and a firm's internal capabilities. The framework shows how these concepts are related to each other and influence the innovation outcome of organisations. The rectangle on the right illustrates the resources outside a company which is mainly the network resources that were identified in the previous chapter. The middle of the framework is the organisation that interacts and transfers knowledge with the partners to access the necessary resources for innovation. An organisation's internal capabilities are mainly the factors that directly impact on innovation performance or provide the necessary environment to leverage the resources transferred from partners in their innovation. Companies use all these resources to generate innovation which might be radical or incremental.

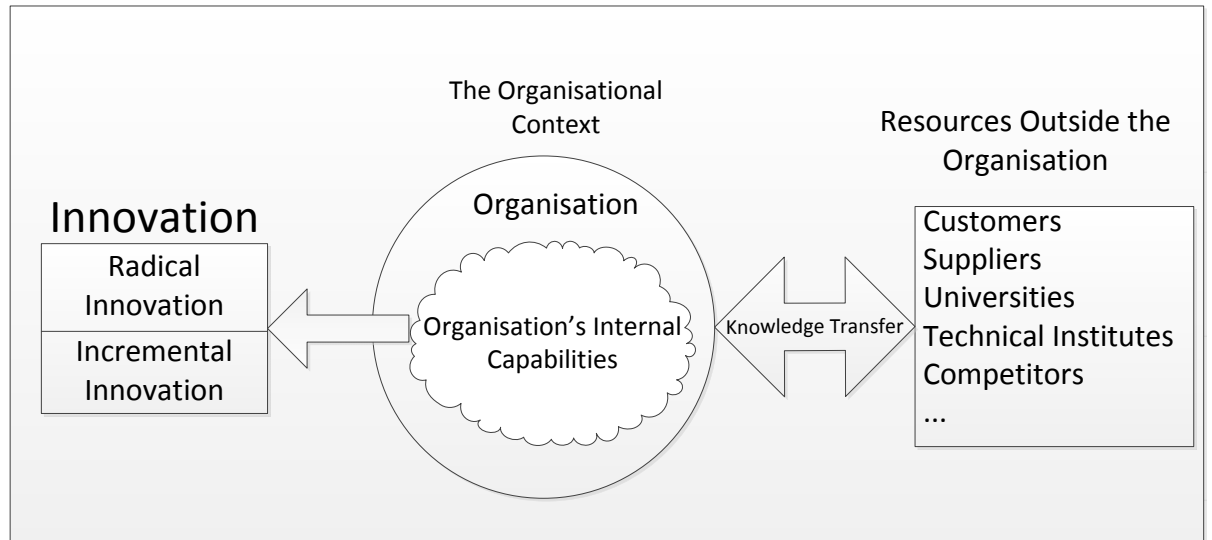


Figure 4.1: An overview of the theoretical framework underpinning the study

Three aspects of ego network are identified: 1) structural properties which address the potential for resources and the context for the flow of resources (Burt 1992), 2) relational properties which reflect the quality of resource flows (Gulati *et al.* 2002), and 3) nodal properties which are about the quality and variety of resources and capabilities of the ego partners (Beckman and Haunschild 2002).

To achieve sustainable innovation, companies must have access to a variety of resources that are continually accessible. One of the reasons that companies are not able to innovate is lack of resources (Ahuja and Lampert 2001, Henderson 1993). To develop and provide necessary resources (e.g. knowledge) for innovation, companies need to invest time and money. For example some companies may not be able to provide the prerequisites for developing knowledge that is necessary for a new product. Sometimes due to the costs it is not beneficial to develop the resources that they only require for a limited period. This is more severe for SMEs due to their limited resources. In this situation the amount of knowledge and resources that a company can access through its ego-network is vital to a

firm's abilities to innovate. Based on this logic the following section presents the hypotheses of the study.

4.3. Structural Properties

4.3.1. Betweenness Centrality

According to the literature review betweenness centrality refers to the frequency that a firm falls between two other firms in their shortest path (Freeman 1979). The main argument in betweenness centrality is that a firm that lies between two other firms that are not connected to each other directly has control on the information and resource flow (Freeman 1979). High betweenness centrality may enable a firm to extract more value from the network because of its strategic position (Gulati *et al.* 2002).

Novelty and the ability to absorb knowledge are two important factors in innovation (Gilsing *et al.* 2008). It was mentioned before that, for incremental innovation, companies need to be able to combine existing knowledge and skills. In contrast, for radical innovation they require the ability to combine and transform the new knowledge acquired from different resources and generate something new (Henderson and Clark 1990). Burt (2004) argued that knowledge, values and behaviors are more heterogeneous between groups rather than within groups. According to this argument inter-organisational networks are not just a medium for knowledge transfer, they create opportunities to combine the existing knowledge and generate new knowledge. Therefore companies, in order to increase their radical innovation abilities, need to develop ties to companies that they are not already connected to the firms in the network group. This is the concept of structural hole in social network studies, which has been introduced by Burt (1992). Burt defines structural holes as a gap in information flows between alters which are not connected to each other but linked to the same ego. An important issue here is developing a tie to other companies that spans a structural hole. The firm's position in the network

can help them to find opportunity to develop non-redundant relations with other companies and benefit from their relation (Gilsing *et al.* 2008). A firm's betweenness centrality helps them to find opportunities to develop non-redundant relations with other companies (Gilsing *et al.* 2008). Higher betweenness centrality means the company is connected to partners that are not connected to each other and the firm is spanning more structural holes. This will enable the focal firm to access novel information and increase the firm's potential for radical innovation. Thus firms with higher network centrality have more opportunities to develop radical innovations.

Although network centrality is important, Gnyawali and Madhavan (2001) show that one consequence of having too many non-redundant network ties is dealing with a high-speed flow of diverse information. Due to the limited resources in SMEs, it is not possible to process and absorb the transferred knowledge if the volume of it exceeds a certain threshold. Moreover, it is argued that looking for novel information through non-redundant ties can cause a random drift so the knowledge base of the company will be changing continuously in different and unrelated directions which makes it hard to integrate and absorb the transferred knowledge (Ahuja and Katila 2004). According to this argument, network centrality is not always useful for radical innovation. It depends on a firm's capabilities and resources to process and absorb transferred knowledge. Therefore, the following hypothesis is proposed:

Hypothesis 1: Radical innovation performance has an inverse U-shaped relationship with the betweenness centrality of a company.

4.3.2. Network Density

Network density is the extent to which network partners are connected to each other. Based on the previous research, network density will increase the absorptive capacity by limiting the novelty creation (Gilsing *et al.* 2008). Inter-organisational networks transfer

and process the information (Ahuja 2000, Freeman 1991). Firms in networks benefit from both direct and indirect ties which play an important role in firm innovation performance (Ahuja 2000). The direct tie in the network not only provides access to the partners' knowledge but also can act as a medium to gain access to the partners' partners knowledge (Gulati and Gargiulo 1999). Previous researchers (Argote and Ingram 2000) found that firms in a network can act as information processing devices. They can process the transferred knowledge from their partners and transfer it to the focal firm. This can be helpful when there is a large technological distance between firms.

Another benefit of being a member of a dense network is the reliability of the information. Since firms receiving the same knowledge from different resources may do triangulation to make sure that the transferred knowledge is reliable, density can increase the absorptive capacity of a firm which will provide the opportunity for radical innovation. Based on this and drawing from the perspective of network closure (Coleman 1988) and embeddedness (Uzzi 1997) it is proposed that network density will increase the chance of radical innovation.

However, high density networks and over-embeddedness (Uzzi 1997) may have a negative effect on innovation. High density may cause redundant information transfer from partners to the focal firm. In an ego network with high density, network members interact mostly with partners inside the network and they will not identify the changes outside their network (Srivastava 2007). The effects of indirect ties will be diminished since companies already know that the knowledge from indirect ties will be almost the same as the knowledge from the direct ties. As a result the opportunities for novel combination will decrease (Gilsing *et al.* 2008). At this stage the advantages of structural trust will be diminished by lack of diversity of knowledge in the network. High interconnectedness decreases the diversity of knowledge that is being accessed by the focal firm (Burt 1992, Uzzi 1997) and therefore decreases the chance of novelty creation.

Another argument against density is unwanted knowledge spill-over to the partners (Gilsing *et al.* 2008). This will limit the opportunities of novelty creation and make firms less inclined to look for such novelty in their network (Gilsing and Nooteboom 2005). Therefore, the following hypothesis is proposed:

Hypothesis 2: Radical innovation performance has an inverse U-shaped relationship with the network density of a company.

4.3.3. Degree Centrality

Degree centrality is the number of direct partners of a firm in a network. Companies with higher degree centrality have more visibility in the network and are more desirable for networking by other companies (Gulati *et al.* 2002). As a result, a firm with a higher degree centrality can attract more resource rich partners (Gulati 1999). Another benefit of degree centrality is the experience gained in firm cooperation (Gulati *et al.* 2002). Moreover, it increases the abilities of the focal firm to extract value from alliances. The power of endorsement is another benefit of having higher status in the network (Stuart 2000). According to resource dependency theory (Pfeffer and Salancik 1987) the power of endorsement can provide opportunities for the focal firm that are not available to others.

Higher ego network size helps focal firms to receive feedback about their products or services from different perspectives. They will have the opportunity to look at their products/services from different aspects and improve them. Moreover, a higher degree of centrality provides the managers of the focal firm with more opportunities to interact with other managers and access their ways of doing things and different approaches to problem solving.

Although partners can help in innovation performance, Ahuja (2000) reveals that having a higher number of partners is not always better. Entering into an inter-organisational

relationship has costs, risks and benefits (Lechner *et al.* 2006). Costs include time and financial resources in the company. Besides the benefits that they have from an informational perspective, each link requires resources to monitor and utilise the links. Therefore although a higher number of links is important for innovation, the number of links that can be utilised efficiently is limited by the available resources in a company. Based on the above arguments it is proposed that:

Hypothesis 3: Incremental innovation performance has an inverse U-shaped relationship with the degree centrality of a company.

Closeness centrality was not included in the theoretical framework. This network measure only applies to socio-centric network and there is no meaning to measure this in an ego-centric network as closeness centrality of the focal firm to all the altars is the same.

4.4. Relational Properties

4.4.1. Strength of Ties

Configuration of ties (e.g. strength vs. weak) is important since actors can extract various forms of benefits from them (Baker 1990). At the inter-organisational level, Rowley *et al.* (Rowley *et al.* 2000, p. 371) define tie strength between firms as “frequency of interaction between partners and their level of resource commitment to the relationship”. Strong ties are sources of private information and critical resources and increase trust and reciprocity between firms (Gulati *et al.* 2002). Strong ties in contrast to weak ties require a higher level of resource commitment, more frequent interactions and up front resources (Rowley *et al.* 2000). Strong ties enable companies to exchange high quality information and tacit knowledge (Rowley *et al.* 2000). According to learning theory, access to knowledge will increase organisational competencies. Companies establish relations with other companies to access and absorb their knowledge in the organisation. Using strong and

weak ties, companies can access their partners' knowledge and assimilate that knowledge in different processes in the organisation.

In an exploitation environment where firms try to use their current information, technologies, skills and abilities (March 1991), those firms that belong to a network with strong ties are more likely to perform better (Gulati *et al.* 2002). Incremental innovation is an outcome of the exploitation environment and companies use their current abilities and information to make minor changes or extend their current products, processes or services. Although incremental innovation firms are more likely to internalise the core innovation/technology, they still take advantage of their external ties. For example they use this knowledge to improve their current technologies and reduce the production costs. An example of this type of relationship is Toyota's suppliers. They participate in voluntary learning in that they present their current operations and receive advice about how to improve it from other suppliers (Dyer and Nobeoka 2000).

Frequent interactions with network partners and commitment of resources are necessary for building strong ties (Granovetter 1985, Krachardt 1992). They provide rich customised information (Rowley *et al.* 2000) and confirm the opinions of their group members (Julien *et al.* 2004) both of which are vital to refine their current technologies and reduce production costs. According to this, the following hypothesis is proposed:

Hypothesis 4: Incremental innovation performance has a positive relationship with the number of strong ties of a company.

Relying on strong ties may block the focal firm's access to new information about the opportunities in the market (Gulati *et al.* 2002). Capaldo (2007) noted that companies that are locked into a network of strong ties may not be able to react quickly to the market change or benefit from new opportunities and face technological discontinuities. Weak ties bring diversity into the network and provide the members with opportunities to access

novel information. Weak ties are sources of new information and opportunities in the market (Granovetter 1985). They reduce a firm's resource dependence on strong partners (Baker 1990).

Configuration of ties depends on the environment in which firms are situated. In an exploratory environment firms are looking for new knowledge and information, thus strong ties are not helpful. According to the definition, radical innovation is the development of a new product that requires significantly new technologies or ideas that are not in the market or require fundamental changes to the existing market (McDermott and O'Connor 2002). Based on the definition, radical innovation is an outcome of an explorative environment. In contrast to incremental innovation, for radical innovation organisations require information that is novel in the business or in the world. Granovetter (1973) argues that weak ties in the inter-organisational networks are sources of new ideas and changes or innovation in the organisations. Weak ties can not only be a medium for new knowledge from other companies but also can act as a bridge between other social entities and a trigger to mix new ideas that lead to change and innovation (Rothwell 1991). According to the above discussion the following hypothesis is proposed.

Hypothesis 5: Radical innovation performance has a positive relationship with the number of weak ties of a company.

4.4.2. Diversity of Ties

Diversity of ties refers to different types of knowledge transfer ties that connect a focal firm to its partners. Tie diversity will provide the focal firm with complementary resources and opportunities to overcome resource barriers and uncertainties in their business. Innovation is a complicated process and firms require knowledge and resources in different areas to be able to develop or improve new products or services.

Understanding market needs, acquiring knowledge of manufacturing process, technical knowledge of products and access to inputs are necessary for a successful innovation (Srivastava 2007). SMEs are not able to provide all the knowledge that is necessary for innovation alone, so they need to establish different types of relation with other companies. Network theory suggests that inter-organisational relationships provide access to information which makes the opportunity for the organisation to improve its knowledge base beyond what they could achieve alone. This idea is also supported by learning theory, that companies can learn and absorb knowledge from their partners. However, establishing new relationships to access knowledge requires extra resources. According to TCE, companies establish relationships to reduce the acquisition cost of what they require. Therefore it is more reasonable to expand the domain of the relationships that they already have and first try to access the required knowledge through these relationships.

Sammarra and Biggiero (2008) found that in an inter-organisational relationship three different types of knowledge may be transferred. For example the knowledge can be market knowledge, technological knowledge or managerial knowledge. New market knowledge can help firms to find the market niche in their business and address it by developing new products or services. Technological knowledge can help them to make fundamental changes in their products or processes of developing the products. They argued that all three are necessary for successful innovation. According to this argument firms not only have different types of ties with different partners but also they have diversity of ties with a single partner.

Establishing different types of knowledge ties with partners increases the potential for the focal firm to access diverse knowledge through its ego network. This diversity of knowledge in a company's knowledge base is a key ingredient for radical innovation. Furthermore, diversity of ties helps the focal firm to acquire a better perspective and

wholesome development (Srivastava 2007). For instance, manufacturing ties are necessary to focus their innovation efforts on the right product; manufacturing and management ties can help to address the process related and project management uncertainties; R&D ties may provide technological knowledge and therefore together they can enhance the focal firm's abilities to develop radical innovation. According to this, greater diversity of ties can help the focal firm to develop and enhance its ability to generate radical innovations. Therefore it is proposed that:

Hypothesis 6: Radical innovation performance has a positive relationship with the diversity of ties of a company.

4.5. Nodal Properties

4.5.1. Diversity of Nodes

Diversity of nodes refers to the differences in ego network members' abilities such as experience, resources and practices. This has an impact on focal firms' innovation (Kaufmann and Todtling 2000, Kaufmann and Todtling 2001). The value of diverse partners is demonstrated by Kaufman and Todtling (2001). Romjin and Albu (2002) supported Kaufman and Todtling's study in their research on small high-technology firms in the UK. Ego networks with diverse nodes provide the focal firm with access to information and resources in different areas and shed light on different approaches and technologies (Pennings and Harianto 1992). It broadens the firm's understanding and lets the focal firm look at the same topic from different perspectives. Baum *et al.* (2000, p. 270) in this regard suggests that "increasing the number of alliances without considering partner diversity can create inefficient configurations that return less diverse information and capabilities for greater cost than a smaller non-redundant set". Therefore diversity of partners can provide the opportunity for a company to access diverse knowledge and

resources in their ego network. This can also help the focal firm to use various channels to seek different solutions in their business (Laursen and Salter 2006).

Radical innovation needs access to a variety of information and the ability to absorb and combine the knowledge. Diversity of partners increases the chance of a firm to access different knowledge, resources and abilities. Subramaniam and Youndt (2005) suggest that those companies that are exposed to a variety of new knowledge and have access to alternate knowledge domains are influenced in terms of their tendency to transform knowledge. Access to diverse knowledge domains increases the opportunity of finding new ways of solving the existing problems (Rosenkopf and Nerkar 2001). Access to alter with different types of knowledge and resources provides the opportunity for the focal firm to overcome its barriers. Firms in networks with diverse nodes have the opportunity to observe various innovation approaches and their consequences which they can use to improve the quality of their innovation efforts (Beckman and Haunschild 2002). Moreover, having access to a diversity of technologies, practices and approaches generates variety in the organisation (McGrath 2001). This internal variety enhances the creativity of the focal firm (Subramaniam and Youndt 2005) and increases the opportunities to be involved in experimentation. Ahuja and Lampert (2001) suggest that experiment is a key factor for radical innovation and not engaging in experimentation inhibits a company's abilities and creativity to generate radical innovation. From this the following hypothesis is proposed:

Hypothesis 7: Radical innovation performance has a positive relationship with the diversity of partners of a company.

4.6. Innovation Management Practices

Goffin and Mitchell (2010) argue that innovation strategy is at the heart of the innovation management practices which affect and shape all the other innovation management

practices in a company. Previous studies (Cooper *et al.* 1999, Griffin 1997) suggest that companies with high innovation performance have a clear strategy for new product/services that guides the company to develop new products and services. From a networking perspective, innovation strategy guides partnerships with others to explore new opportunities (Goffin and Mitchell 2010). Thus, innovation strategy also affects the networking activities of a company. This means that, for companies that do not have a clear innovation strategy, their networking activities and their partners may not be beneficial to their innovation performance. Companies without a clear innovation strategy waste their resources by establishing relations with partners that are not beneficial for their innovation activities. Therefore innovation strategy guides innovation directly by providing a clear path on a company's innovation activities and indirectly by shaping other innovation management practices and networking activities. Since innovation strategy is a key player in the Pentathlon framework and affects all the other practices the following hypotheses are proposed:

Hypothesis 8a: Incremental innovation performance has a positive relationship with the innovation strategy of a company.

Hypothesis 8b: Radical innovation performance has a positive relationship with the innovation strategy of a company.

Hypothesis 9a: Incremental innovation performance has a positive relationship with the level of idea management of a company.

Hypothesis 9b: Radical innovation performance has a positive relationship with the level of idea management strategy of a company.

Hypothesis 10a: Incremental innovation performance has a positive relationship with the level of portfolio management of a company.

Hypothesis 10b: Radical innovation performance has a positive relationship with the level of portfolio management of a company.

Hypothesis 11a: Incremental innovation performance has a positive relationship with the procedures for implementation of ideas of a company.

Hypothesis 11b: Radical innovation performance has a positive relationship with the procedures for implementation of ideas of a company.

Hypothesis 12a: Incremental innovation performance has a positive relationship with the level of human resource management of a company.

Hypothesis 12b: Radical innovation performance has a positive relationship with the level of human resource management of a company.

Table 4.1 presents the list of hypotheses and the dependent and independent constructs for each hypothesis.

Figure 4.2 illustrates the theoretical framework of the study which is based on the developed hypotheses. This figure represents the constructs of the study and how they are related to each other based on the hypotheses. As shown in the model diversity of ties, betweenness centrality, density, weak ties, diversity of ties and innovation strategy are proposed to be related to radical innovation performance. Strong ties, degree centrality and innovation strategy are also proposed to be related to incremental innovation performance. Innovation strategy, idea management portfolio management, implementation and human resources management are proposed to be related to both radical and incremental innovation.

Table 4.1: Summary of the hypotheses, dependent and independent variables

#	Hypothesis Statement	Dependent Construct	Independent Construct
1	Radical innovation performance has an inverse U-shaped relationship with betweenness centrality of a company	Radical Innovation	Betweenness Centrality
2	Radical innovation performance has an inverse U-shaped relationship with network density of a company	Radical Innovation	Density
3	Incremental innovation performance has an inverse U-shaped relationship with degree centrality of a company	Incremental Innovation	Degree Centrality
4	Incremental innovation performance has a relationship with number of string ties of a company	Incremental Innovation	Number of Strong Ties
5	Radical innovation performance has a positive relationship with number of weak ties of a company	Radical Innovation	Number of Weak Ties
6	Radical innovation performance has a positive relationship with diversity of ties of a company	Radical Innovation	Diversity of Ties
7	Radical innovation performance has a positive relationship with diversity of partners of a company	Radical Innovation	Diversity of Nodes
8a	Incremental innovation performance has a positive relationship with innovation strategy of a company	Incremental Innovation	Innovation Strategy
8b	Radical innovation performance has a positive relationship with innovation strategy of a company	Radical Innovation	Innovation Strategy
9a	Incremental innovation performance has a positive relationship with the level of idea management of a company	Incremental Innovation	Idea Management
9b	Radical innovation performance has a positive relationship with the level of idea management strategy of a company	Radical Innovation	Idea Management
10a	Incremental innovation performance has a positive relationship with the level of portfolio management of a company	Incremental Innovation	Portfolio Selection
10b	Radical innovation performance has a positive relationship with the level of portfolio management of a company	Radical Innovation	Portfolio Selection
11a	Incremental innovation performance has a positive relationship with procedures for implementation of ideas of a company	Incremental Innovation	Implementation
11b	Radical innovation performance has a positive relationship with procedures for implementation of ideas of a company	Radical Innovation	Implementation
12a	Incremental innovation performance has a positive relationship with the level of human resource management of a company	Incremental Innovation	Human Resource Management
12b	Radical innovation performance has a positive relationship with the level of human resource management of a company	Radical Innovation	Human Resource Management

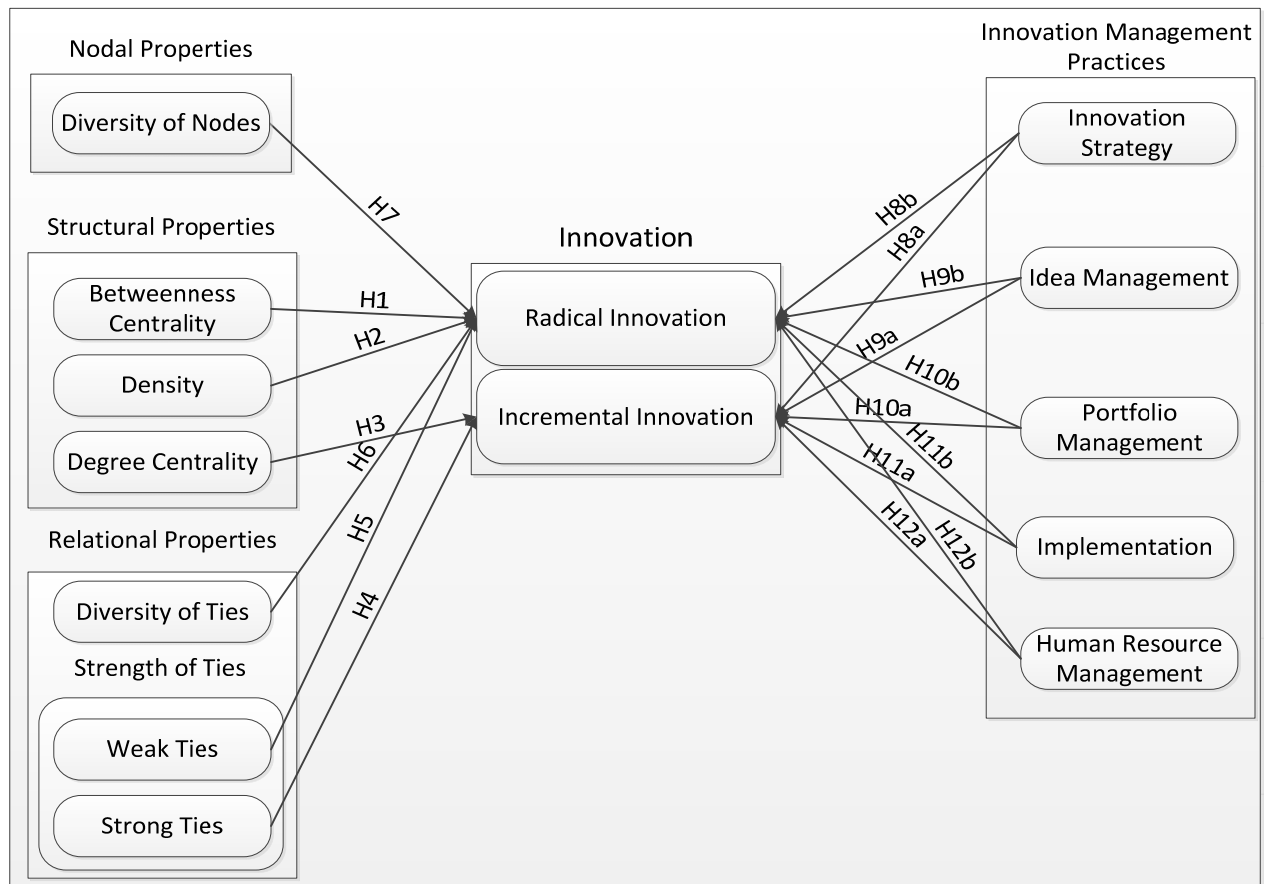


Figure 4.2: Theoretical framework of the study

4.7. Measures

Different methods have been employed to operationalise and calculate the dependent, independent and control variables of the study. In the following section each method is explained in detail.

4.7.1. Dependent Variables

Radical and incremental innovations are the dependent variables of the study. A new instrument has been developed to measure these two constructs. The detail of the scale development is provided in the next chapter under 'Scale Development'. Respondents were asked to rate the questions compared to similar companies in the same sector (1: much weaker to 5: much stronger). According to a pilot study it was easier for managers

to use this scale to answer the questions (compared to asking the number of innovations they had). Moreover, since respondents are comparing themselves with their competitors, it is possible to study the innovation performance of the companies in different industries. Another benefit of using this measure is that companies in some sectors do not need to be as innovative as the companies in other sectors. Therefore it is not appropriate to compare their innovation outputs with companies in other industries. The new scale will address this issue by measuring the innovation performance of companies compared to their competitors in the same sector. In fact the new scale is asking how good they are in their industry.

4.7.2. Independent Variable

In the following section the detail of how each measure was calculated is explained.

4.7.2.1. Betweenness Centrality

According to the theoretical framework the betweenness centrality for the sociocentric network (whole network) needs to be measured. However, the collected data will be the egocentric network, which cannot be measured for betweenness centrality according to Freeman's definition. Marsden (2002) argues that when it is not practical to collect sociocentric data, betweenness measure using egocentric data could be a consistent measure for Freeman's betweenness measure. Moreover, Everett and Borgatti (2005) in their investigation found that ego betweenness is highly correlated with betweenness of the actor in a complete network. According to these arguments although the betweenness centrality for an egocentric network will be lower than the betweenness centrality in the sociocentric it is still possible to use this measure to study the relations between this network construct and the innovation performance. To calculate the betweenness centrality, the method by Everett and Borgatti (2005) was followed. For example A is the adjacency matrix for one of the company's networks. Calculating $A^2[1 - A]_{ij}$, where 1 is

the matrix of all 1's, gives the number of geodesics of length two. Betweenness centrality is the sum of the reciprocal values of the entries.

$$A = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \end{bmatrix} \implies A^2[1 - A] = \begin{bmatrix} * & * & * & * & * \\ * & * & * & 2 & * \\ * & * & * & * & 2 \\ * & * & * & * & 2 \\ * & * & * & * & 2 \end{bmatrix}$$

In the above example the betweenness centrality is $\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = 2$.

4.7.2.2. Ego Network Density

As mentioned in the literature review there are two measures for density: local density and global density. In this research the local density measure was used because the theories underlying the hypothesis are closer to the ego network. The underlying theory for the density hypothesis is Coleman's (1988) closure argument (this has been explained in Chapter 3) which is consistent with local density measure.

Information about the partners and the relation between them were used to calculate density. In order to calculate the density of the ego network the approach suggested by Scott (2000) was adopted. In an egocentric network it is usual to eliminate the ego and all the ties related to the ego. It means that just the relation among partners will be considered for the density. According to this approach the density of the ego network will be the number of existing ties among partners of the ego, divided by the total number of possible ties among the partners.

$$Density = \frac{2l}{n(n-1)}$$

Where n is the number of partners and l is the number of ties between partners.

4.7.2.3. Degree Centrality

Ego network size or degree centrality is measured as the number of alters which are directly connected to the ego (Freeman 1979, Marsden 2002). For ego network degree centrality is $N-1$, where N is the number of nodes in the network.

4.7.2.4. Strength of Ties

According to the literature review strength of ties is a construct with the following dimensions: amount of time, emotional intensity, intimacy, and reciprocal services that characterise the relationships. Two important points about this measure are that: first, there is no study that measures all the dimensions simultaneously and second, these dimensions are developed for the relation between individuals. Previous studies aimed to measure one or two dimensions at the same time for their purpose. For example Rowley *et al.* (2000) adopted Contractor and Lorange's (1988) classification for alliance types and divided these alliance types into two groups: weak ties and strong ties. The logic behind this classification is the amount of time and resource commitment for each strong and weak tie. Relations in the strong tie category, in addition to higher level of resource commitment, require more frequent interactions and up front resources (Rowley *et al.* 2000). On the other hand alliances in the weak tie category need less resource commitment and less frequent relations (Rowley *et al.* 2000). Frequency and closeness are usually measured together as a proxy for tie strength. However, these two measures are often highly correlated, suggesting that they are measuring the same underlying construct (Hansen 1999). In addition to that, in other studies (DiMaggio and Louch 1998, Uzzi 1996, Uzzi 1997) frequency has been shown to predict results such as joint problem solving, knowledge sharing and altruism. In this study tie strength is measured using the definition by Gulati *et al.* (2002). They defined strong ties as a network tie that connects a focal firm to another firm and they have an intensive interaction with each other. In

contrast a weak tie connects a focal firm to its partners in which they have very few interactions with each other. According to this definition frequency criteria were used to measure the strength of ties. Companies were asked about the frequency of their relationships with each of the partners. Ties with daily and weekly contacts are strong ties and ties with monthly and quarterly contacts are considered weak ties. A similar approach has been used in the study of Ouimet *et al.* (2004).

4.7.2.5. Diversity of Nodes

Diversity of nodes refers to the difference between partners' abilities like resources, knowledge, experience etc. To calculate the diversity of nodes (partners), a method by Laursen and Salter (2006) was adapted. They identified 16 different sources of information and knowledge for innovation activities and classified them into four categories.

Table 4.2: Sources of innovation and knowledge for innovation activities (Laursen and Salter 2006)

Type	Knowledge source
Market	Supplier of equipment, material, component, or software Clients or customers Competitors Consultants Commercial laboratories/R&D enterprises
Institutional	Universities or other higher education institutes Government research organisations Other public sector, e.g., business links, government offices Private research institutes
Other	Professional conferences, meetings Trade associations Technical/trade press, computer databases Fairs, exhibitions
Specialised	Technical standards Health and safety standards and regulations Environment standards and regulations

Table 4.2 shows each category and types of knowledge sources that belong to each category. They counted the number of resources that each company uses as sources of

information and used it as their measure for the firms' search breadth. For this study companies were asked about the main business of their partner and type of partner (supplier, customer, competitor, etc.). Using this information and the classification by Laursen and Salter the number of unique resources that they were using was calculated as the diversity of nodes.

4.7.2.6. Diversity of Ties

According to the theoretical framework, diversity of ties refers to different types of knowledge transfer relationships that a company has with its partners. Companies were asked about the types of knowledge that they have transferred with their partners. For the diversity of ties, the number of ties that have been used to transfer unique types of knowledge was counted. This method is similar to the method that Beckman and Haunschild (2002) developed to measure network multiplexity except they considered types of relations (e.g. alliance and interlock) but here the types of knowledge were counted (e.g. training, market, technology).

4.7.2.7. Innovation Management practices

Questions developed by Oke (2007) were adopted to measure the concepts in the Pentathlon framework (innovation strategy, human resource management, implementation, selection, creativity and idea management). Please see appendix A for more details.

4.7.3. Control Variables

In order to examine the effect of the theorised variable on radical and incremental innovation, the effects of the following variables have been controlled. The control variables are company age, company size, R&D intensity, employees' education and industry sector. These variables are identified based on prior literature and they control

for the firm level differences that may account for differential abilities on different types of innovation performance.

4.7.3.1. Company Age

Company age is one of the factors that prior studies suggest may influence the innovation performance of a company (Sørensen and Stuart 2000). Older companies are better at exploitation and younger organisations are better in explorations (Gilsing *et al.* 2008). Company age was calculated as the number of years the company has been in business.

4.7.3.2. Company Size

Firm size has been measured as the total number of employees (Ahuja and Lampert 2001).

4.7.3.3. R&D Intensity

R&D expenditure is one of the key factors that affects the innovation performance of a company (Kortum 1993). R&D intensity is the emphasis that a focal firm places on R&D. Respondents were asked about their total sales and the proportion of total sales invested in their R&D. R&D intensity was measured by dividing R&D investment by the number of employees in the company. To reduce the effect of outliers in the data, the natural logarithm of the R&D intensity was used in the analysis.

4.7.3.4. Employee Education

Employees' education is expected to increase the absorptive capacity of companies. Absorptive capacity is crucial to acquire and integrate the transferred knowledge to the company. Here it is calculated as the proportion of all employees that hold a degree (e.g. BSc, MSc, MPhil or PhD).

Table 4.3: Summary of the variables and their definitions

Variables		Description
Dependent Variables		
1	Incremental Innovation	Minor changes and extensions to the current products/services/processes
2	Radical Innovation	New products/services/processes not existing before or requiring fundamental changes to the existing market
Independent Variables		
1	Strong Ties	Intensive interactions between partners
2	Weak Ties	Very few interactions between partners
3	Density	Number of existing ties among partners of the ego, divided by the total number of possible ties among the partners
4	Betweenness Centrality	The fraction of the shortest paths of knowledge transfer between partners that pass through the focal firm
5	Ego Network Size	Number of partners
6	Diversity of Ties	Different types of knowledge being transferred between partners
7	Diversity of Nodes	differences in focal firm's partners' abilities such as experience, resources and practices
8	Innovation Strategy	There is a well-defined innovation strategy in the organisation
9	Idea Management	There are procedures to collect ideas in the organisation
10	Portfolio Selection	There are procedures to select from the collected ideas
11	Implementation	There are procedures to implement selected ideas
12	Human Resource Management	There are procedures to address people and organisational climate issues.
Control Variables		
1	Company Age	Number of years in business
2	Company Size	Number of employees
3	R&D Intensity	R&D investment divided by the number of employees in the company (natural logarithm then taken)
4	Employee Education	Proportion of employees that hold a degree
5	Industry Sector	Nominal variable to control for the industry effect

4.7.3.5. Industry Sector

Lane and Lubatkin (1998) argued that exchange process, knowledge acquisition, and relationship outcomes vary by industry sector. Industry sector is a nominal variable to control the industry effect.

Table 4.3 shows the summary of the concepts that have been used in the hypotheses development and their definitions.

4.8. Summary

This chapter started by proposing the underpinning theoretical framework of the study. To answer the research question twelve hypotheses were developed based on the concepts and arguments reviewed in previous chapters. Also the theoretical framework of the study has been designed according to the developed hypotheses. In order to test the hypotheses, dependent variables, independent variables and control variables were identified and explained. The last part of the chapter provided the explanation of how the constructs are observed as variables and operationalised empirically by measurement.

The chapters so far have provided the necessary foundation to examine the research question of the study. In the next chapter the methodology for data collection, questionnaire design, implementation of the research and data analysis methods are explained.

5. Chapter 5: Research Methodology

5.1. Introduction

This chapter begins by providing an overview of different research philosophies and justification for the chosen research philosophy of this study. Next, the decision between qualitative and quantitative study is made and the research design of the study is explained. Steps that have been taken to design the questionnaire including validity and reliability are discussed. The details of a pilot study and design of a new measurement instrument for radical and incremental innovation are described. Next, the study design, sample selection, sample size and data collection is presented. Finally, a brief explanation of the analytic tools used for data analysis is provided.

5.2. Research Philosophies

Before discussing the research method of the study it is necessary to distinguish the research paradigm that is applicable to this research. Guba and Lincoln (1994, p. 105) mention that “Questions of method are secondary to questions of paradigm, which we define as the basic belief system or world view that guides the investigation, not only in choices of methods but in ontologically and epistemologically fundamental ways”. Orlikowski and Baroudi (1991) identify three paradigms in research: positivist, interpretivist and critical. They establish their work on Chua’s (1986, p. 604) three sets of philosophical beliefs: ontology, epistemology and the relationship between knowledge and the empirical world. These beliefs “delineate a way of seeing and researching the worlds” (Chua 1986, p. 604). First a general explanation of the philosophical beliefs is provided and then each paradigm is explained based on these beliefs.

Ontological assumptions: ontological assumptions are concerned with the essence of the phenomena under investigation and how the world operates (Orlikowski and Baroudi 1991). Objectivism and subjectivism are two aspects of ontology (Saunders *et al.* 2007). Objectivism portrays the existence of the empirical world as independent from humans. On the other hand subjectivism understands the empirical world as a consequence of the actions of social actors.

Epistemological assumptions: epistemology is about what the valid knowledge is in a field of study (Saunders *et al.* 2007). For example in a positivist paradigm an acceptable and true theory is not falsified by testing it with different empirical events (Chua 1986).

Relationship between knowledge and the empirical world: this belief is concerned with the relationship between theory and practice (Orlikowski and Baroudi 1991). It looks at the bigger picture or the goal of the research and the researcher: what the researcher is intending to achieve with this research and what he/she thinks is appropriate to achieve with this research.

Validated and reliable methods are favoured in a positivist paradigm in order to describe and control phenomena in a relatively objective way (Plack 2005). Interpretivism aims to understand the complexity of social phenomena. This paradigm attempts to understand the complex meanings in social life and the reasons behind people's actions (Orlikowski and Baroudi 1991). Researchers with a critical approach aim to use the research findings to make improvements in the context of the study. Despite the other two paradigms, which aim mainly to predict or explain the current situation, the critical paradigm is concerned about relationships in social systems and tries to reveal any conflicts that may exist in their structure. This research is embedded in the positivist paradigm. It aims to discover the effect of the inter-organisational relationships on innovation.

In terms of ontological assumption, positivists argue that reality is objective and it is independent of humans. They also describe reality objectively which doesn't need a human interpretation. In order to understand a phenomenon in this paradigm the researcher has to develop appropriate constructs and instruments to capture the principle of the phenomena. The researcher is a passive actor in this paradigm and does not get involved in the phenomena (Orlikowski and Baroudi 1991). In the critical paradigm reality is shaped over time by different social forces such as human beings, organisations and societies. These social forces are not limited to existing in particular states; they are being created over time. From an interpretivist perspective, reality is subjective and depends on the context in which it is being studied. In this perspective the social world is being made by humans' actions and reactions (Orlikowski and Baroudi 1991). Besides positivists, where the researcher discovers an objective reality, interpretivists believe that social reality can only be interpreted. The nature of this thesis is to discover the relationship between inter-organisational relationships and innovation. Therefore it is related to the positivist's ontological assumptions.

Regarding the epistemological assumptions, positivists are concerned with the empirical testability of theories. They use hypothetic-deductive theory testing to verify or falsify hypotheses. Interpretivists believe that hypothetical deduction and statistical methods are not appropriate for understanding social processes. Instead, the researcher has to interact with the social world to be able to understand it. In the critical perspective, researchers believe that knowledge is embedded in social and historical practices (Chua 1986) and they are involved with those being researched. This study is grounded on positivists' epistemological assumptions since it involves theory testing through hypotheses development. A theoretical framework has been developed based on the literature and contains twelve hypotheses.

In terms of the relationship between theory and practice, positivists believe that with given general laws and manipulable conditions it is possible to produce a desired result. In contrast, interpretivists believe that the researcher is always part of the phenomena that are being studied and their prior beliefs, knowledge and assumptions will affect their investigations. A critical research paradigm employs theory to increase awareness and improve the current situation. Benson (1983) argues that critical researchers have to go beyond studying and theorising, they have to effect the change in the phenomena that are being studied. The relationship between theory and practice in this thesis is based on a positivist's beliefs since it aims to investigate a causal relationship and examines the outcomes in a specified condition.

5.3. Research Strategy

After identifying the research paradigm of the study, the next major concern is the decision between qualitative and quantitative approaches. In order to distinguish the appropriate research strategy it is necessary to identify the principal orientation to the role of theory in relation to the research.

Bryman (2008) classifies this as deductive and inductive theory. In deductive theory, the researcher uses the current knowledge and theoretical consideration on a specific domain to develop hypotheses which should be tested empirically. After deducing the hypotheses, the researcher has to translate them to researchable entities and operational terms in which data will be collected based on these concepts. In contrast to deductive, the inductive process starts with observation and then the theory will be drawn based on the outcome of the observation. Although the process for both deductive and inductive seems sequential the last step for both of them involves a movement in the opposite direction (Bryman 2008). For deduction this happens when the researcher infers the theoretical implication of the findings and for induction it happens when the theoretical reflection on

data has been carried out and the researcher wants to collect more data to find the situations that theory will or will not hold.

Now that the role of theory in relation to research is clarified, it is easier to identify the appropriate research strategy. Qualitative research involves in-depth examination of a relatively small number of cases, examining cases in detail by employing techniques that are designed to enable clarification of theoretical concepts based on empirical data (Ragin 1994). On the other hand, quantitative strategy is mainly about measurable issues where analysis of these measures leads to a conclusion based on variables. Table 5.1 shows the fundamental differences between a qualitative and quantitative research strategy based on epistemology, ontology and the relation between theory and research.

Table 5.1: Differences between qualitative and quantitative strategies (Source: Bryman (2008, p. 22))

	Quantitative	Qualitative
Principal orientation to the role of theory in relation to research	Deductive: testing of theory	Inductive: generation of theory
Epistemological orientation	Natural science model, in particular positivism	Interpretivism
Ontological assumption	Objectivism	Constructionism

This research is a deductive theory testing study since it involves reviewing the current knowledge in a particular domain (innovation, inter-organisational knowledge transfer and social network) and deducing hypotheses based on this knowledge. Moreover, it is necessary to interpret the hypotheses into researchable entities, collect the empirical data based on these concepts and test the hypotheses. Based on this argument (deductive research) and the research paradigms in the previous part (positivist research paradigm) a quantitative strategy is the appropriate research strategy for this study.

5.4. Research Design

The main steps in the process of quantitative research are: Theory (literature review), hypothesis, research design (including developing measures based on the concepts, location selection, select research respondents), data collection, process and data analysis, findings and write up (Bryman 2008). Research design is the step before the actual implementation of the study and it involves preparing a detailed plan of the method that will be used in the research. A survey method has been adopted for the data collection since it is the usual means of collecting empirical data in quantitative studies (Saunders *et al.* 2007). Structured interview and self-completion questionnaire are the two main modes of administering a survey (Bryman 2008).

In the following sections each of the five stages of the research design (location selection, survey method, respondent's selection, questionnaire design and pilot study) will be explained in detail. A pilot study was conducted to test and revise the questionnaire before collecting the main data.

5.4.1. Survey Method

The most widely used modes of survey administration are interview (face-to-face, telephone) and self-completion questionnaire (supervised, postal, internet). The main advantages of interviews are: higher response rate, control of interview situation, collection of detailed information and the ability to clarify and use open ended questions. The disadvantages are: the high cost, time consuming for implementation and inaccessibility to interviewees (Frankfort-Nachmias and Nachmias 1996). On the other hand the advantages of using questionnaires are: low cost, completion at respondents' convenience, possibility of anonymity and removal of interviewer bias, and applicable to geographically dispersed population. The disadvantages are: low response rate, low control of the situation, and time taken for returning the questionnaire that needs greater

persistence. Also, respondents are unable to seek clarification and it is difficult to collect detailed information (Frankfort-Nachmias and Nachmias 1996).

While the interview mode seems to have the advantage of higher response rate it is not practical in the context of this research due to the geographically dispersed population, interviewer bias and the need for a large number of respondents. Therefore, based on cost and time, it was decided that the research would be conducted using a self-completion questionnaire. The drop and collect method was not practical again due to the geographically dispersed population. Therefore postal and web questionnaires were adopted to collect the empirical data of the study. In order to address the low response rate problem in the questionnaire method, Dillman's (2007) tailored design method was adopted. The detail of the method will be explained in the next sections.

5.4.2. Questionnaire Design

In the questionnaire design stage, there are many factors that should be taken into account in order to increase the response rate and collect the correct information. Overall presentation is one of these factors that plays a significant role in the response rate. Aspects of presentation include: length, number of questions, user friendliness, ticking versus circling, name of the researcher, anonymity, deadlines, type of outgoing postage, type of return envelope, pre-contacts, follow-ups, offer of results, personalisation, topic interest, auspices of survey, and numerous types of incentives (Dillman 2007). All these techniques were built into the design of this questionnaire. Respondents were asked to tick responses, cover letters were addressed to the person, a paid return envelope was enclosed and cover letters were printed on university headed paper (See the appendix B.2 for the covering letter of the survey). The covering letter included a number of essential sections, such as an explanation of the purpose of the survey and its usefulness, incentive of a free report of the survey, the importance of their response, and guarantees of anonymity and confidentiality of the responses.

To increase the response rate Dillman's (2007) Tailored Design Method (TDM) was adopted in designing the self-completion questionnaire. The TDM approach is a holistic design method that provides detailed guidance for every single step of the design and data collection including structuring of the questionnaire to the wording and timing of the cover and follow-up letters. Table 5.2 reports a summary of the steps and a list of tasks that need to be done in each step. Dillman (2007) suggests that the layout of the questionnaire encourages the response. The following factors were considered for the layout of the questionnaire:

Numbering, formatting, ordering, cover and last page design: cover of the questionnaire included a short title (The Survey for Innovation Performance of SMEs) and information about the researcher and institute. An image related to innovation was added on the cover to encourage the respondent to read the rest of the questionnaire and give an idea about the topic of the study. An identification number was assigned to each questionnaire for anonymity and follow-up purposes. The first version of the questionnaire (Appendix C.1) was prepared and used for the pilot study. After this step the questionnaire was redesigned into a booklet (Appendix C.2). A booklet format was selected not only because they look more professional and well-organised, but also they are easy to follow and the pages will more likely stay together (Bradburn *et al.* 2004, Dillman 2007).

The final version of the questionnaire developed for this study included 23 main questions. Related questions were grouped on the same page and ordered based on the importance in the study. In the last version of the questionnaire the first set of questions were about performance and absorptive capacity of the company. Then the respondents were asked about their radical, incremental, innovation performance and innovation management practices. The last set of questions was the social network questions.

Table 5.2: Summary of the elements of the Tailored Design Method

	Steps	Tasks	Description
1	Writing questions	<ul style="list-style-type: none"> a. Which question structure is most appropriate? b. Principles for writing survey questions 	Includes guidelines on different types of measurements and writing questions.
2	Constructing the questionnaire	<ul style="list-style-type: none"> a. Criteria for design b. Questionnaire formats (booklets, ..) c. Criteria for ordering the questions d. Principles for constructing questionnaire pages e. Questionnaire cover page f. Designing back cover g. Pretesting 	Focuses on questionnaire construction including order of the questions, layout and conducting a pilot test.
3	Survey Implementation	<ul style="list-style-type: none"> a. Respondent friendly questionnaire b. Four contacts by first class mail, with an additional special contact c. Return envelope d. Personalisation of correspondence e. Incentives 	Includes methods of increasing response rate and reducing non-response error.
4	Reduction of Coverage and Sampling Errors	<ul style="list-style-type: none"> a. Reducing coverage error b. Sampling method 	Guidelines on coverage and sampling issues

Choice of first question: The first question of the questionnaire is very important since it encourages the respondent to answer the rest of the questionnaire. The first question should be easy to answer, apply to all respondents, easy to read and understand (Dillman 2007). The questionnaire started by asking the main products and services of the company and continued with questions about age and performance.

The web-based questionnaire followed the same layout and considerations as the paper-based questionnaire (Appendix C.3). The web-based questionnaire was designed using SNAP 10 (professional software for questionnaire design) and uploaded on a web-host provided by the university.

5.4.3. Validity and Reliability

In a positivist paradigm the main purpose of scientific research is discovering the law which makes it possible to predict and interpret phenomena. Therefore the quality (validity and reliability) of the instrument that is being used to collect the data for this purpose is significant. Validity of a scale means that the researcher is measuring the concept that is intended to be measured (Kogovšek and Ferligoj 2005). On the other hand, reliability refers to the ability to obtain the same score as many times as a concept is being measured with the assumption that the real score of the concept does not change (Kogovšek and Ferligoj 2005). The procedure for assessing reliability of the measures is explained in the next chapter in the discussion of the procedure for establishing the measurement model and structural model.

5.4.3.1. Validity

There are two types of validity that need to be dealt with in this section: face validity and content validity. Face validity ensures that the designed questions reflect the content of the construct. Face validity can be established by asking experts in the field to judge

whether the questions are related to the concept that is the focus of attention. Content validity is whether the measure addresses all aspects of the underlying construct.

Face Validity: The guidelines by Hardesty and Bearden (2004) were followed to ensure the face validity of the measures.

- All the measures were developed based on a strong theoretical background with careful attention to the definition of each construct.
- The measures were developed based on the relevant measures that have already been tested in relevant literature, i.e. innovation literature for radical, incremental and innovation management measures, social network and inter-organisational literature for network related measures, strategic management and organisational performance literature for performance construct.
- An expert review of the questionnaire is recommended (DeVellis 1991) to help ensure the face validity. The complete questionnaire was sent to three experts in the field. Some recommendations regarding the wording of the questions, removing some duplicate items and the layout of the questionnaire were applied after their review.

Content Validity: face validity is important but not enough for ensuring the validity of the constructs. All the constructs in the questionnaire should pass content validity, convergent validity, criterion validity and discriminant validity tests. The last three tests will be conducted in the next chapter.

Content validity is used to ensure the designed measure represents the entire domain of the construct (Hardesty and Bearden 2004). Content validity in this research was addressed by identifying all aspects of the construct domain through reviewing extant literature in the area. Different facts of each construct domain were identified and

included in the questionnaire subject which contributed to “unique and useful information” (Ironson *et al.* 1989, p. 199).

5.4.4. Language

Language is important to help respondents to understand the question and be able to answer it correctly (DeVellis 1991). Through the questionnaire design words that the respondent can clearly and easily understand were used. Also for those questions that include some words that respondents may not be familiar with, a simple definition was provided just before the question. Detailed guidelines were provided at the beginning of the questionnaire and where it was necessary. The language was tested during both pilot interviews and the expert review of the questionnaire and some changes were made to make the questionnaire clearer and easier to respond to.

5.4.5. Questionnaire Structure

As mentioned before, survey is the main method for collecting empirical data. The questionnaire was designed according to the hypotheses, variables, measures and previous literature. During the design of the questionnaire the instruments that had previously been tested in other research were used, adopting them according to the requirements of this study.

Table 5.3: General business information survey items

1	What are the main services/products offered by your company?
2	How long has your company been in business?
3	How many employees do you have?
4	How much did you invest in your internal R&D in 2009?
5	How much were your total sales in 2009?
6	For the employees of your company please ESTIMATE the proportion that hold a degree, e.g. BA/BSc, or higher degree, e.g. MA/PhD:

The questionnaire consists of four main parts. The covering letter is the first part of the questionnaire. It explains the purposes of the study and confidentiality of the data (Appendix C.1). The next section (Section A: General Business Information) collects information about company profile which also includes some of the control variables (e.g. annual turnover, R&D investment, number of employees). Table 5.3 represents the questionnaire items for this section.

Table 5.4: Incremental and radical innovation survey items (Darroch and Jardine 2002)

Incremental Innovation	
1	We improve or revise existing products or services
2	We add new products or services to our existing ranges
3	We introduce new ranges of products or services not previously offered by this company
4	We reposition existing products or services
5	We change the way we make or deliver products or services
Radical innovation	
6	We develop products or services that offer greater advantages to customers than any other product or service currently available
7	We develop products or services that better meet the needs of customers than any other product or service currently available
8	We have launched products or services that are the first of their kind in the world
9	We develop products or services that require customers to substantially alter their behaviour

Section B (Product, Service and Process Innovation) contains questions about the dependent variables of the study. This part of the questionnaire begins with an innovation definition and then continues with questions about different types of innovations. Questions in this section were based on the research by Darroch and Jardin (2002). This

measure was adopted due to its ability in measuring different types of innovation from a consumer and company perspective. The importance of considering these two perspectives in measuring different types of innovation was discussed in Chapter 1. Interviewees had to indicate how many times they had undertaken each action in their company during the last year (1 = never, 2= rarely (1 or 2 times), 3 = sometimes (3 to 5 times), 4 = frequently (6 to 10 times), and 5= very frequently (more than 10 times)). Table 5.4 shows the questionnaire items of incremental and radical innovation.

Table 5.5: Social network structure survey items

1	Please write the name of the companies, universities, institutes or laboratories that you have had an inter-organisational relationship with in 2009. If it is not possible to provide the real name of your partners you can write Firm A, Firm B and so on in each row.
2	For each of the companies you have provided please fill in the rest of the table according to the following guidelines.
3	a. Business type: what is their main business? (consultancy, university...)
4	b. Formal/informal: The relation with your partner is formal (e.g. formal alliance, partnership, joint venture or etc.) or informal.
5	c. Type of the knowledge: Companies in their relationship usually transfer different types of knowledge e.g. technological knowledge, managerial knowledge, market knowledge, R&D knowledge etc. Please specify what types of knowledge your partners transfer to you.
6	d. How often do you make contact with this company? (e.g. Once in a week, more than once in a week, once in a month, once in a year).
7	e. How long have you been in a knowledge transfer relationship with this company? (e.g. 5 years, 10 months).
8	f. Where is your partner located? (local, regional, national, international)
9	g. Medium: What kind of medium do you use mainly for your communications with this firm? (e.g. email, face to face, telephone, video conference, ...)
10	Please write the name of your partners in the first column and first row of the following table. Please report to the best of your knowledge which of your partners know one other? (For example if firm A has relations with firm B please mark the related cell).

Section C collects information about the network structure of the organisation and its partners. The beginning of the section is the definition of the inter-organisational relationships and it continues with questions about network structure. ‘Name interpreter’ was employed to elicit and identify partners. In the first version of the questionnaire respondents were asked to write the name of their partners they had an inter-organisational relationship with in 2009.

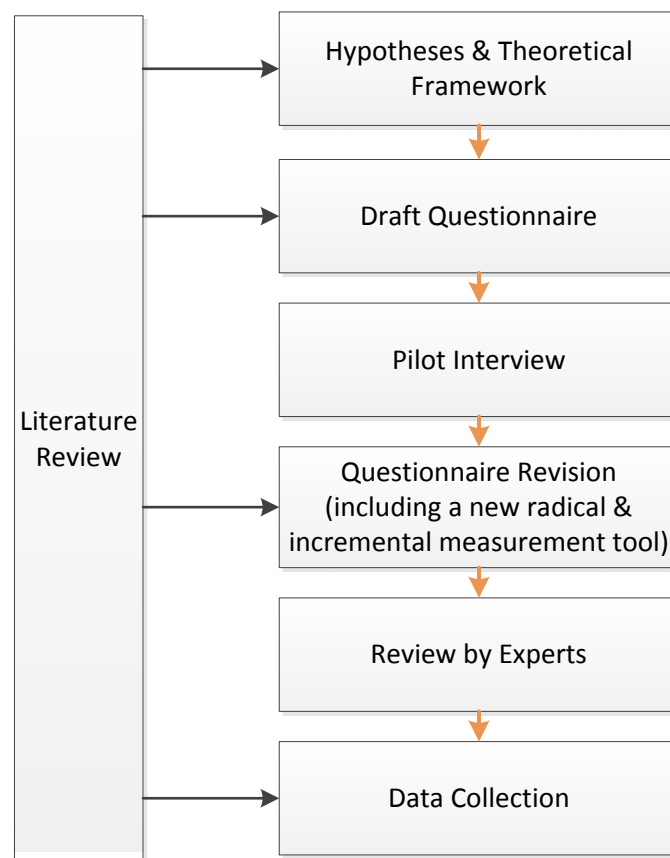


Figure 5.1: Stages of the questionnaire design

This will elicit a list of uniquely identified partners. Then the ‘name interpreter’ questions were asked. These are questions that the respondent should answer for each partner separately. This part of the questionnaire consists of two sections: Section one collects data on all the network structures except the relation between partners. Section two gathers data on the relation between partners. Data from this part together with the

previous part was used to calculate the betweenness centrality of the focal firm and the local density of the network. Table 5.5 represents the questionnaire items of this section.

Figure 5.1 illustrates the different stages that have been taken to design and test the questionnaire before the main data collection stage.

5.4.6. Pilot Study

After preparing the first version of the questionnaire (Appendix C.1) a pilot study was conducted. The main objectives of the pilot study were to:

- test the developed questionnaire
- ensure the validity and reliability of the data that is going to be collected
- better understand inter-organisational relationship and knowledge transfer in the real world
- identify other important factors that contribute to the firm's innovation performance

To address the objectives of the pilot study, as mentioned before, three experts in academia reviewed the questionnaire and provided comments about the structure and some of the constructs in the questionnaire.

The next step was choosing companies for pilot interviews. A list of 40 SMEs was prepared from the Gibson-Index database (UK's comprehensive SMEs database) with 'Innovation' as the search keyword and Bedfordshire as the location. Five SMEs were chosen randomly for the interview. The interviews took 40 minutes on average and consisted of two parts. The first part was testing the questionnaire, in which interviewees were asked to answer the questions and provide comments if they have any problem in answering the questions.

The second part of the interview was answering the interview questions. The questions in the second part were designed in a way to understand what other factors contribute to different types of innovation, what managers think about different types of innovation, its usefulness in their business, the barriers for them for being innovative and questions about some of the social network characteristics. The reason for asking questions about network properties was finding some evidence to support the hypotheses (for the interview protocol and interview questions see appendix D.1 and appendix D.2).

In the following section the results of the interview analysis are explained. The first part of this section is about the changes that have been made to the questionnaire after the interview. Afterwards the result of the analysis of the interviews is explained. In the second part, thematic analysis has been used to find barriers and resources for innovation and some preliminary evidence that supports the developed hypotheses.

5.4.6.1. Questionnaire Improvement

Improving Innovation measurement: Most of the comments on the questionnaire were on the innovation measurement (Appendix C.1, section B). At the beginning the interviewees had to answer this part of the questionnaire according to the provided 1 to 5 scale. In response to each question they had to indicate how many times they had undertaken that action in their company during the last year (1 = never, 2= rarely (1 or 2 times), 3 = sometimes (3 to 5 times), 4 = frequently (6 to 10 times), and 5= very frequently (more than 10 times)). But during the first interview, the interviewee struggled to answer the innovation questions according to the scale. The main problem was they undertake these actions (e.g. improving or revising existing products or services, developing products or services that offer greater advantages to consumers than any other product) in their organisation but it was hard for the interviewee to quantify it in the

context of the provided scale. For example in response to the question about developing new products/services that require customers to substantially alter their behaviour he said:

“The answer is yes but it is very difficult to quantify because we have a small number of customers who have hundreds of employees, so it’s a multi parapet”.

And about the whole innovation measurement he mentioned:

“The difficulty with the innovation measure is it prejudices the units of measurements. In terms of responding to your questions I am not really able to answer them properly”.

After the first interview the search for other scales suitable for the measure but easier for companies to answer continued. The scale provided by Subramaniam and Youndt (2005 p. 463) was found to be appropriate for this purpose. In this scale they asked respondents to answer questions about radical and incremental innovation compared to the competition (1= weaker than competition; 4= equal to competition; 7= stronger than competition). The reason for choosing this scale was because it is easier for managers to use this scale to answer the questions. Moreover, since they are comparing themselves with their competitors, it is possible to study the innovation performance of the companies in different industries which was not possible with the previous scale. Companies in some sectors do not need to be as innovative as the companies in other sectors so it is not appropriate to compare their innovation outputs in different industries. The main reason is some firms are very innovative in their sector but when compared to companies in other sectors they are not innovative and this is because of the nature of their business. The new scale addresses this issue by measuring the innovation performance of the companies compared to their competitors in the same sector. In fact the new scale is asking how good they are in their industry. In the remaining interviews

the new scale was used and the interviewee did not have any problem with that. Moreover, the previous scale was explained to each interviewee and they all agreed that the new scale is easier and more sensible for them to answer.

Clarifying Inter-Organisational Relationship: After reviewing the previous literature the following definition for inter-organisational relationship was developed. ‘Inter-organisational relationships refer to all types of knowledge transfer between companies which contribute to their innovation. This knowledge transfer relationship can range from informal relationships between managers of the company to formal alliances between them’. But during the interviews it was realised that managers, by this definition, (Appendix C.1, Section C) did not consider the knowledge transfers with their customers. In the interviews they all mentioned that the knowledge from their customers about their products, services and sometimes ideas about new products is very important. Therefore the definition was revised in a way to remind managers about all different types of inter-organisational knowledge transfer. The new definition is ‘Inter-organisational relationships refer to all types of knowledge transfer relations between companies. These relationships are formal and can be with any type of organisation, customer, supplier, partner, university or laboratory’. In the new definition informal relationships are excluded. The reason for this has been explained in the ‘inter-organisational relationship’ section of Chapter 3.

Comments on methods of data collection: Interviewees also provided some comments about the questions that collect data about the network structures (Appendix C.1, Section C). The questions and the table for the answers were in two separate sheets and they said it is hard for them to read the questions and answer them on another page. Therefore for the final version of the questionnaire the questions and answers were designed on the same page. Moreover, the second interviewee mentioned that it is easier for them and increases the response rate to send the questionnaire online instead of sending it by mail

(designing questionnaire and sending it to companies was part of their business activities). Therefore using an online questionnaire was considered for data collection as well as sending a mail questionnaire. This enabled managers to choose the method that is more convenient for them.

So far the improvements on the questionnaire based on the pilot study have been explained. In the next part the analysis of the interviewees' responses to the interview questions is presented.

5.4.6.2. Understanding Factors Affecting Innovation

Thematic analysis of interview data provides rich information and in-depth understanding on a number of important issues associated with the current practice and factors connected with the innovation in SMEs. The following thematic based discussions are according to the pilot interview analysis.

Barriers: As mentioned before, one of the objectives of the pilot study and interview was identifying other factors that contribute to a firm's innovation performance. To address this objective, interviewees were asked to list the barriers and resources for their innovation. All the interviewees listed *cost* and *resource* as the main barriers for innovation in their company. Interviewee 1 mentioned

“One is the cost of the innovation, and the other is the space that you need for innovation [...] so you've got to create space for people to innovate. They [employees] got a busy diary and doing lots and lots of things it requires space for them to have the intellectual capacity to do things”.

Another manager (interviewee 3) regarding the financial barriers indicated that

“Financial I would say is the main barrier. We struggle to find the funds to invest in our innovative ideas”.

Resources for Innovation: Regarding resources for innovation almost all the interviewees agreed that *partners, customers and managers' previous experience* are the most important resources for new ideas and innovation in their company. Interviewee 2 mentioned

“We have a big partner relationship with them. It is a global consultancy firm. So we use some ideas from them...”

Also manager number 3 pointed out

“Can be talking to our customers, they might have the idea they want us to implement, or we can see some opportunities for something that we can do for them that we might also sell to somebody else”.

One of the managers mentioned that their R&D team is very important in their innovation and another manager of a small company pointed out that using forums and online resources are important for him in finding new ideas or making changes in their current process or services. They specially were asked about the factors that help in radical and incremental innovation. Almost all of them mentioned that the same factors are important in both radical and incremental innovation. One of the managers regarding incremental innovation mentioned

“It is kind of similar but the other important thing with incremental innovation is to have ways of listening to your customers to get feedback to find out from them what they would like different”.

Moreover, manager 5 on radical innovation mentioned

“I think listening to our customers is another thing that led the idea to come into the organisation and then come up with some radical ideas”.

Their opinion about other factors for different types of innovation was different so it is not possible to say which one is really important for which types of innovation.

5.4.6.3. Preliminary Analysis on Research Hypotheses

Although the number of pilot interviews may not be appropriate for hypothesis testing and the main method is survey questionnaire, the comments made by interviewees still provided support for some of the hypotheses.

Diversity of partners: In order to support the developed hypotheses and find some preliminary evidence, questions were asked about different types of partners and diversity of relations. Regarding the diversity of nodes and its effects on radical innovation they asserted interesting ideas which support hypothesis 7. Interviewee 4 mentioned that

“I had an idea to license out our business. No one else in this type of company came up with that idea. What we now developed as a service has been enhanced because I have spoken to the legal partner, I have spoken to the IT partner, I have spoken to the recruitment partner. People have been giving me ideas on how I execute them and how I deliver that”.

This example here supports the argument that variety in partners will help the focal firm to use various channels to seek different solutions and make the opportunity for radical innovation.

Strength of Ties: Regarding the strength of ties one of the interviewees provided an interesting example. The example was about introducing a new service in their sector (radical innovation) using cloud computing. They have an IT-partner and they rarely contact this partner. However, in one of their meetings this partner gave the idea about using cloud computing as a new way of delivering their service to the customers. Using this service in their business was an innovation that no-one had used before.

The pilot study provided the opportunity to test the questionnaire in the real world and find its deficiencies and revise the questionnaire accordingly. In addition to that the interviews shed more light on the inter-organisational knowledge transfer and improved the researcher's knowledge.

5.4.7. Developing a New Innovation Measurement Tool

This section explains the details of developing a new instrument for radical and incremental innovation. Following the pilot study a further literature review was conducted on the measure for different types of innovation and certain limitations were identified regarding this measure, which will be explained in the following section.

5.4.7.1. Limitations of the Previous Measures:

After conducting the pilot analysis and further research on literature some inconsistency was found in the innovation measure. The innovation measure in the first version of the questionnaire was based on research by Darroch and Jardine (2002). However, after data collection and analysis there was an item of measurement, which was radical innovation, that they included in the incremental innovation section (Appendix C.1, section B shows the final developed and tested measure).

The item that is making the inconsistency is 'We often introduce new ranges of products or services not previously offered by this company' which is a radical innovation based on the typology they have used (discussed in Chapter 2) but ended up in incremental innovation after the factor analysis. Another problem with this measure is that there is a question to capture incremental process innovation (question 5) but there is not one for radical process innovation. An extensive literature search yielded no valid instrument to measure radical and incremental innovation from both a company and customer perspective. Developing a new measure seemed essential to address all these shortcomings in radical and incremental innovation measures.

5.4.7.2. Scale Development

The first step of the scale development is the creation of items related to the construct. There are two main approaches for item generation: Deductive and Inductive (Hinkin 1998). The deductive approach is used when there is enough theoretical foundation to provide the required understanding for the initial set of items. The inductive approach is appropriate when the conceptual foundation is not enough to identify all the dimensions of the concept for item generation. In this research the first approach is adopted. The item generation started by reviewing literature and identifying different aspects of both radical and incremental innovation. A comprehensive definition for both constructs is provided in Chapter 2. During the item generation those definitions were consulted as the reference to create items related to each construct. After identifying all aspects of each construct the researcher has to generate questions related to each aspect. As already mentioned, there is a vast amount of research for both radical and incremental innovation and most of it measures different aspects of each construct; therefore, it was decided that the existing items from the reviewed literature for item generation should be used and where necessary add questions to meet all the requirements of this step. Tables 5.6 and 5.7 are the generated items for incremental and radical innovation respectively.

Table 5.6: Incremental innovation survey items

Statement	Underlying Construct	Reference
We often add a new product or services to our existing ranges	Product/service innovation	(Darroch and Jardine 2002)
We make minor changes or extensions to the current products, existing services or processes of the organisations	Product/service and process innovation	(McDermott and O'Connor 2002)
We make minor improvements or adaptations to existing products/Services	Product/service innovation	(Oke <i>et al.</i> 2007)
We make major improvements or adaptations to existing products/Services	Product/service innovation	(Oke <i>et al.</i> 2007)
We make changes (products/services or processes) that reinforce how we currently compete.	Product/service and process innovation	(Subramaniam and Youndt 2005)
We make changes in our products/services and processes like changes which are “insignificant,” minor, or do not involve a sufficient degree of novelty. (Novelty refers to the aesthetic or other subjective qualities of the product.)	Product/service and process innovation	(Popadiuka and Choob 2006)
We often improve or revise existing products or services	Product/service innovation	(Darroch and Jardine 2002)
We make changes that reinforce our prevailing product/service lines.	Product/service innovation	(Subramaniam and Youndt 2005)
We make changes in the processes of delivering a product or services that improve price/performance at a rate consistent with the current technological trajectory.	Process innovation	(Reichstein and Salter 2006)
We often change the way we make or deliver products or services.	Process innovation	(Darroch and Jardine 2002)
We often reposition existing products or services.	Product/service innovation	(Darroch and Jardine 2002)
We exploit the potential of the established design	Product/service innovation	(Henderson and Clark 1990)
We make changes that reinforce our existing expertise in prevailing products/services.	Product/service innovation	(Subramaniam and Youndt 2005)
We introduce any new or significantly improved processes for producing or supplying products (goods or services) which are new to our firm	Process innovation	(Reichstein and Salter 2006)

Table 5.7: Radical innovation survey items

Items	Underlying Construct	Reference
We develop products or services that offer greater advantages to customers than any other product or service currently available.	Product/service innovation	(Darroch and Jardine 2002)
We introduce new products that provide substantially higher customer benefits relative to previous products in the industry.	Product/service innovation	(Chandy and Tellis 1998)
We develop products or services that better meet the needs of customers than any other product or service currently available.	Product/service innovation	(Darroch and Jardine 2002)
We introduce new products/services to an existing market	Product/service innovation	(Oke <i>et al.</i> 2007)
We introduce new products/services to a new market	Product/service innovation	(Oke <i>et al.</i> 2007)
We have launched products or services that are the first of their kind in the world.	Product/service innovation	(Darroch and Jardine 2002)
We develop products or services that require customers to substantially alter their behavior.	Product/service innovation	(Darroch and Jardine 2002)
We introduce new products that incorporate a substantially different core technology	Product/service innovation	(Chandy and Tellis 1998)
We make changes that fundamentally change our prevailing products/services.	Product/service innovation	(Subramaniam and Youndt 2005)
We make changes that make our existing expertise in prevailing products/services obsolete.	Product/service innovation	(Subramaniam and Youndt 2005)
We develop new products/services that require significantly new technology or ideas that did not exist in the market before	Product/service innovation	(McDermott and O'Connor 2002)
We revise the processes of delivering product/services that offer a significant (30-50%) reduction in costs.	Process innovation	(McDermott and O'Connor 2002)
We develop new products/services that requires fundamental changes to the existing market	Product/service innovation	(McDermott and O'Connor 2002)
We make changes that make our prevailing product/service lines obsolete.	Product/service and process innovation	(Subramaniam and Youndt 2005)
We create new major product/service programs leading to expansion of current markets	Product/service innovation	(Koberg <i>et al.</i> 2003)
We introduce products/ services that offer an entirely new set of performance features	Product/service innovation	(McDermott and O'Connor 2002)
We introduce new or significantly improved processes for producing or supplying products (goods or services) which are new to our industry (process innovation).	Process innovation	(Reichstein and Salter 2006)

A closer inspection of the items revealed that some of the questions are addressing a single aspect of radical/incremental innovation. For example, items 1 to 8 in the incremental innovation are questioning the same aspect of incremental innovation with different wording. Hinkin (1998) points out that it is important to keep the scale concise and avoid unnecessary questions. Therefore, after a close review of the generated items and consulting an expert the redundant items were removed from the list. In some cases two related items were retained to test for response bias. Other guidelines such as making items simple and short, using language familiar to the target respondent, keeping items consistent in terms of perspective and addressing only a single issue in each item (Hinkin 1998) were followed (for the final version of the developed scale please see appendix C.2, section B).

5.4.8. Final Version of the Questionnaire

The new innovation measure replaced the innovation measure in the questionnaire. Table 5.8 illustrates the final version of the measurement instrument. Also questions regarding innovation management practices were added to section B of the questionnaire.

The layout of the questions on section C was revised to provide a respondent friendly layout. The social network questions were structured into a table to make it easier for respondents to answer. To reduce the concerns regarding the confidentiality of the partners' information, companies were asked to write only the initials (up to 10) of their partners that they had knowledge transfer within 2010 (name generator). This will provide respondents with a list of their partners and help them to answer the name interpreter questions.

Table 5.8: Radical and incremental innovation survey items

Items	Construct	Reference
Incremental Innovation		
We often improve or revise existing products or services	Product/service innovation	(Darroch and Jardine 2002)
We add new products or services to our existing ranges	Product/service innovation	(Darroch and Jardine 2002)
We make changes that reinforce our prevailing product/service lines	Product/service innovation	(Subramaniam and Youndt 2005)
We often reposition existing products or services	Product/service innovation	(Darroch and Jardine 2002)
We exploit the potential of the established design	Product/service innovation	(Henderson and Clark 1990)
We often change the way we make products or deliver services	Process innovation	(Darroch and Jardine 2002)
We introduce new or significantly improved processes for producing or supplying products (goods or delivering services) which are new to our firm	Process innovation	(Reichstein and Salter 2006)
Radical Innovation		
We develop products or services that offer greater advantages to customers than any other products or services currently available	Product/service innovation	(Darroch and Jardine 2002)
We develop products or services that better meet the needs of customers than any other product or service currently available	Product/service innovation	(Darroch and Jardine 2002)
We develop products or services that require customers to substantially alter their behavior	Product/service innovation	(Darroch and Jardine 2002)
We introduce new products/services to an existing market	Product/service innovation	(Oke <i>et al.</i> 2007)
We introduce new products/services to a new market	Product/service innovation	(Oke <i>et al.</i> 2007)
We develop new products/services that require significantly new technology or ideas that did not exist in the market before	Product/service innovation	(McDermott and O'Connor 2002)
We create new major product/service programs leading to expansion of current markets	Product/service innovation	(Koberg <i>et al.</i> 2003)
We develop innovations that make our prevailing product/service lines obsolete	Product/service and process innovation	(Subramaniam and Youndt 2005)
We introduce new or significantly improved processes for producing or supplying products (goods or delivering services) which are new to our industry	Process innovation	(Reichstein and Salter 2006)

There are two ways to ask name interpreter questions. First, asking respondents to answer all the name interpreter questions for each partner (alter by alter) or second, answer each questions for all partners (question by question). It is advisable to ask questions alter by alter (Kogovšek and Ferligoj 2005). However, in a questionnaire the order of answering questions depends on the respondent. The name interpreter ones were designed in a way

that the respondent could answer them both ways depending on the respondent's preference. The name interpreter questions were about the main business of the partner, frequency of making contact with the partner, duration of the knowledge transfer relationships, location of the partner, type of the partner and form of inter-organisational relationship. The final version of the questionnaire was reviewed by two experts and received no further comments (see appendix C.2 for the final version of the questionnaire).

5.5. Study Design

All the previous studies in this area (networking and innovation) used a lag between establishing the relation with partners and its effects on the innovation performance. The main reason for this lag between dependent variable and independent variable is that in a causal relationship where the dependent variable is not manipulable the cause must be present before the effect (Cook and Campbell 1979). Once a new relationship has been established it takes time until the focal firm can benefit from the new knowledge or resources in their innovation. Following previous studies (Ahuja 2000, Gilsing *et al.* 2008, Powell *et al.* 1996) there is a one year lag in examining the effect of a relationship on innovation outcome. In the questionnaire respondents were asked about their knowledge transfer activities with their partners in 2010 and their innovation performance in 2011. Moser and Kalton (1971) suggest that a 12 month period is practical for the respondent to remember the required information.

A key informant approach (Brush and Vanderwerf 1992, Chandler and Hanks 1993) was adopted to ensure that a high proportion of the responses are valid. In studying smaller social units such as SMEs using a single key informant approach such as the managing director of the company seems sufficient since this person should be the person most

familiar with both the organisation's performance and their relation with different partners. Thus the questionnaire was sent to the managing director of the companies.

5.6. Sample

This section comprises all the issues regarding the sampling frame, industry and location of the target companies.

5.6.1. Industry Selection

One of the limitations of the previous studies in this area is that most of them focus on a single industry. The main reason that they had to focus on just one industry was the measure for dependent variable. They all used patent databases as the source for innovation output of the firms and the fact that industries vary in their patenting tendency forced them to focus on a single industry. In this research the main method for collecting empirical data was survey and part of the questionnaire which measures the innovation output of the companies was designed in a way which asks respondents to answer the questions compared to the competition. This strategy addressed the patent tendency problem and made it possible to focus on different industries instead of just one industry. The reasons for choosing a high-tech sector have already been explained in the first chapter.

For this research two industries, software supply and consultancy and manufacture of chemicals and chemical products, were chosen. There are three main reasons for choosing these two industries for the sample. First, in both industries it is important to invest in R&D and innovation. Second, the research question is about radical and incremental innovation and according to the taxonomy of innovation introduced in Chapter 2, (figure 2.5) product, service and process are the building blocks of each of these innovations. Therefore it is important to include companies in the sample that represent all these blocks. Third, testing the hypotheses in different industries will make it possible to assess

to what extent the companies' performance in radical and incremental innovation remains invariant across the industry, and therefore increase the generalisability of the results.

5.6.2. Location Selection

Two main criteria were considered to select the geographical location of the study. First the area should include enough businesses to allow the proposed analysis to take place. Second, choosing a bigger geographical location will increase the generalisability of the study. Considering these two criteria England, Scotland, Wales and Northern Ireland were selected as the locations of the study.

5.6.3. Relationships Selection

The key difference between network studies and other traditional organisational studies is sampling the relationships as well as the persons. This means that there are two different sampling units: organisations and partnerships. One of the most critical decisions in network studies is identifying the boundaries of the relations (Laumann *et al.* 1983). Nodes and relations are the main constructs for all network settings. Therefore for the sampling purpose it is necessary to consider sampling both nodes and relations which are not independent from each other. Zaheer and Usai (2004) suggested that a proper solution for this problem is to rely on theory and find an answer for the question "what ties to which kinds of organisations would possibly be predicted by theory to influence the outcome we are studying?" According to the research question and the objectives of the research all types of formal relationships that can contribute to innovation output of the focal firm should be considered. According to this argument knowledge transfers with companies in other sectors (low and medium- tech) as well as the companies in the same sector (high-tech sector) were considered for data collection. Moreover, since the outcome interest is innovation output, including ties with universities and research labs in addition to other firms was necessary.

5.6.4. Sample Selection

In order to obtain sample SMEs in the manufacturing chemical industry and software supply and consultancy in the UK, the FAME (Financial Analysis Made Easy) database was utilised. FAME is a computerised database covering major UK companies and includes information about UK Standard Industrial Classification (SIC) codes, address, telephone number, name of the director/manager, number of employees and latest turnover. Although FAME has a lot of information about companies it has its own drawbacks. The major problem is the inaccuracy of some of the information. For example the name of the manager and addresses of some of the companies do not seem to be entirely reliable. This limitation may cause a lower response rate since the targeted company/person will not receive the questionnaire.

In order to construct the sample, the entire population of firms with SIC code 24 (manufacture of chemicals and chemical products) and SIC code 722 (software consultancy and supply) with number of employees less than 250 and annual turnover less than 50 million euros a year (EU definition) (commission 2011) and located in England, Scotland, Wales and Northern Ireland were selected from FAME. The search query returned 1563 companies for chemical and 3516 for the software industry. After removing those companies that did not have contact information, 1033 for chemical and 2010 for the software industry remained.

5.6.5. Sample Size

There are many guidelines for researchers to calculate the appropriate size of the sample. Bentler and Chou (1987) suggest that when the data is normally distributed and there are many indicators of latent variables the ratio between number of responses per free parameter should be 1:5. However, the ratio will increase to 15 when the data is not normally distributed and the assumptions of multivariate analysis are violated (Bentler and Chou 1987). In the case of doing confirmatory factor analysis Anderson and Gerbing

(1984) and Hair *et al.* (2010) suggest that the sample size of 100 to 150 is appropriate for a convergent and proper solution. Moreover, the minimum sample size for maximum likelihood estimation is 100. According to these rules of thumb a minimum of 100 responses is required for this study to conduct further analysis. 700 companies were chosen randomly from each industry. So the sample size of the study is 1400 and due to the deficiencies of FAME (this has already been discussed in the previous section) the response rate is expected to be lower than the average response rate. Therefore with 10% response rate there should be about 140 responses which is enough for conducting the analysis. Although this is just used as a guideline there are criticisms about these rules of thumb (described before) which will be explained in section 5.8.

5.7. Data Collection

Following Dillman's tailored method a pre-notification letter (appendix B.1) was prepared. Evidence from other studies shows that sending a pre-notification letter increases the response rate of the research (Darroch and Jardine 2002, Huang *et al.* 2004). Due to the limitations on resources a pre-notification letter has been sent to only 400 of the sampled companies in each sector (400 to chemical and 400 to software industry). The pre-notification included information about the purpose of the study and the date that they will receive the main questionnaire. One week after sending the pre-notification, the main questionnaire booklet together with a cover letter (appendix B.2) and a pre-paid envelope were sent to the companies. To increase the response rate companies were randomly contacted through email or telephone and encouraged to respond to the questionnaire.

In total, over a period of three months 107 companies answered the questionnaire. 417 companies replied back by telephone, sending back the blank questionnaire, email or mail. From this 359 mentioned that the addressee is not in the company anymore and the

other 58 wrote that they are not interested or they are too busy to fill in the questionnaire. Therefore the response rate was 10.8%. Reviewing the relevant literature shows a low response rate in the questionnaire surveys which were carried out in SMEs such as 11% in Ramsey *et al.* (2003) and 10.4% in Daniel and Wilson (2002). Moreover, Baruch and Holtom (2008) mentioned that research at organisational level or top manager level suffers from low response rates. They indicate that this low response rate is because of the increased difficulty in obtaining a response from this population. The difficulty of collecting primary data from executive level managers has also been mentioned in Subramaniam and Youndt's (2005) study as one of the main reasons for the low response rate.

From those that had not responded to the questionnaire, 100 companies were randomly contacted by phone. They were asked about the reasons for not participating in the survey. There were different reasons for not responding to the questionnaire such as 54% were too busy, 42% said the addressee had already changed jobs, 1% of the companies had gone bankrupt and 3% had not received the questionnaire. Based on this the two main reasons for not participating in the survey were the person not being in the company anymore or the person was too busy to answer the questionnaire. Considering these factors, arguably, the response rate in the research would be higher. Also another reason for the low response rate was the inaccuracy of the information of the FAME database. However, using this database was unavoidable since this was the only accessible resource at the time of the research.

5.8. Data Analysis

Statistical analysis and social network analysis were the methods of data analysis in this research. Statistical analysis included: uni-variate analysis, bi-variate analysis and multi-variate analysis techniques. Social network analysis involved using measures to calculate

network properties including betweenness centrality, density, diversity of ties, diversity of nodes, strength of ties and degree centrality.

5.8.1. Statistical Techniques

Data was coded and entered into SPSS and cleaned. Statistical methods were used to analyse radical innovation, incremental innovation and innovation management practices (innovation strategy, human resource management, implementation, portfolio management, and idea management). Statistical analysis involved descriptive, inferential and Partial Least Squares (PLS) modeling.

To test the measurements and the hypotheses of the study, Structural Equation Modelling (SEM) techniques were adopted. SEM was chosen over simple regression methods for two reasons: first there are two dependent variables in this research. Multiple regression models are based on one dependent variable and therefore are less appropriate for this research. SEM has the ability to calculate a series of separate, but interdependent, multiple regression models at the same time by specifying the structural model. Second, there are seven latent variables in the model which require confirmatory factor analysis. In addition to that, SEM provides the ability to calculate measurement error in the estimation process for latent variables. The capability of SEM in bringing the measurement and structural model into a simultaneous analysis, provides the opportunity for researchers to conduct factor analysis and observe estimation error in one single task, which is a more rigorous analysis (Gefen and Straub 2005). Therefore SEM was the most appropriate technique for the purpose of this study.

SEM techniques can be covariance-based (the methods used in LISREL and AMOS) or variance-based (methods used in PLS). For example, the covariance-based method requires normality and usually a large sample size to be able to conduct the analysis. In covariance-based methods, analysis tends to be confirmatory. This means that a strong

theory and measures that have been well studied before are required to conduct this type of analysis (Chin and Newsted 1999). A covariance-based SEM approach has some limitations compared to a variance-based approach. There are two serious problems that might happen in covariance-based SEM: inadmissible solutions and factor indeterminacy (Fornell and Bookstein 1982). There is no such limitation in PLS. PLS is a non-parametric estimation procedure (Wold 1982). It is an iterative combination of principal component analysis for the measurement model and path analysis to capture the structural model of the constructs (Eggert and Ulaga 2010). It can be a strong method for analysis since its requirements on measurement scale, sample size and residual distribution are minimal (Chin *et al.* 2003). PLS uses an iterative algorithm consisting of a series of ordinary least square analyses and does not have the identification problem for recursive models.

It is argued that in terms of concept and practice, PLS-SEM and multiple regressions are similar (Hair *et al.* 2011). The main goal is maximising the explained variance in the dependent construct as well as evaluating the data quality on the basis of measurement model characteristics (Hair *et al.* 2011). Like the covariance-based technique in PLS there are two types of models: inner model and outer model. The inner model includes the latent variables and the relationships between them. The outer model consists of the latent variables and their indicators. The outer model shows how each latent variable is connected to its indicators. The algorithm first estimates the outer model and then the inner model. One of the reasons that PLS requires a smaller sample size compared to other SEM methods is that only one part of the model is involved in the analysis at any time which makes it similar to running several multiple regressions. PLS uses resampling methods such as Bootstrap, Jackknif or Blindfold to calculate t-values for the loadings.

It has been mentioned that PLS demands a lower sample size compared to other SEM techniques. The minimal recommendation to conduct analysis with PLS is from 30 to 100

cases (Chin and Newsted 1999). There is a rule of thumb that many researchers have used to calculate the appropriate size for their analysis. The rule of thumb is that the minimum number of cases suitable for PLS analysis is equal to the portion of the model with the largest number of predictors multiplied by ten (Hair *et al.* 2011). Another more relaxed rule of thumb is to use five instead of ten (Chin *et al.* 2003). However, this rule of thumb has been criticised by researchers (Marcoulides *et al.* 2009, Marcoulides and Saunders 2006). It is recommended that researchers, in order to determine the appropriate sample size for analysis, conduct a power analysis based on the portion of the model with the highest number of predictors (Chin and Newsted 1999, Marcoulides and Saunders 2006) and match the result with Cohen's (1988) power analysis table.

According to Chin and Newsted (1999) using PLS is adequate if the data does not meet the requirement for other methods such as minimum sample size and normality. Also, when the researcher aims to make a prediction and the model is new and changing, it is appropriate to use PLS. Regarding using PLS-SEM over CB-SEM (Covariance-Based), it has been suggested that the PLS-SEM result is a good proxy of CB-SEM when there are some problems such as Heywood cases and inflated parameter estimates (Hair *et al.* 2011). Moreover, it is suggested that when established and newer items are employed in a study, which is the case in this research, using PLS is more appropriate (Fornell and Bookstein 1982, Hulland 1999).

Commensurate with the above guidelines, PLS-SEM was employed as the main technique of the data analysis for this study. The software that was used for the PLS analysis was WarpPLS (Kock 2012).

5.8.2. Fuzzy Set Qualitative Comparative Analysis

Additional analysis was conducted in this research using a new method called Fuzzy Set Qualitative Comparative Analysis (fsQCA). Using this method adds value to the study as

it examines the interaction between different causal and outcome factors. Charles Ragin invented fsQCA in 1987 based on a set theoretic approach that reveals relationships of necessity and sufficiency between causal and outcome conditions. Regression methods are basically different from this approach since they are not able to understand the variables as configurations even by adding interaction terms (Ragin 2008a). Rihoux and Lobe (2009, p. 171) in this regard explain that “it would make no sense in (fs)QCA to isolate ‘the net, independent effect of [a] condition’ since cases are conceived as configurations of conditions; it is not an individual condition that matters but the configuration of conditions that does”.

fsQCA is based on the QCA method. Variables in QCA are allowed to take only two mutually exclusive states, membership (1) and non-membership (0). Fuzzy sets extend the abilities of QCA and permit cases to take values anywhere from 0.0 to 1.0. Using fsQCA is more appropriate here compared with the basic QCA. The reason is QCA only permits membership and non-membership in a set, but using fsQCA gives the ability to different levels of membership (e.g. full membership, strong but not full membership, weak members of a set and full non-membership). For example, in the context of this study, there are companies with high (radical/incremental) innovation performance. There are other companies that, although their innovation performance is not as high as the first group, their performance is still above the average. The third group is those below average and the fourth group is those whose performance is very weak. If a researcher had employed QCA instead of fuzzy set for the previous example then there would have been only two groups (high performance and low performance) so a lot of interesting information would have been missed.

Moreover, there are recent studies (Fiss 2007, Fiss 2009, Greckhamer *et al.* 2008) that recommend using QCA and fuzzy sets in organisations and strategy settings due to the new insights and understandings that this method can offer on causally complex issues.

fsQCA enables the researcher to find different combinations of causal conditions that may lead to the same outcome (Berg-Schlusser *et al.* 2009). Conventional statistic methods are concerned with the net effect of an independent variable on an outcome. But this is a bit far from reality. In the real world there are many other conditions and relationships that impact on the variables. In addition to that, it is hard for organisations to perform well in all the antecedents of a phenomenon. fsQCA takes a different approach and considers multiple and different causal paths that are satisfactory for that causal condition (Berg-Schlusser *et al.* 2009).

In this study a combination of network characteristics and innovation management practices were hypothesised as the causal conditions that influence on radical and incremental innovation performance of companies. The statistical analysis in the next chapter reveals how different variables impact on their radical and incremental innovation performances. However, as mentioned before, it is hard for companies to pursue a higher level of every antecedent to achieve higher performance. Using the same theoretical foundation, different combinations of these factors are studied in Chapter 7 to determine which combinations of them provide higher performance on different types of innovation.

It is necessary to bear in mind that this method of analysis does not overrule the contribution of conventional statistic methods (e.g. the method in the next chapter). The statistical methods are important to recognise the significance of the relationship of network characteristics and innovation management practices with radical and incremental innovation performance. The fsQCA method (and Chapter 7) attempts to describe different combinations of the factors that exist among the comparable cases that result in higher radical and incremental innovation performance. Ragin (2008a) describes this method not as a replacement for conventional statistic methods but a complimentary technique. In fact, during the analysis using fsQCA there are situations where the results

from Chapter 6 are consulted in order to provide the necessary theoretical and practical foundation to continue the analysis.

5.9. Summary

This chapter covered the fundamental steps that have been taken to implement this study. Different research philosophies and the adapted research philosophy for this research were explained. The challenges and the necessary measures that have been taken to select the appropriate method for the research strategy, research design and data collection were described in detail. A pilot study was conducted to confirm the criteria for validity and reliability of the questionnaire. Moreover, the steps of designing a new measure for radical and incremental innovation were explained. After that, the details of the data collection, sample size and response rate were provided. The last part of the chapter covered the methods that will be used for the data analysis in the next two chapters.

The next chapter is about the analysis of the collected data. The analytical tools that have been used for this purpose are explained and detailed information regarding the result of the study is provided.

6. Chapter 6: Analysis and Results

6.1. Introduction

This chapter explains the statistical methods that have been used to analyse the collected data and examine the theoretical framework of the study. First the respondents, non-respondents, early and late respondents' statistical details are provided. Second, different phases of data screening and data cleaning are explained. After that, the details of measurement model evaluation including reliability and validity test of the constructs are given. Fourth, the structural model evaluation and hypotheses testing to examine the theoretical framework of the study is described. The final section of the chapter discusses the power analysis of the study and appropriateness of the sample size for the analysis.

6.2. Respondents' Characteristics

Data from all usable questionnaires was entered into SPSS, following reviewing and coding the data. The majority of the responses (60%) were received from the firms in chemical industry and the remaining responses (40%) were from the companies in IT industry. Table 6.1 presents an overview of the number of respondents. A Chi-Square goodness-of-fit test was conducted to determine that the percent of the sector population in the sample population and respondents were similar. The null hypothesis was that there is no significant difference between the percentage of the sector distribution of the respondents and the sample population.

Table 6.1: Number of respondents in each sector

Industry	Sample		Respondents		Chi-Square Values
	Frequency	Percent	Frequency	Percent	
Software consultancy and supply	700	50%	42	39.2%	2.332
Manufacture of chemicals and chemical products	700	50%	65	60.7%	2.289
Total	1400	100%	107	100%	

The following formula from Sheskin (2007) was employed to calculate the chi-square value:

$$X^2 = (\text{observed value} - \text{expected value})^2 / (\text{expected value})$$

where the observed value is the percentage of the respondent and expected value is the percentage in the sample. The last column of the table 6.1 presents the result of the Chi-Square test. Table of critical values of chi-square in Tabachnick and Fidell (2007) was used to test the significance of the hypothesis. With the significance level of 0.05 and degree of freedom 1 the hypothesis was rejected in both tests. Therefore the null hypothesis was accepted and there was no significance difference between the industries in the sample and the responses.

In order to provide a comprehensive overview of the profile of respondent organisations, other background data was collected. This includes age of the companies, number of employees and their total sales in 2010. Table 6.2 represents the summary of the profile of the respondents.

Table 6.2: Profile summary of the respondents

	Count	Per cent
Age		
Less than 5 years	2	1.9%
6 to 10 years	3	2.9%
11 to 15 years	11	10.7%
16 to 20 years	15	14.6%
More than 20 years	72	69.9%
Number of Employees		
1-9	3	2.9%
10-50	43	41.7%
51-150	45	43.7%
151-250	9	8.7%
More than 250	3	2.9%
Total Sale in 2010 (£)		
Less than 1 million	2	1.9%
1 to 5 million	45	43.7%
6 to 10 million	17	16.5%
11 to 15 million	22	21.4%
16 to 20 million	6	5.8%
21 to 25 million	2	1.9%
More than 26 million	9	8.7%

6.3. Non-Response Bias

Examining non-response bias is a major concern in survey research. Non-response bias is a method to assess representativeness of the sample. Non-response effect appears when there is a systematic difference between the answer of the respondents of the questionnaire and non-respondents, while the non-respondents are excluded from the sample as a non-random subset of the population (Groves 2004). Armstrong and Overton (1977) identified three methods of testing non-response bias. The first method is using known values (such as age, sex or business sector) to compare the composition of

respondents and non-respondents. The second method is extrapolation. In this method the assumption is those respondents that require more pressure (follow-up email or reminder) are similar to non-respondents. One of the common types of extrapolation method is analysing waves of questionnaire. In this method a wave analysis was conducted by comparing the answers between early and late respondents. The last method involves sending questionnaire to the sample of non-respondents. The last method, although believed to be the most rigorous method, is the most expensive and time consuming way.

In this research the two first methods, comparison with known values for population and successive wave analysis, are employed to examine non-response bias of the study. The detail of the methods is explained in the following sections.

6.3.1. Respondents' and Non-Respondents' Sector Comparison

In this method sector distribution was compared between the respondents and non-respondents. All the respondents and non-respondents were classified in two sectors. A chi-square test of difference was conducted on the two sectors (table 6.3). The test of distribution was not significant at $\alpha = .05$ confidence level, which indicates that there is no significant difference between the two groups (respondents and non-respondents) in business sectors.

Table 6.3: Respondents and non-respondents sector comparison

Industry	Non-Respondents		Respondents	
	Frequency	Percent	Frequency	Percent
Software consultancy and supply	657	50.8%	42	39.2%
Manufacture of chemicals and chemical products	634	49.1%	65	60.7%
Total	1291	100%	107	100%

Chi-Square = 2.4, df = 1, (P = 0.121, $\alpha = 0.05$)

6.3.2. Analysis of Early and Late Respondents

The wave analysis is based on the assumption that early respondents and late respondents are similar (Dalecki *et al.* 1993). Analysis was performed using a t-test for independent samples on key metric variables and chi-square test on ordinal and nominal variables. Early and late respondents were differentiated using the date that questionnaires were received. Early respondents are those responses that were received before the first reminder (n = 34) and late respondents are those that were received after the first reminder (n = 73). Two groups were compared on company age, number of employees and company total sale in 2010 (Table 6.4). The result showed no difference between the two groups at $\alpha = 0.05$ significance level.

Table 6.4: Chi-square for non-response bias

Variables	P-Value	Chi-Square
Company Age	.721	2.079
Number of Employees	.252	5.363
Company Total Sale in 2010	.232	8.079

In addition to that, the variables of measurement constructs for both independents and dependents variables were compared between early and late respondents (Table 6.5). All the tests showed no significance difference between early and late respondents on all the variables. According to this the non-response error was not a major problem within this study and further analysis could be conducted.

Table 6.5: T-Test for non-response bias

Variables	Early Respondents (responses received before first reminder n = 34)	Late Respondents (responses received after first reminder n =73)	P-Value	T-Statistic
	Mean	Mean		
Betweenness Centrality	2.83	4.69	.329	-.981
Degree Centrality	2.77	3.15	.501	-.676
Ties Diversity	2.4516	2.0867	.115	1.591
Density	.19884	.15414	.523	.641
Number of Strong Ties	1.58	1.36	.469	.726
Number of Weak Ties	1.29	1.56	.239	-1.185
Nodes Diversity	1.8947	2.0833	.550	-.600
Radical Innovation	3.3065	3.1643	.383	.876
Incremental Innovation	3.4086	3.4659	.631	-.481
Innovation Performance	3.5484	3.3887	.314	1.013
Company Performance	3.5215	3.5825	.681	-.413

6.4. Data Screening

After entering the data into SPSS and prior to conducting any analysis, a rigorous examination of the data was undertaken. According to the definition that has been used in this study for SMEs, companies with more than 250 employees and total sale of more than 50 million euro were removed from the dataset (1 case). Following recommendations by Hair *et al.* (2010) data was screened thoroughly and following assumptions were evaluated: missing data, normality and homoscedasticity.

Missing Data: To keep most of the cases in the analysis, data was tested for missing values. Following guidelines by Hair *et al.* (2010), cases with more than 10% missing

values were removed from the sample. Three cases were identified and deleted. The level of missing data for the remaining cases was low enough to continue to the next step. In the next step data was tested for the randomness of missing data. The test of the missing values showed that data was missing completely at random (MCAR) (Hair *et al.* 2010). The next stage was selecting imputation method. The remaining missing values were replaced using the expectation-maximisation (EM) method. The reason for using EM compared to other imputation methods (e.g. listwise deletion, mean substitution, and regression substitution) was that the EM approach has the advantage of avoiding impossible matrices, avoiding over fitting and producing realistic estimates of variance (Tabachnick and Fidell 2007).

Normality: Multivariate normality is another fundamental requirement for conducting multivariate regression analysis (Pallant 2007). To make sure that the data is normally distributed, Skewness and Kurtosis tests were employed. Using probability plot and histograms is also another way of testing normality (Hair *et al.* 2010). In test of normality using skewness and kurtosis, the z scores should be higher than -1.96 and lower than +1.96 to consider the distribution normal (Hair *et al.* 2010). A visual check of histogram and probability plot was also conducted along with statistical test of skewness and kurtosis.

Skewness index for betweenness centrality was not within the acceptable range (-1.96 and +1.96). Also Kurtosis index for betweenness centrality and diversity of nodes was not within -1.96 and +1.96 range. To meet the requirement of the multivariate regression the variables were transformed (Hair *et al.* 2010). Since there was positive skewness in the variables, following guidelines by Hair *et al.* (2010), logarithm value of the variables was calculated. The histogram and probability plot of the final variables did not show any major deviation from normality.

Homoscedasticity: Homoscedasticity refers to the dependent variable exhibiting equal level of variance across the range of predictor variables (Hair *et al.* 2010). Using visual examination of data plot homoscedasticity was considered to exist (Hair *et al.* 2010).

6.5. Model Evaluation: Measurement Model Results

The items of the latent variables measures (type of innovation and innovation management practice) were adapted from previous studies in the field. Before conducting any hypotheses test it was necessary to examine the scales to understand how well the measured variables represent the underlying constructs.

The first step in evaluating a PLS model is to present the measurement model result. Measurement model refers to the latent variables and their respective indicators. In this step the validity and reliability of the measures that were used to represent each construct were examined. There are two methods of model evaluation. In the first method the researcher should draw all the possible structural links between the latent constructs in the model and set the PLS inner weighting option to factorial scheme. This method will ignore the direction of the arrows and calculate the inner weights using pairwise correlation (Chin 2010). The second method is drawing the actual structural model based on the theoretical framework and examines the measurement model with that particular structural model (Chin 2010). There is no function in WarpPLS for the first method therefore the second method was used in this study. Following guidelines by Chin (2010) the structural model of the study was drawn based on the theoretical framework of the study. Figure 6.1 illustrates the structural model that has been used to evaluate the measurement model. Due to the limitations in the software the variable names must be less than eight characters. Table 6.6 shows the description of each variable that has been used in the model.

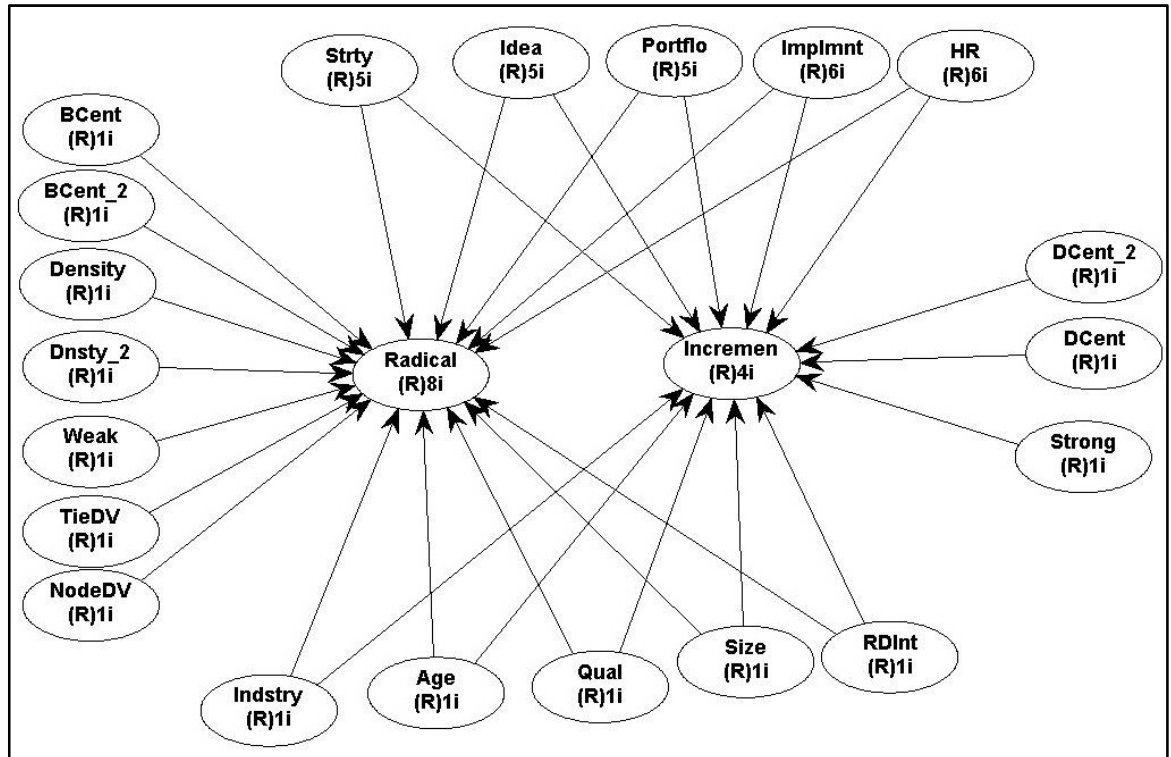


Figure 6.1: Structural model of the study

In order to add the U-shape relationships to the model, the squared value of the variables with inverse U-shape relationship were calculated and added to the model. Preliminary analysis (examining correlation between variables) revealed that these three variables were highly correlated with their respective squared value. The squared values are derived from the raising power of the original variables, therefore they are highly correlated. This will raise the problem of multicollinearity which affects the result of the analysis. Multicollinearity happens when two or more independent variables predicting a dependent variable are highly correlated to each other. This will cause strange results when studying how well an independent variable contributes to dependent variables. This happens because the two collinear variables contribute redundant data to the dependent variable and this will cause the other variables appear less important than they really are.

Table 6.6: Description of variables

	Variable Name	Description
1	Radical	Radical innovation performance
2	Incremen	Incremental Innovation performance
3	Strty	Innovation strategy (Pentathlon framework)
4	Idea	Idea management (Pentathlon framework)
5	Portflo	Portfolio management (Pentathlon framework)
6	Implmnt	Implementation (Pentathlon framework)
7	HR	Human resource management (Pentathlon framework)
8	BCent	Betweenness centrality of a focal firm
9	Density	Density of a network
10	Dnsty_2	Squared value of density (inverse u-shaped relation)
11	Weak	Number of weak ties
12	Tie DV	Diversity of ties
13	Node DV	Diversity of nodes
14	DCent_2	Squared value of degree centrality (inverse u-shaped relation)
15	DCent	Degree centrality of a focal firm
16	Strong	Number of strong ties
17	Indstry	Control for industry
18	Age	Age of the company
19	Qual	Qualification level of the employees
20	Size	Number of employees
21	RDInt	R&D Intensity
22	BCent_2	Squared value of betweenness centrality (inverse u-shaped relation)

There are different methods to address this issue such as removing one of the collinear variables, obtaining more data, mean-centre and orthogonalisation. For polynomial terms it is recommended to use centring and orthogonalisation method (Saville and Wood 1991). First the centring method was employed and values for betweenness centrality, density and degree centrality were centred. To centre the values, the mean for each variable was calculated and subtracted from all the data points in the variable. The

squared value of the centred values was calculated and the correlation was examined. Density and degree centrality still had correlation above .85 (Kock 2012) with their squared value and therefore the orthogonalisation method was employed for these two variables. For betweenness centrality the centred value was used in the rest of the analysis (the correlation between the original value and centred value was less than .85).

Orthogonalising a variable can be understood as finding the residual of the quadratic term in the variable space (Saville and Wood 1991). Figure 6.2 is the visualisation of the orthogonalisation method in the subject space. In subject space orthogonalisation is the process of subtracting a vector from its projection (Saville and Wood 1991).

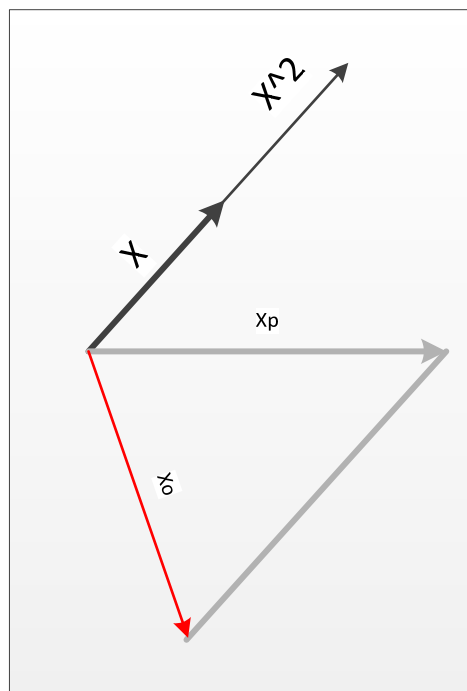


Figure 6.2: Orthogonalisation in subject space (Adopted from Yu (2000))

In the above figure, vector x is the variable and vector x^2 is the squared value of the vector x . As it is shown, the squared value is strongly associated with the vector X . In variable space this means that these two are highly correlated. To solve the collinearity a projection vector of X^2 should be drawn. In variable space this is known as the predicted variable (y). X_p in the figure is the projection vector of the X^2 . The next step is to create another vector that is orthogonal (a variable that is not correlated) to X but is conceptually

equivalent to x^2 (Yu 2000). Using subtraction method, vector X_0 was drawn. X_0 although conceptually equivalent to X^2 but is not related to X at all.

In the variable space the following formula was used to orthogonalise the variables:

$$X^2 = f(x) + e$$

where x is the variable, X^2 is the squared value of the variable and e is the unstandardised residuals. The above regression was calculated using SPSS and the unstandardised residual of the result was used as the squared value for degree centrality and density (Brock *et al.* 2006). The correlation between the variables and their respective squared term was less than the threshold value (0.85). Table 6.9 represents the correlation between the variables.

6.5.1. Construct Validity

Assessing construct validity of a measure provides confidence that the measured items from a sample represent the true score of the population that the sample has been taken. Hair *et al.* (2006, p. 776) defined construct validity as “the extent to which a set of measured items actually reflects the theoretical latent construct those items are designed to measure”. Two tests have been conducted to demonstrate construct validity of the measure: Convergent Validity and Discriminant Validity.

Convergent Validity: convergent validity examines whether indicators that are related to each other based on the measurement model are related to each other based on the sample. Convergent validity of the model was examined using factor loading and significance of the indicators. In the first run of the model there were some indicators that did not load significantly on their corresponding constructs. Table 6.7 presents the constructs and their factor loadings. Following guidelines by Hair *et al.* (2011) indicators with loading below 0.5 were removed from the model. The constructs that did not meet the criteria were Radical Innovation, Incremental Innovation, Idea Management and Portfolio Management. After removing each indicator the model was run again and

inspected for validity. Table 6.8 shows the variables in the measurement model and their loadings. The bold numbers in each column are the loadings of each indicator on its latent construct. The size of the factor loading of all the remaining indicators of each construct was above 0.6 and all the indicators were significantly ($P < .001$) related to their latent construct (Hair *et al.* 2011). Based on this test the measurement model meets the criteria for convergent validity.

Another indicator for convergence is the value of Average Variance Extracted. The threshold value for AVE is 0.5. An AVE below this threshold point indicates that, on average, there is more error in the construct rather than the variance explained by the latent variable (Hair *et al.* 2010). The last column of the table 6.10 presents the value of AVE for each latent construct in the study.

Discriminant Validity: Discriminant validity shows that a construct is related to its own measure rather than any other measure. If two constructs do not meet the requirements for discriminant validity then those two might be a similar construct and need to be measured as one construct. To test discriminant validity square roots of Average Variance Extracted (AVE) was compared with correlations among the constructs (Chin 2010). To make sure that each construct is more highly related to its own measures than other constructs, the square root of AVE should be higher than any value in the same column and row. Table 6.9 represents the correlation between the constructs and the values on the diagonal of the table are the square root of AVE for each construct.

Another test of discriminant validity is checking all the values in factor loading table. All the factor loadings of each indicator on its related construct should be higher than its loading on any other construct (Chin 2010). All the above mentioned tests were conducted and all the constructs met the criteria for discriminant validity.

Table 6.7: Initial indicator loadings on their constructs

	Radical	Incremental	Innovation Strategy	Idea Management	Portfolio	Implementation	HR
Rad1*	(0.802)	0.212	-0.104	-0.119	0.288	-0.181	-0.067
Rad2*	(0.823)	-0.023	-0.168	0.054	0.203	-0.304	0.082
Rad3*	(0.625)	0.008	-0.440	0.146	-0.248	0.062	0.538
Rad4	(0.547)	0.413	0.100	-0.157	-0.032	0.252	-0.183
Rad5*	(0.588)	-0.016	0.143	-0.295	-0.325	0.474	-0.147
Rad6*	(0.857)	0.041	0.036	0.128	-0.118	-0.018	-0.220
Rad7*	(0.805)	-0.040	0.201	-0.012	0.083	0.149	-0.010
Rad8*	(0.666)	-0.048	-0.094	0.041	-0.041	-0.027	-0.046
Rad9*	(0.763)	-0.450	0.298	0.121	0.037	-0.192	0.083
Inc1*	-0.235	(0.792)	-0.243	0.077	0.027	-0.314	0.383
Inc2*	-0.088	(0.612)	0.098	-0.441	-0.129	0.331	0.179
Inc3*	-0.330	(0.639)	0.229	-0.312	0.024	0.327	-0.020
Inc4	-0.150	(0.569)	-0.051	0.240	-0.268	0.469	-0.398
Inc5	0.244	(0.562)	-0.025	0.075	0.497	-0.163	-0.313
Inc6	-0.033	(0.436)	-0.033	0.532	-0.669	0.071	-0.115
Inc7*	0.588	(0.602)	0.072	-0.004	0.345	-0.613	0.088
Innovation Strategy1*	0.563	-0.357	(0.780)	-0.044	0.158	-0.089	0.341
Innovation Strategy2*	0.141	-0.201	(0.896)	-0.099	-0.035	-0.002	0.110
Innovation Strategy3*	-0.054	0.066	(0.800)	-0.172	0.016	0.028	-0.047
Innovation Strategy4*	-0.263	0.354	(0.767)	-0.010	0.074	-0.154	-0.321
Innovation Strategy5*	-0.379	0.158	(0.845)	0.317	-0.191	0.198	-0.095
Idea Management1*	0.228	0.116	0.116	(0.781)	0.591	-0.500	-0.234
Idea Management2*	0.614	-0.482	0.156	(0.721)	0.159	-0.573	-0.282
Idea Management3*	-0.260	0.082	-0.190	(0.788)	-0.521	0.282	0.337
Idea Management4*	-0.185	0.029	0.044	(0.781)	-0.379	0.691	0.325
Idea Management5*	-0.423	0.556	0.169	(0.211)	0.317	-0.188	-0.491
Idea Management6	-0.257	0.074	-0.175	(0.709)	0.089	0.115	-0.042
Portfolio Management1	-1.008	0.929	-0.062	0.306	(0.263)	0.111	0.081
Portfolio Management2*	-0.013	-0.245	0.517	-0.310	(0.799)	0.412	-0.017
Portfolio Management3*	-0.350	0.502	0.209	-0.040	(0.750)	0.034	-0.033
Portfolio Management4*	0.116	-0.397	-0.405	0.475	(0.632)	-0.641	0.095
Portfolio Management5*	0.592	-0.328	-0.326	0.154	(0.569)	-0.240	-0.188
Portfolio Management6*	0.176	0.017	-0.153	-0.260	(0.733)	0.215	0.087
Implement1*	-0.097	0.377	-0.197	0.409	0.181	(0.700)	-0.122
Implement2*	0.073	0.313	0.208	-0.368	0.111	(0.755)	0.105
Implement3*	-0.426	0.405	-0.164	0.236	-0.204	(0.806)	-0.174
Implement4*	-0.095	-0.140	0.034	-0.072	-0.130	(0.802)	0.047
Implement5*	0.487	-0.470	0.205	-0.299	-0.108	(0.781)	-0.112
Implement6*	0.064	-0.430	-0.092	0.114	0.177	(0.808)	0.242
HR Management1*	0.102	0.330	0.214	-0.016	-0.280	-0.105	(0.661)
HR Management2*	0.385	-0.314	0.317	-0.047	-0.044	-0.166	(0.872)
HR Management3*	-0.172	-0.040	-0.024	-0.053	-0.091	0.240	(0.899)
HR Management4*	-0.170	0.116	-0.053	-0.007	-0.074	0.276	(0.906)
HR Management5*	-0.226	0.034	-0.251	0.079	0.221	-0.162	(0.822)
HR Management6*	0.134	-0.062	-0.208	0.060	0.279	-0.175	(0.682)

*: P values <.001

Table 6.8: Indicators loading on their constructs (after removing indicators with low factor loading)

	Radical	Incremental	Innov Strty	IdeaMgmt	Portfolio	Implementation	HR
Rad1	(0.816)	0.140	-0.056	-0.138	0.261	-0.154	-0.090
Rad2	(0.843)	-0.001	-0.168	0.051	0.090	-0.286	0.096
Rad3	(0.632)	0.047	-0.451	0.170	-0.336	-0.000	0.501
Rad5	(0.585)	0.142	0.102	-0.277	-0.406	0.562	-0.156
Rad6	(0.863)	0.096	0.019	0.143	-0.209	0.012	-0.237
Rad7	(0.800)	-0.150	0.278	-0.096	0.252	0.158	-0.017
Rad8	(0.659)	0.259	-0.134	0.095	-0.084	0.084	-0.162
Rad9	(0.756)	-0.475	0.347	0.019	0.257	-0.204	0.121
Inc1	-0.152	(0.853)	-0.265	0.263	-0.155	-0.234	0.244
Inc2	-0.168	(0.770)	0.040	-0.223	-0.134	0.449	-0.102
Inc7	0.558	(0.607)	0.097	-0.003	0.389	-0.525	0.055
Inc3	-0.218	(0.647)	0.211	-0.079	-0.001	0.266	-0.252
Inov Strty1	0.523	-0.360	(0.780)	-0.129	0.302	-0.092	0.388
Inov Strty2	0.113	-0.087	(0.896)	-0.098	-0.050	0.001	0.094
Inov Strty3	-0.108	0.173	(0.800)	-0.106	0.004	0.010	-0.122
Inov Strty4	-0.195	0.220	(0.767)	0.003	-0.045	-0.150	-0.288
Inov Strty5	-0.323	0.060	(0.845)	0.321	-0.188	0.210	-0.080
IdeaMgmt1	0.174	0.056	0.183	(0.772)	0.752	-0.503	-0.285
IdeaMgmt2	0.601	-0.525	0.236	(0.728)	0.340	-0.608	-0.251
IdeaMgmt3	-0.241	0.029	-0.214	(0.783)	-0.596	0.265	0.397
IdeaMgmt4	-0.215	0.211	-0.021	(0.796)	-0.501	0.671	0.241
IdeaMgmt6	-0.298	0.209	-0.180	(0.712)	0.053	0.126	-0.140
PortfolioMgmt2	-0.163	-0.051	0.489	-0.272	(0.789)	0.464	0.026
PortfolioMgmt3	-0.310	0.352	0.235	-0.024	(0.704)	0.106	0.038
PortfolioMgmt4	-0.012	-0.198	-0.403	0.426	(0.616)	-0.568	0.176
PortfolioMgmt5	0.398	-0.109	-0.336	0.213	(0.626)	-0.253	-0.243
PortfolioMgmt6	0.135	-0.023	-0.119	-0.211	(0.777)	0.087	-0.004
Implement1	-0.148	0.471	-0.230	0.536	0.008	(0.700)	-0.177
Implement2	0.163	0.145	0.251	-0.318	0.201	(0.755)	-0.003
Implement3	-0.362	0.243	-0.154	0.230	-0.278	(0.806)	-0.131
Implement4	-0.107	-0.035	-0.023	-0.058	-0.259	(0.802)	0.097
Implement5	0.427	-0.396	0.207	-0.365	0.021	(0.781)	-0.094
Implement6	0.031	-0.369	-0.059	0.013	0.318	(0.808)	0.281
HRMgmt1	0.142	0.225	0.213	-0.057	-0.362	-0.038	(0.661)
HRMgmt2	0.352	-0.247	0.325	-0.112	-0.006	-0.177	(0.872)
HRMgmt3	-0.150	-0.105	-0.019	-0.062	-0.058	0.216	(0.899)
HRMgmt4	-0.127	0.068	-0.037	0.025	-0.044	0.234	(0.906)
HRMgmt5	-0.232	0.023	-0.270	0.097	0.083	-0.154	(0.822)
HRMgmt6	0.058	0.118	-0.222	0.129	0.394	-0.146	(0.682)

All the loadings are significant at P<.001

Table 6.9: Correlation between constructs (values on the diagonal of the table are the square root of AVE for each construct)

	1	2	3	4	5	6	7	8	9	10	11
1. Radical	(0.751)										
2. Incremental	0.517	(0.726)									
3. Innovation Strategy	0.572	0.510	(0.819)								
4. Idea Management	0.460	0.501	0.711	(0.759)							
5. Portfolio Management	0.236	0.381	0.526	0.519	(0.706)						
6. Implementation	0.379	0.391	0.623	0.656	0.695	(0.776)					
7. Human Resource	0.504	0.515	0.672	0.673	0.580	0.661	(0.813)				
8. BCent	0.052	0.003	0.082	0.055	0.111	0.113	-0.040	(1.000)			
9. Density	0.052	-0.055	0.086	0.016	-0.075	-0.035	0.004	-0.187	(1.000)		
10. Density^2	-0.140	-0.077	-0.227	-0.200	-0.090	-0.098	-0.171	-0.492	0.000	(1.000)	
11. Weak Ties	0.246	0.106	0.107	-0.073	0.066	-0.048	0.068	0.455	0.149	-0.406	(1.000)
12. Tie DV	0.248	0.053	0.001	0.053	-0.024	0.030	0.197	0.172	0.212	-0.096	0.140
13. Node DV	0.161	0.136	0.146	0.083	0.167	0.108	0.158	0.549	0.217	-0.402	0.610
14. DCent^2	0.139	0.077	0.131	0.119	0.022	0.083	-0.077	-0.142	-0.158	0.218	-0.307
15. DCent	0.156	0.088	0.183	0.154	0.164	0.164	0.030	0.863	0.169	-0.482	0.527
16. Strong Ties	0.315	0.376	0.189	0.361	0.056	0.221	0.215	0.306	0.328	-0.115	0.208
17. Industry	-0.360	-0.294	-0.232	-0.255	-0.247	-0.147	-0.139	-0.118	-0.075	0.059	-0.080
18. Age	-0.454	-0.183	-0.378	-0.285	-0.059	-0.321	-0.340	-0.056	-0.013	0.144	-0.011
19. Qualification	0.437	0.389	0.488	0.369	0.314	0.447	0.375	0.207	0.032	-0.251	0.177
20. Size	0.092	0.055	0.113	-0.019	0.227	0.040	0.081	0.353	-0.042	-0.323	0.486
21. RDIntensity	0.262	0.382	0.266	0.185	0.193	0.179	0.212	0.148	-0.075	-0.122	0.073
22. BCent^2	0.084	-0.084	0.047	0.015	-0.009	0.021	-0.179	0.678	-0.004	-0.149	0.216

	12	13	14	15	16	17	18	19	20	21	22
1. Radical											
2. Incremental											
3. Innovation Strategy											
4. Idea Management											
5. Portfolio Management											
6. Implementation											
7. Human Resource											
8. BCent											
9. Density											
10. Density^2											
11. Weak Ties											
12. Tie DV	(1.000)										
13. Node DV	0.372	(1.000)									
14. DCent^2	-0.333	-0.385	(1.000)								
15. DCent	0.239	0.689	0.000	(1.000)							
16. Strong Ties	0.319	0.413	0.071	0.559	(1.000)						
17. Industry	-0.212	-0.024	-0.215	-0.182	-0.264	(1.000)					
18. Age	0.088	0.029	-0.094	-0.012	-0.212	0.237	(1.000)				
19. Qualification	0.074	0.119	0.163	0.274	0.350	-0.584	-0.456	(1.000)			
20. Size	0.271	0.326	-0.286	0.295	-0.085	-0.073	0.332	0.010	(1.000)		
21. RDIntensity	0.111	0.101	-0.072	0.115	0.124	-0.306	-0.136	0.119	0.265	(1.000)	
22. BCent^2	0.011	0.214	0.486	0.729	0.381	-0.251	-0.055	0.225	0.101	0.036	(1.000)

6.5.2. Construct Reliability

To test the reliability of the measures used in the questionnaire, internal consistency method was employed. This method assesses the inter-correlation of the items in a measure and ensures that all the items are measuring the same construct. The Cronbach's alpha and composite reliability test was conducted to test the reliability of the constructs. Table 6.10 shows the values of the tests for each latent variable. Cronbach's alpha value should be above 0.6 (Nunnally and Bernstein 1994) and composite reliability should be above 0.7 for all the latent variables (Hair *et al.* 2011). All the constructs met the minimum criteria and passed the reliability test.

Table 6.10: Values for reliability and validity test of the constructs

	Composite Reliability	Cronbach's Alpha	AVE
Radical	0.910	0.886	0.564
Incremental	0.814	0.691	0.527
Strategy	0.910	0.867	0.671
Idea	0.871	0.815	0.576
Portfolio	0.831	0.744	0.499
Implementation	0.901	0.867	0.603
HR	0.920	0.893	0.661

All the tests that have been conducted were successful which leads to the conclusion that the measures developed for this study including radical and incremental innovation were valid, reliable and internally consistent.

6.6. Model Evaluation: Structural Model Results

After examining the appropriateness of the measurement model, the next step in the analysis was to provide evidence supporting the theoretical model as demonstrated in the structural model. In WarpPLS p-values are estimated for the paths in the model and used to test the significance of the relationships. In social science the significance level is $\alpha = 0.05$ and if P-value is less than α then the null hypothesis is rejected at that level of statistical significance. This means that the probability of the null hypothesis being supported is less than 5% (Kline 2004).

A hierarchical method was employed to test the effect of each set of the variables and their significance in the final model. Also to test the inverse U-shape relationships, in addition to the significance of path, the significance of the R^2 change before and after including the squared value of the variables to the model should be examined. First, the baseline model was established using the control variables of the study (Model 1). Model 2 includes innovation management variables in addition to the control variables. In the next stage network variables of the study were added to the base model (Model 3) and in the last stage all the variables were added to the model for the hypothesis test (Model 4). The significance of the relationships was tested using the Bootstrap approach (Chin 1998). The number of resamples for bootstrap algorithm was 100. Table 6.11 represents the result of the analysis in each step. Conclusions were made based on the full model (Model 4).

Figure 6.3 presents the final model (model 4) which includes all the variables and links between the variables. Latent variables are represented by ovals. Solid lines show the hypothesised relationships and dotted lines are the relations between control variables and dependent variables. The hypotheses that were supported are shown in bold type and the β coefficient is shown.

One of the control variables showed a negative effect on radical innovation performance. Company age was negatively related to radical innovation ($\beta = -.280$, $P < .05$) implying that younger companies perform better in radical innovation compared to older companies.

Table 6.11: Result of the analysis

Variables	Incremental Innovation				Radical Innovation			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Control Variables								
Industry	.027	-.005	.069	.034	-.121	-.228*	-.037	-.112
Company Age	.059	.157	.063	.142	-.394**	-.242*	-.414**	-.280*
Size	-.064	-.118	.082	-.014	.185*	.145	.107	.035
Employee Qualification	.388**	.232*	.342***	.189	.173	-.017	.182	-.018
R&D Intensity	.369*	.292	.335*	.265	.101	.015	.137	.057
Innovation Management								
Portfolio Management		.057		.149		-.216*		-.125
Innovation Strategy		.127		.213		.313*		.325**
Human Resource		.272*		.196		.249*		.059
Idea Management		.184		.063		.041		.131
Implementation		-.130		-.141		.03		.069
Network Properties								
Degree Centrality			-.283*	-.242				
Degree Centrality ^{^2}			.061	.044				
Number of Strong Ties			.407**	.365**				
Betweenness Centrality							-.471***	-.381**
Betweenness Centrality ^{^2}							.238*	.217*
Density							-.143	-.168*
Density ^{^2}							-.023	.031
Diversity of Nodes							.099	.020
Diversity of Ties							.257**	.260**
Number of Weak Ties							.222	.313*
ΔR^2		.166***	.97**	.230***		.144***	.110*	.238***
R^2	.270	.436	.367	.500	.342	.486	.452	.580

* P < .05, ** P < .01, *** P < .001

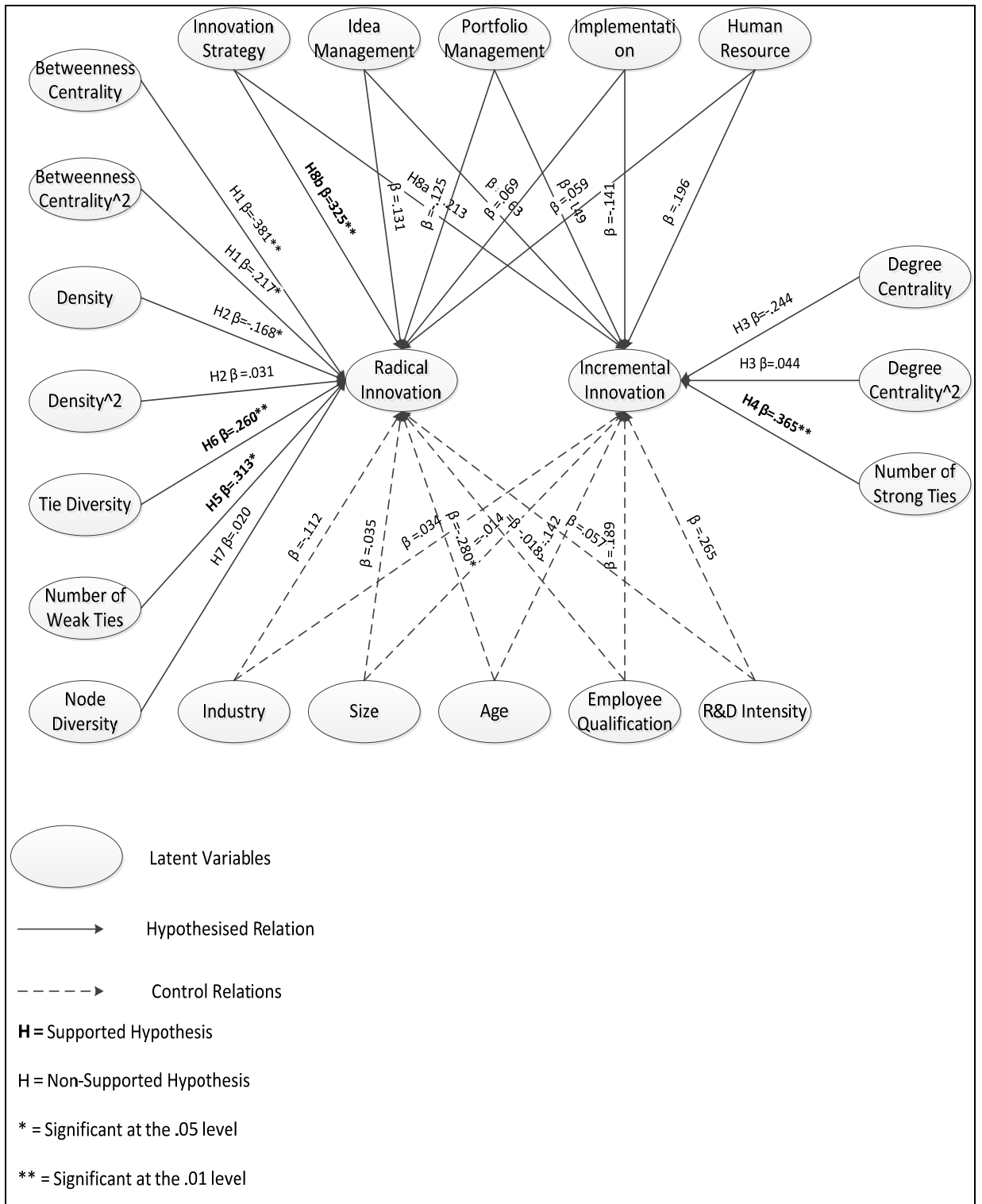


Figure 6.3: Final PLS model of the study

The first hypothesis (H1) was radical innovation performance has an inverse U-shaped relationship with betweenness centrality. The relationship with the linear term and the quadratic term is significant; however this is not sufficient to test the hypothesis. As suggested by Chin *et al.* (2003) a hierarchical approach was employed to test this relationship in which the first model was estimated with the main effect and another model with the quadratic term. Then the two models (with and without quadratic term) were examined to see whether they were significantly different in terms of explained variance (Chin *et al.* 2003). An incremental F-test (Tabachnick and Fidell 2007) was employed to examine whether the quadratic term added explanatory power to the final model. The F-test revealed that the difference between two models was significant ($R^2(\text{without quadratic term}) = .560$; $R^2(\text{with quadratic term}) = .580$; $F(1, 86) = 4.095$, $P < .05$). However, the beta coefficient between betweenness centrality and radical innovation is negative and beta coefficient between its square value and radical innovation is positive. This means that the relation between betweenness centrality and radical innovation is a U-shape relationship (counter to the developed hypothesis). Therefore hypothesis 1 was not supported.

For the second hypothesis (H2) the relation between density and radical innovation performance was significant but the relation between the squared term and radical innovation performance was not significant, therefore the inverse U-shape relation between density and radical innovation was not supported (Hypothesis 2). Also the inverse U-shape relationship between number of partners and incremental innovation performance was not supported (H3). Hypothesis 4, incremental innovation performance has positive a relationship with number of strong ties, was supported ($\beta = .365$, $P < .01$). Hypothesis 5, radical innovation performance has a positive relationship with number of weak ties, was also supported ($\beta = .313$, $P < .05$). The findings shows support for hypothesis 6, radical innovation performance has a positive relationship with diversity of

ties ($\beta = .260$, $P < .01$). Finally hypothesis 7, radical innovation performance has a positive relationship with diversity of partners, the relationship was not significant and thereby hypothesis 7 was not supported.

Table 6.12: Summary of hypothesis test result

H#	Hypothesis	Result
H1	Radical innovation performance has an inverse U-shaped relationship with betweenness centrality of a company	Not Supported
H2	Radical innovation performance has an inverse U-shaped relationship with network density of a company	Not Supported
H3	Incremental innovation performance has an inverse U-shaped relationship with degree centrality of a company	Not Supported
H4	Incremental innovation performance has a relationship with number of string ties of a company	Supported
H5	Radical innovation performance has a positive relationship with number of weak ties of a company	Supported
H6	Radical innovation performance has a positive relationship with diversity of ties of a company	Supported
H7	Radical innovation performance has a positive relationship with diversity of partners of a company	Not Supported
H8a	Incremental innovation performance has a positive relationship with innovation strategy of a company	Not Supported
H8b	Radical innovation performance has a positive relationship with innovation strategy of a company	Supported
H9a	Incremental innovation performance has a positive relationship with the level of idea management of a company	Not Supported
H9b	Radical innovation performance has a positive relationship with the level of idea management strategy of a company	Not Supported
H10a	Incremental innovation performance has a positive relationship with the level of portfolio management of a company	Not Supported
H10b	Radical innovation performance has a positive relationship with the level of portfolio management of a company	Not Supported
H11a	Incremental innovation performance has a positive relationship with procedures for implementation of ideas of a company	Not Supported
H11b	Radical innovation performance has a positive relationship with procedures for implementation of ideas of a company	Not Supported
H12a	Incremental innovation performance has a positive relationship with the level of human resource management of a company	Not Supported
H12b	Radical innovation performance has a positive relationship with the level of human resource management of a company	Not Supported

Out of the ten hypotheses on innovation management practices only one hypothesis was supported. Innovation strategy was positively and significantly related to radical

innovation ($\beta = .325$, $P < .001$) which means hypothesis 8b was supported. However, innovation strategy was not significantly related to incremental innovation performance; therefore hypothesis H8a was not supported. Idea management, portfolio management, implementation and human resource management were not significantly related to radical or incremental innovation and therefore hypotheses H9a, H9b, H10a, H10b, H11a, H11b, H12a and H12b were not supported.

Comparing the explained variance between different models revealed that adding each set of variables significantly improve the explanatory power of the model, which suggests that these variables significantly contribute to explaining firm's incremental and radical innovation performance. All subsequent models add significant explanatory value when compared to the model1 in both incremental and radical innovation. For both types of innovation the variables in full model (model 4) contribute significantly to the explanatory power (ΔR^2 (Incremental) = .230, ΔR^2 (Radical) = .238). Table 6.12 shows a summary of the result of the hypotheses testing.

6.7. Effect Size and Sample Size

One aspect of published research that is usually subject to debate by scholars is relying on statistical tests and not taking into account the effect sizes. Chin and Newsted (1999) in a comparison of the required minimum sample size for PLS and CB-SEM clearly mentioned that sample size for PLS model requires a power analysis based on the portion of the model that has the highest number of predictors (p. 314). In addition to this, there are editorials (Marcoulides *et al.* 2009, Marcoulides and Saunders 2006) that explain the necessity of conducting a power analysis instead of using the 10 cases per indicator rule of thumb. Kline (2009) describe not reporting the effect size in studies as a defect in research studies report. Therefore it is necessary for this study to report the effect size information. Effect size is defined as “the magnitude of the impact of the independent

variable on the dependent variable” (Kline 2009, p. 153). As it is explained in the previous chapter, in PLS analysis only the part with largest number of predictors is important in determining the adequate sample size. The logic behind this rule of thumb is that at any one time, only one part of the model is involved in the analysis. Therefore, having enough cases to satisfy the part with highest number of predictors, means that there are enough cases for the analysis. Based on this the recommended method for determining effect size is to look at the portion of the model that requires the largest multiple regression. Chin and Newsted (1999) recommend finding the largest of the following:

1. The block with the highest number of formative indicators
2. The dependent latent variable with the largest number of independent variables affecting it

To determine the accurate estimate of the sample size, researchers should specify the effect size and use Cohen’s (1988) or Green’s (1991) power tables. In this study there are two dependent variables (radical innovation performance and incremental innovation performance) that each of them have 17 and 13 independent variables affecting them respectively. In order to calculate the effect size, researcher must look at the R^2 value of the dependent variables. Cohen (1988) introduced three level of effect size for small, medium and large effect which are R^2 s of .02, .13, and .26 respectively. Going back to the result of the study (table 6.11), R^2 value for incremental innovation performance was .500 and for radical innovation performance was .580. Both of these constitute large effect size in accordance to Cohen’s guidelines. In order to determine the appropriate sample size, the number of predictors of each dependent variable was matched to table 6.13 which is Green’s condensed version of Cohen’s table.

The table shows the sample size that is required to conduct a hypothesis test with power of .80. According to the table, the number of predictors for each variable and power of the study, the necessary sample size to conduct the analysis is between 67 and 77 which is below the sample size that has been used in this study ($N = 103$). The detail information of the sample size requirement for each dependent variable in this study can be found in table 6.14.

Table 6.13 Sample size required to test the hypothesis with a power of .80 (Alpha = .05) (Green 1991)

Number of Predictors	Effect Size		
	Small	Medium	Large
1	390	53	24
2	481	66	30
3	547	76	35
4	599	84	39
5	645	91	42
6	686	97	46
7	726	102	48
8	757	108	51
9	788	113	54
10	844	117	56
15	952	138	67
20	1066	156	77
30	1247	187	94

Table 6.14 Detail of the sample size requirement for this study

	Incremental Innovation	Radical Innovation
R²	.500	.580
Number of Predictors	13	17
Effect Size	Large	Large
Sample Size	56 - 67	67 - 77

6.8. Summary

This chapter provided detailed explanation on the statistical methods that have been used to analyse the data and test the hypotheses of the research. Preliminary analysis on respondent characteristics and non-response bias test confirmed the suitability of the data for further analysis. Data was screened and tested for missing values and normality. Reliability and validity (including convergent validity, discriminant validity and composite reliability) of the constructs were examined during the measurement evaluation stage. In the model evaluation stage the hypotheses of the study were tested and the overall framework was examined. The last part of the chapter was dedicated to the effect size of the study and sufficiency of sample size.

In the next chapter, data is analysed using a different approach called fsQCA (as explained in Chapter 5). Using fsQCA the interaction between different causal and outcome factors will be examined. Using the same theoretical foundation, different combinations of network characteristics and innovation management practices are examined to find out which combination of these factors leads to higher performance in radical/incremental innovation.

7. Chapter 7: Data Analysis Using FsQCA

7.1. Introduction

This chapter employs a new approach to analyse the data and looks at the data from a different perspective to shed more light on the factors that contribute to the radical and incremental innovation performance of companies. First, an introduction about the adopted method and its different stages is provided. Then the detail of the analysis of the data using this method is explained.

7.2. Fuzzy set Qualitative Comparative Analysis

In order to examine the causal relation of organisations' social network characteristics and innovation management practices with their radical and incremental innovation performance, this study employs the Fuzzy Set Qualitative Comparative Analysis (fsQCA) method. This method is based on set-theoretic and was first developed by Charles Ragin in 1987. Conventional statistical methods look for net-additive and the independent effect of variables; however, fsQCA is designed to unravel the relationship between cause and outcome using set theoretic concepts (Ragin 2008a, Rihoux and Ragin 2009). FsQCA itself is based on a method named QCA. In QCA the cause and outcome in each case are assigned values of 0 or 1 and the rest of the analysis is based on these new values. In fsQCA the use of fuzzy sets is combined with the analysis of cases as configurations. In this approach the values are ranged from 0 to 1, based on the degree of membership of each case in different combinations of causal conditions (Ragin 2008a). These calibrated values are used for the rest of the analysis and they will be examined for the necessity of their inclusion in achieving an outcome. Then the conditions are

compared with other conditions to decide which ones are adequate for the outcome. At the end, using Boolean algebra, all the sufficient and necessary conditions are reduced to create a set of combinations of the causes that lead to the outcome (Rihoux and Ragin 2009).

7.2.1. Transforming Data into Fuzzy Set

In this study, according to the reviewed literature and the developed framework, the network characteristics and innovation management practices are the causal conditions and the radical and incremental innovation performances are the outcome conditions. As described earlier, the first step in fsQCA analysis is calibrating the causal and outcome conditions. In this research the direct method was adopted as the method of calibration (Ragin 2008a). In direct method the conditions are calibrated using the following three qualitative anchors: the threshold for full membership (0.95), the threshold for full non-membership (0.05), and the cross-over point (0.5) (Ragin 2008a). The variables are convertible to fuzzy set membership using the 'calibrate' function available in fsQCA software (Ragin 2008b). To calibrate the variables the researcher has to develop a breakpoint for each of the anchors which must be based on a rationale (Ragin 2008a). For those variables based on a Likert scale (radical and incremental innovation performance and innovation management practices variables) the original values of 5, 3, and 1 were set as full membership, cross-over point and full non-membership respectively. As previously explained, imposing the thresholds by the researcher should be based on substantive expertise and knowledge. In this study it is difficult to determine subjectively what constitutes, for example, high betweenness centrality or low diversity of ties. A thorough literature review seeking to find any relevant literature about this issue was unsuccessful. Therefore, following the suggestions of Rihoux and Ragin (2009) in this research the distribution in each condition was used as a guideline to set the threshold points. Cluster-analysis function in the Tosmana (Cronqvist 2005) 'Thresholdsetter',

software for Multi Value Qualitative Comparative Analysis (MVQCA), was used in order to find the gaps according to the distribution of the conditions. This function calculates the distribution of scores arithmetically and clusters them into a number of groups that have been set (in this research it is 3). Therefore the data was first imported into Tosmana to determine the anchor points for calibration of each network variable. Then the data was imported into fsQCA (Ragin *et al.* 2006) software for fuzzy set qualitative comparative analysis, for calibration and the next steps of the analysis. Table 7.1 shows the anchor point of each network variable acquired from Tosmana.

Table 7.1: Anchor points for calibrating the network variables

Variable	Range	0.05	0.5	0.95
Betweenness centrality	0 – 45	8.5	17	31
Degree Centrality	0 – 10	1.5	3.5	8
Tie Diversity	0 – 4	.5	1.5	3.5
Density	0 – 1	.09	.53	.83
Strong Ties	0 – 8	1.6	3.5	7
Weak Ties	0 – 4	0.5	2.5	3.5
Node Diversity	0 – 8	0.5	2.5	5.5

7.2.2. Constructing the Truth-Table

The next step of the fsQCA is constructing the truth table. There are three conditions that are important in constructing a crisp truth table based on fuzzy set membership score: (1) The direct relationship between the rows of the crisp truth table and the possible combination of causal conditions (or corners of the vector space defined by fuzzy set causal conditions) (2) The distribution of cases across different combinations of the causal conditions, and (3) The consistency of the causal combination in which each causal condition should be a subset of the outcome (Ragin 2008a).

First, the number of rows in the truth table is equal to the possible combinations of the causal conditions. The number of combinations of the causal conditions is equal to 2^k , where k is the number of causal conditions (Ragin 2008a). In this study the number of rows of the initial truth table was 2^{10} (k = relevant network characteristics and innovation management practices) for radical innovation truth table and 2^7 for incremental innovation truth table. However, since not all the possible combinations are present in the cases, there were some rows with zero number of cases representing them; these are called remainders (Ragin 2008a). Therefore, it was necessary to find a threshold value for the number of cases to reduce the truth table.

Second, the key task in this step is choosing a threshold value for the number of cases that represents each corner of the vector space. Ragin (2008a) suggests that when there is a limited number of cases available then the threshold value should be 1 or 2. For a higher number of cases the threshold value should be higher. Fiss (2011) in a study with 205 cases used the threshold value of three. In this research there are 103 cases available. Based on the guideline by Ragin (2008a) and the study by Fiss (2011) a threshold value of 2 was set.

Third, it is necessary to choose a threshold for the consistency values of the configurations in the truth table. The configurations with consistency values above the threshold are coded 1 and those below the threshold are coded 0 (Ragin 2008a). Ragin (2008a) suggests that gaps in the high consistency values are useful for establishing a consistency threshold and those below 0.75 show substantial inconsistency. In this research the consistency threshold was 0.9 for radical innovation and 0.98 for incremental innovation. For radical innovation 11 cases were coded 1 and two cases were coded 0. For incremental innovation there were 15 cases all of which were coded 1. Table 7.2 and table 7.3 report the results of the set-theoretic consistency assessment for the cases that

meet the strength of evidence threshold (configurations with 2 or more cases and consistency value above the explained threshold).

7.3. Findings

Ragin (2008b) in the fsQCA user manual explains that the software provides three solutions in the output: (1) Complex solution (solution without logical remainder), (2) intermediate solution (solution including logical remainders that make sense), and (3) parsimonious solution (solution with all logical remainders without evaluation of their plausibility). However, it is suggested that researchers interpret intermediate solutions since they do not allow removal of necessary solutions (Ragin 2008a). Due to this, only the intermediate solutions are interpreted in this research.

Table 7.4 summarises the intermediate solution for radical innovation as the outcome. Black circles represent the presence of the causal condition and white circles represent the absence or negation of causal conditions. For example, solution 3 in the table signals a logical statement “Strategy•Idea•Portfolio•Implementation•~HR•~Betweenness Centrality•Tie Diversity•~Node Diversity” where “~” represents the negation of fuzzy set and “•” represents the operation of logical AND on fuzzy set.

Table 7.2: Radical innovation truth table

fstrategy	fidea	fportfolio	fimplement	fhr	fbcent	ftiedv	fdensity	fweak	fnodedv	number	frad	Raw consist.
1	1	1	1	0	1	0	0	0	1	2	1	1
1	1	0	1	1	0	1	1	1	1	2	1	1
1	1	1	1	1	0	1	0	1	1	3	1	0.99
1	0	1	0	0	0	0	0	1	1	2	1	0.98
1	1	1	0	0	0	1	0	1	1	3	1	0.97
0	0	0	0	0	0	1	0	0	1	3	1	0.96
1	1	1	1	0	0	1	0	0	0	2	1	0.94
1	0	0	0	0	0	1	0	0	0	3	1	0.94
1	1	1	1	1	0	1	0	0	0	8	1	0.92
1	1	1	1	1	0	0	0	0	0	3	1	0.91
1	1	1	1	0	0	1	1	0	0	2	1	0.90
0	0	0	0	0	0	1	0	0	0	5	0	0.87
0	1	0	0	0	0	0	0	0	0	2	0	0.84

Table 7.3: Incremental innovation truth table

fstrategy	fidea	fportfolio	fimplement	fhr	fdcent	fstrong	number	finc	Raw consist.
1	1	0	1	0	1	1	2	1	1
1	0	1	0	0	0	0	2	1	1
1	1	1	1	0	1	0	4	1	1
1	1	1	1	1	0	1	2	1	1
1	1	1	0	0	1	0	4	1	1
1	1	1	1	1	1	1	3	1	1
1	0	0	0	0	1	0	2	1	0.99
1	1	1	1	1	1	0	5	1	0.99
1	1	0	1	1	1	0	2	1	0.99
1	1	1	1	0	0	0	3	1	0.99
0	0	0	0	0	0	0	4	1	0.98
0	1	0	0	0	0	0	3	1	0.98
1	1	1	1	1	0	0	10	1	0.98
1	0	0	0	0	0	0	3	0	0.96
0	0	0	0	0	1	0	4	0	0.96

Table 7.4: Configurations for higher radical innovation performance

	Solutions								
	1	2	3	4	5	6	7	8	9
Innovation Management Practices									
Strategy		●	●	●	●	●	●	●	●
Idea	○	○	●	●	●	○		●	●
Portfolio	○	○	●	●	●	●	●	●	○
Implementation	○	○	●	●	●	○	○	●	●
HR	○	○	○	●	○	○	○	●	●
Social Network Properties									
Betweenness Centrality	○	○	○	○	●	○	○	○	○
Tie Diversity	●	●	●				●	●	●
Density	○	○		○	○	○	○	○	●
Weak Ties						●	●	●	●
Node Diversity	●		○	○	●	●	●		●
Raw Consistency	0.96	0.94	0.92	0.90	1	0.97	0.97	0.97	1
Raw Coverage	0.24	0.31	0.40	0.47	0.06	0.21	0.21	0.26	0.11
Unique Coverage	0.01	0.03	0.03	0.12	0.03	0.01	0.00	0.02	0.01

Solution coverage: 0.735183

Solution consistency: 0.898899

“●” : Presence of the causal conditions.

“○” : Absence or negation of the causal conditions.

The blank cells represent ‘don’t care’ conditions.

Table 7.5 summarises the intermediate solution for incremental innovation as the outcome. For all the solutions (complex, parsimonious and intermediate) for both radical and incremental innovation see appendix E.1 and E.2.

In addition to the configurations, each table includes information on raw consistency, raw coverage, unique coverage, solution coverage, and solution consistency. The consistency measure is similar to correlation estimates in statistical hypothesis testing (Woodside *et al.* 2011). Consistency measures the degree to which the configurations are subsets of the outcome. In other words, consistency is the degree to which cases sharing the same combination of conditions have the same outcome in question (Ragin 2008a). Coverage

values are similar to effect size estimate in statistical analysis (Woodside *et al.* 2011). Coverage is the degree to which the cases are covered by a specific configuration (Ragin 2008a). Raw consistency is the consistency of each configuration and solution consistency is the consistency of the whole solution. Solution coverage is the coverage of the cases by the whole solution and unique coverage is the coverage of the outcome that is covered only by each solution.

Table 7.5: Configurations for higher incremental innovation performance

	Solutions						
	1	2	3	4	5	6	7
Innovation Management Practices							
Strategy	●	○	●	●	●	●	●
Idea	●		●	●	●	○	○
Portfolio	●	○	●			○	●
Implementation	●	○		●	●	○	○
HR		○	○		●	○	○
Social Network Properties							
Degree Centrality		○	●	●	●	●	○
Strong Ties				●			
Raw Consistency	0.97	0.95	1	1	0.98	0.99	1
Raw Coverage	0.65	0.37	0.27	0.11	0.29	0.18	0.32
Unique Coverage	0.18	0.09	0.01	0.00	0.00	0.00	0.01

Solution coverage: 0.811624

Solution consistency: 0.958704

“●” : Presence of the causal conditions.

“○” : Absence or negation of the causal conditions.

The blank cells represent ‘don’t care’ conditions.

A careful inspection of the coverage and consistency values of tables 7.4 and 7.5 revealed that there are configurations with a unique coverage close to zero. This means the outcome of these configurations has already been covered in other configurations in the solution. In the solution for radical innovation, configuration 7 shows 0 unique coverage and the raw coverage is only 0.21. This configuration was not interpreted in the final

result due to its low effect in the solution. There are more configurations with this problem in the solution for incremental innovation. Unique coverage for configurations 4, 5 and 6 are 0 and the raw coverage of these configurations are also low (below 0.3). Although the unique coverage for these configurations is zero only one of them can be removed from the solution without affecting the result because some of these solutions may cover each other's cases and removing all three cases may result in removing some of the cases from the solution.

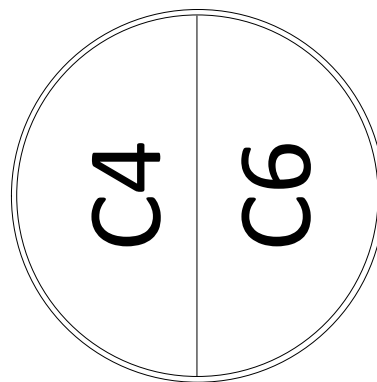


Figure 7.1: Illustration of possible coverage of configurations 4, 5 and 6

Figure 7.1 illustrates the plausible situation that removing all three configurations may eliminate some of the cases from the solution. In this figure, assume that the outer circle is configuration 5 and the other two semi-circles inside are configurations 4 and 6. In this situation the unique coverage of each configuration is zero because they are covered by other configurations. However, removing all three may also cause a problem. Therefore only one of the configurations with the lowest raw coverage (solution 4) was removed from the solution since it is already covered by other configurations in the solution.

Before explaining the result of the study it is necessary to bear in mind that the negative sign for innovation management practices means that their absence is important in the outcome; however the interpretation is different for network variables. In the calibration stage the anchor points for network variables were chosen based on the distribution of

cases with a high value for each network characteristic (for example high network density). Therefore the negative sign in the result for network variable is in fact a low value of that network variable in that configuration (for example Density means high density and ~Density means network with low density).

7.3.1. Radical Innovation

Table 7.4 reports that all consistency values are above 0.9 or 0.8, indicating that these configurations are sufficient conditions causing high radical innovation performance. Solution coverage is above 0.7 which indicates that the solution explains a large proportion of radical innovation performance. In terms of raw coverage, the higher the raw coverage indicates that the configuration explains a larger proportion of the radical innovation performance.

Solutions 4 and 8 show that companies that have all innovation management practices in place, as well as low betweenness centrality and low density network, coupled with low node diversity or high number of weak ties and tie diversity have higher radical innovation performance.

Solution 5 indicates that the presence of strategy, idea, portfolio, implementation and absence of HR coupled with high betweenness centrality and node diversity and low density will result in higher performance in radical innovation. Solution 3, similar to solution 5, suggests that the presence of strategy, idea, portfolio and implementation and absence of HR together with low betweenness centrality, node diversity and high tie diversity will result in better radical innovation performance. In contrast, configurations 1 and 2 indicate that low betweenness centrality, density and high tie diversity together with innovation strategy or node diversity in the absence of other innovation management practices will lead to high radical innovation performance.

Combination number 6 suggests that the presence of strategy and portfolio management together with low betweenness centrality, density and high number of weak ties and node diversity in the absence of other innovation management practices will lead to high radical innovation performance. The last configuration for high radical innovation performance is configuration 9 which indicates that in a dense network the presence of strategy, idea management, implementation and HR together with low betweenness centrality and high tie diversity, high number of weak ties and high node diversity will lead to higher radical innovation performance.

7.3.2. Incremental Innovation

Table 7.5 reports that all consistency values are above 0.95, indicating that these configurations are sufficient conditions causing high radical innovation performance. Solution coverage is above 0.8 which indicates that the solution explains a large proportion of incremental innovation performance. In terms of raw coverage, the higher the raw coverage indicates that the configuration explains a larger proportion of the radical innovation performance.

Configuration 1, which has the highest unique and raw coverage in the solution, indicates that the presence of strategy, idea, portfolio and implementation will lead to higher incremental innovation performance. In contrast with configuration 1, configuration 2 implies that a lower degree centrality can solely create high incremental innovation performance given the absence of other factors.

Configuration 6 suggests that the presence of strategy and high degree centrality and the absence of other innovation management practices is another way of achieving high incremental innovation performance. Configuration 3 indicates that in addition to the factors that are present in configuration 6, companies need to have idea and portfolio management in place in order to improve their incremental innovation performance.

Configuration 5 indicates that strategy, idea, implementation and HR combined with high degree centrality can lead to high incremental innovation performance. The last configuration in the solution is configuration number 7. This configuration suggests that a combination of strategy, portfolio and low degree centrality in the absence of idea management, implementation and HR is another way of achieving high incremental innovation performance.

7.4. Summary

This chapter provided details on the different steps that have been taken to analyse the data using fuzzy set qualitative comparative analysis. A short introduction on fsQCA, its difference with QCA and an overview of the steps involved in the method was provided. Then the methods that have been employed in the transformation process were explained. Next, the detail on construction of the truth table was provided and the last part of the chapter was about the findings of the analysis.

The next chapter contains a detailed discussion of the findings of the two methods (statistical analysis and fuzzy set qualitative comparative analysis) and their relationship to each other.

8. Chapter 8: Discussion

8.1. Introduction

The aim of this chapter is to discuss the findings of the study presented in the two previous chapters. This chapter explains the result, its connections and contradictions to previous studies in detail. First the findings of the statistical analysis are discussed based on the hypotheses and theoretical framework of the study. The last part of the chapter explains the result of the analysis using fsQCA and how the findings of these two methods resonate with each other.

8.2. Discussion of the Statistical Analysis

This research began by observing two main streams of innovation studies. The first stream (more traditional organisational studies) focuses on firms' internal capabilities and resources for innovation. The second stream highlights the network of relationships that the company is embedded in which serves as both a resource and a medium to access external resources (Ahuja 2000, Gulati *et al.* 2000). Those research studies applying network concepts at the firm level mostly studied innovation as a general concept and failed to attend to the internal capabilities of firms in their studies. Studying network theory and innovation together with the internal capabilities of a company can provide a richer explanation of the firm level innovation outcome. In this research, the relation between network structure and specific types of innovation was explored. In addition to that, this study went beyond the assumptions that network characteristics alone can generate innovation by taking into account the internal capabilities of firms. In particular,

it examined how firms can benefit from their network structure in their radical and incremental innovation with innovation management practices in place.

8.2.1. Betweenness Centrality and Radical Innovation

The findings did not support the inverse U-shaped relationship between radical innovation and betweenness centrality. Although the relationships were significant, it was a U-shaped relationship which is in contrast with the developed hypothesis. There may be one plausible reason for this U-shaped relationship. The role of betweenness centrality within the ego network may be an important role only when the ego network becomes larger than a certain level. Networks with low betweenness centrality are scarce in the structural hole due to the connection between partners. This means that companies in that network do not have access to novel information. However, when betweenness centrality increases, the number of partners that are connected to each other will reduce and therefore access to novel information increases. This will provide firms with access to novel information and increase the chance for a novel combination of knowledge and consequently radical innovation.

A different reason that this hypothesis was not supported might be the measure that has been used for betweenness centrality, which is not the real measure of betweenness centrality. As explained in Chapter 4, the original measure of betweenness centrality was designed for sociocentric networks and since an egocentric approach was adopted in this research it was not possible to use that measure in this study. The measure for egocentric betweenness centrality gives a lower value than the original measure of betweenness centrality. This might be one of the reasons that the findings did not support this hypothesis.

8.2.2. Density and Radical Innovation

There was no support for the inverse U-shaped relationship between density and radical innovation performance. One reason might be that a network with high density is low in number of structural holes. Therefore the focal firm is limited in terms of access to novel information, which is an important factor for radical innovation. Zaheer and Bell (2005) argue that fast access to new knowledge is reflected in the company's new product and services. Therefore, since network closure limits the access to this information it is not contributing to radical innovation performance.

In contrast to the developed hypothesis, density was negatively and significantly related to radical innovation. This implies that a network with more connections between its ego partners negatively affects the radical innovation performance of the focal firm. This supports Burt's (1992) argument of structural holes and is in contrast to Colman's (1988) closure argument. From Burt's perspective, an ego network where the partners are not connected to each other is preferred over a network with highly connected partners. The structural hole argument states that increasing the density of the network will negatively influence performance. This is because the more interconnected the network, the fewer opportunities the companies have to access and broker unique information. Structural holes increase the ego access to diverse and novel information which is necessary for radical innovation.

This finding is also in contrast to Gilsing *et al.* (2008) who found an inverse U-shaped relation between density and exploration environment. One reason might be the global network density measure, used by them, in contrast with the local density measure which has been used in this study. This implies that lower interconnectedness between companies' immediate network partners and high interconnectedness in their sociocentric network is the ideal setting for radical innovation. Lower local density increases the chance of structural holes in the network and therefore access to novel information on

both sides of the relation. On the other hand higher global density (up to a threshold point) is beneficial by limiting the novelty and improving the absorptive capacity of the companies in the network. According to the findings of this research and the study by Gilsing *et al.* (2008) this network setting provides the ideal environment for exploration and radical innovation.

According to these findings, in order for companies to improve their radical innovation performance need to establish relation with companies that the company itself and its partners does not already have a relation and therefore increase the chance to access to novel information. In addition to that, they have to provide the environment (e.g. innovation strategy) to be able to absorb this knowledge and employ it in their innovation activities.

This findings although against the developed hypothesis, is significant due to the strong arguments in literature and statistical support behind it. Therefore it was decided to include this network characteristic in the framework.

8.2.3. Degree Centrality and Incremental Innovation

There was no support for a relationship between the number of partners (degree centrality) and incremental innovation. One reason might be that degree centrality only counts the number of partners and assumes that the partners are homogeneous and there is no difference between their abilities, resources and type of relationship such as strength of the relationship. In reality it is different and partners have different knowledge and resources. This also might be the reason that there are limited and mixed findings in the literature about the relation between degree centrality and innovation performance. For example Shan *et al.* (1994) found a positive relation between number of ties between start-up companies and established ones and their innovation performance. On the other hand, Stuart (2000) did not find any relation between number of alliances and firm

performance. In this study he measured the performance by innovation and sale growth rate. This supports the finding in this study that there is no relation between number of partners of an ego and its incremental innovation performance.

8.2.4. Strength of Ties and Different Types of Innovation

Overall, the findings provide strong support for the basic assumption that different characteristics of an inter-organisational network can influence radical and incremental innovation performance. The result revealed that the number of strong ties positively influences incremental innovation performance. Strong ties, by providing feedback on a company's current products/services and providing knowledge on their current direction and rich customised information, enables companies to exploit their current information, technologies and abilities to improve their product/services or make changes in the process of delivering services or production line. Strong ties provide partners with detailed information about the ways that things are being done in the organisation (Elfring and Hulsink 2003); therefore, the knowledge from these partners is more important in improving the processes, products or services.

This result is also in line with the findings by Rowley *et al.* (2000). They found that in an exploitative environment the number of strong ties is positively related to company performance. Incremental innovations happen in an exploitative environment where companies try to adapt their current resources and abilities. In an exploitative environment, the emphasis of companies is on refining an existing product/service/process (incremental innovation) by gathering specific information that provides deeper knowledge on a specific area (Rowley *et al.* 2000). Strong ties are sources of customised and fine-grained information (Krachardt 1992, Uzzi 1997) and therefore can provide the focal firm with specific information and feedback about their products or services which, if adopted properly, can contribute to their incremental innovation performance.

The number of weak ties was also significantly related to radical innovation performance. This is in line with Zaheer and Bell's (2005) argument that access to new information can be reflected in new products and services. Weak ties, by providing access to novel information and opportunities in the market, improve a company's radical innovation performance and enable them to respond rapidly to market changes. This also supports the argument by Rowley *et al.* (2000) that weak ties are beneficial for exploration purposes. When companies are working on a radical innovation, the level of uncertainty is high and in order to successfully develop the innovation, they need to address this uncertainty by acquiring knowledge and information in those areas. Weak ties are one of the mediums that companies can employ to access this information and address the uncertainty.

From a theoretical perspective, these results are insightful for understanding the network requirements of radical and incremental innovation. The need for deep knowledge and feedback on product, service or process, which is necessary for incremental innovation, is well served through strong ties. In contrast, weak ties provide access to unique and new information which is necessary for radical innovation.

8.2.5. Diversity of Ties and Radical Innovation

The diversity of the relationships of the focal firm and its partners was also positively related to the radical innovation performance of companies. The more diverse the type of relationships means the more diverse the knowledge that is being transferred to the company. The benefit is that companies have already invested their resources to establish a relationship with a partner, keeping the relationship limited will not let them benefit from the relation to the highest potential. Therefore it is more efficient to try to increase the domain of the relationship and use the partners' expertise in different areas. Radical innovation is a complicated process that requires knowledge and expertise in various areas. Different types of knowledge transfer that a company has with its partners can help

them in this process and provide the focal firm with the knowledge to find the market niche for a new product or service as well as the knowledge that is necessary for developing a new product/service or process. This supports the findings by Sammarra and Biggiero (2008) that different types of knowledge are necessary for successful innovation. A radical innovation requires a variety of resources, approaches and creative thinking to identify opportunities, define a solution and operationalise it. Companies need to have a good understanding in different areas such as the changing needs of customers, knowledge of the manufacturing process, technical knowledge of products and access to key input in order to be able to develop a successful radical innovation. Diverse ties with partners can assist companies to provide the knowledge and other resources that they need for this process. For example, marketing ties provide marketing knowledge which increases the effectiveness of innovation by matching the innovation with customers and end-users' requirements (Yli-Renko *et al.* 2001). Ties that provide technological knowledge may help to address technological uncertainty through understanding of technological developments (Caloghirou *et al.* 2003). Hagedoorn *et al.* (2000) suggest that this type of tie can also increase innovation efficiency, assist companies with entry into new technological frontiers, and share innovation cost and risk. Another example is manufacturing knowledge. Ties that transfer manufacturing knowledge may assist the ego in the implementation stage of the radical innovation. Jayanthi and Sinha (1998) outlined that manufacturing is a critical stage that creates pressure between exploration and exploitation. Manufacturing knowledge transfer with partners that have expertise in this area may bring in their respective knowledge and combine their knowledge to develop a better understanding of the process. Overall, when a company has different types of knowledge transfer through its ties with its partners, the company is exposed to different opportunities that can bring complementary resources to the organisation and address the uncertainties involved in the process of radical innovation.

8.2.6. Diversity of Nodes and Radical Innovation

Converse to the developed hypothesis, the findings did not support the relationship between diversity of partners and radical innovation. This is not an unexpected result, since Goerzen and Beamish (2005) in their study found that diversity is negatively related to the performance of large organisations. This is because of the increasing cost and resources required to manage these relationships, which diminishes the benefit of increasing the diversity of partners. Similar rules may apply to radical innovation. Although diversity may help with the transfer of new knowledge and experiences to an organisation, the resources that are required to manage these relationships may not let the company invest their resources in adopting this knowledge and developing the innovation itself.

There are two other plausible reasons for this. First, this phenomenon might be due to the type of partners. The type of partners in networking seems to be related to the type of innovation (Freel 2003, Kash and Rycraft 2000). For example, incremental innovators rely more on their customers as innovation partners (Biemans 1991) but radical innovators collaborate more with suppliers, consultants (Ragatz *et al.* 1997) and universities (Liyanage 1995). The main reason for this phenomenon seems to be the type of knowledge that each partner can provide to the focal firm. Customers can provide information about the focal firm's products or services and therefore companies can identify their weaknesses and improve their products/services or processes (incremental innovation). In contrast universities, consultants and suppliers can provide information about new technologies or market niches and other areas which are new to the focal firm. This knowledge allows the focal firm to integrate different knowledge bases and skills and increase the chance of a novel combination of knowledge (radical innovation). The second reason for why the outcome did not support this hypothesis might be because of the resources and abilities of the partners. Perhaps establishing a relation with different

partners is not enough and companies should try to establish their relation with resource rich organisations. This will provide the company with the opportunity to benefit from the variety of knowledge and resources that they can access through their partners. Relationships with companies that do not provide complementary resources are not beneficial because they do not fulfil the focal firm's resource requirement. Therefore in addition to diversity of partners, companies need to consider other factors in establishing relations with other organisations. This argument requires further investigation in future studies.

8.2.7. Innovation Management Practices and Different Types of Innovation

Findings showed that having an understandable and working innovation strategy plays a significant role in a company's radical innovation performance. This is specifically important since the relation of some of the network variables (density and number of weak ties) were not significant before adding innovation management constructs to the model. This shows how innovation strategy can guide a company to leverage their network resources in their innovation activities. These results resonate with the findings of previous studies such as Oke (2007), Griffin (1997) and Cooper et al (1999). These studies suggest that companies with high innovation performance have a clearly defined new product strategy in place that guides them through different stages of new product and service development. Innovation strategy provides a clear path for the entire organisation to focus their efforts and resources on the same innovation. Studies by Kuczarski & Associates (1994) and Mercer Management Consulting (1994) suggest that management support and commitment (providing adequate funding and resources) to the innovation activity and communication of a firm's new product development strategy are important in high performance companies. The other innovation management practices were positively related to radical innovation but the relationships were not significant. One possible explanation for this may be the flexibility that is required for

development of radical innovation in an organisation. The process of radical innovation requires different resources due to its complexity and the strict guidelines (e.g. for selecting ideas and implementing them) may restrict this process.

Counter to the developed hypothesis, none of the innovation management practices were significantly related to incremental innovation. One reason for this phenomenon might be the general belief on the difference between radical and incremental innovation. Oke (2007) suggests that there is a general opinion that innovation is mainly about radical product and service innovation. Perhaps those who responded to the innovation management practice questions have only considered radical innovation. This may be a reason for the incremental innovation relationship not being supported here.

Although only one hypothesis of innovation management practices was supported, the R^2 in model 2 for both radical and incremental innovation shows that innovation management practices play an important role in the radical and incremental innovation performance of the companies. In addition to that, the relation between density and radical innovation was not significant before adding the innovation management practices. This implies that although networks with low density increase the access to new information, companies need to have appropriate innovation management practices in place to be able to take advantage of this information in their radical innovation.

Another finding related to innovation management practices was the number of weak ties. The relationship between number of weak ties and radical innovation was not significant before including the innovation management practices. This implies that having only the right network resources without internal capabilities cannot make any difference to a company's innovation performance. This supports the findings by Julien *et al.* (2004) which showed that absorptive capacities impact on a firm's ability to benefit from their

weak ties. Innovation management practices provide the environment that is necessary for the company to be able to benefit from the potential network resources.

In this chapter so far, the findings of the PLS method, its relevance and difference to previous studies were discussed. In the next part the findings of the study using the fsQCA method and its relation to the previous findings are explained.

8.3. Discussion of the Fuzzy Set Qualitative Comparative Analysis

As explained in Chapters 2 and 3 there are several anecdotal and empirical studies that document different factors impacting on an organisation's radical and incremental innovation performance. However, previous studies, including Chapter 6 of this research, focus on the influence of individual factors on different types of innovation performance. These studies imply that organisations should seek to perform well in all the areas to be able to achieve the anticipated outcome. However, such a performance in all the areas is unlikely for enterprises, specifically for SMEs, due to their limited resources. Organisations are able to focus their expertise and resources on some of these factors and therefore it is important to understand what combination of these characteristics can assist them to achieve their goals. This study looks at different configurations of these factors and identifies the paths that can lead to high radical or incremental innovation performance. In addition to that this research is one of the few studies that applies the fsQCA method on network characteristics. The fsQCA helps to understand which factors are relevant to achieve the desired outcome and what combinations of these factors will lead to that outcome (Fiss 2011).

The finding of the study identifies several causal paths to achieve high performance in radical and incremental innovation. These results imply that there is no single factor that guarantees the anticipated outcome which means no one factor is a key success to higher radical and incremental innovation performance. Also, while there are different factors

and different paths to achieve the desired outcome there is no single configuration or factor necessary to take for success.

This study recognises some common rules behind different configurations for both radical and incremental innovation. Along with the presence of other conditions, the innovation strategy can create high radical and incremental innovation performance. There are only two configurations (one in radical and one in incremental solution) that do not include innovation strategy. This finding resonates with the result from the statistical test that revealed a significant relationship between strategy and radical innovation. In addition to that the presence of network variables in almost all the configurations is in line with the statistical result of the study. In terms of radical innovation, based on the statistical analysis, the presence of high tie diversity, low density network or high number of weak ties was one of the factors that led to high radical innovation performance. At least one of these factors was present in the fsQCA solution that, combined with other factors, leads to higher radical innovation performance. This confirms the importance of these factors in higher radical innovation performance which was already anticipated in the hypotheses and established in the statistical analysis.

Moreover, the result shows how the combination of some of the network variables with innovation management practices can result in a desirable outcome. For example, number of partners (degree centrality) was not significantly related to a company's incremental innovation performance in the statistical analysis. However, using fsQCA revealed that the combination of this network variable with other factors provides different avenues of achieving higher incremental innovation outcome. This finding resonates with the literature that was used to develop hypothesis 3 of the study (relation between degree centrality and incremental innovation performance). This shows that degree centrality, although alone cannot make a difference, when other factors are present, plays a significant role in incremental innovation performance.

Oke (2007) in his study found a significant relation between radical innovation performance and all the innovation management practices. The result in this study shows that although innovation management practices are important in the performance of this type of innovation, the presence of all these factors is not necessary to achieve this goal. Out of 9 configurations in radical innovation solution, only one solution demands the presence of all the management practices and there are 8 other combinations with no requirement of all the innovation management practices. This finding is useful for enterprises because there may be no need for them to be perfect in all the conditions to achieve better radical innovation performance.

Another finding that contrasts with the findings of Oke (2007) is that he did not find any significant relation between incremental innovation performance and innovation management practices. However, the findings in this study show that although these practices alone are not related to incremental innovation performance (according to the statistical analysis), a combination of these factors can lead to the desired outcome (higher incremental innovation performance). A clear implication of this finding is that innovation management practices alone are not sufficient for incremental innovation and in fact, they provide the necessary environment to leverage the knowledge and other resources that a company accesses through its strong ties. This shows that these factors are necessary to complement each other in order to achieve a higher performance in incremental innovation.

8.4. Summary

The findings of the study using two analysis methods (PLS-SEM and fsQCA) were discussed in this chapter. The first part of the chapter was dedicated to the discussion of the result of the statistical analysis. The result and its connection to previous studies were discussed according to the hypotheses. The second part of the chapter was about the

findings of the fsQCA method. In this part the result of the method and its relevance to the findings of the statistical method and previous studies were discussed. Moreover, the findings that were in contrast with the previous studies were explained and discussed in detail.

9. Chapter 9: Conclusion

9.1. Introduction

This final chapter provides a summary discussion of the findings produced by this study. First, the research aim and objectives are reviewed and how this study addressed the aims and objectives is discussed. This is followed by a discussion on the theoretical contributions and practical implication. Finally, limitations and suggestions for future research are presented.

9.2. Overview of Research Aim and Objectives

This study attempts to advance our knowledge and understanding on the effects of inter-organisational network properties on innovation performance in the context of UK high tech SMEs. This has been achieved through the use of the ego-network concept from social network analysis and the development of a new measurement tool for radical and incremental innovation performance.

This thesis has been concerned with the following research question:

- **How and to what extent are inter-organisational networks impacting on different types of innovation in SMEs?**

To answer this research question, a theoretical framework consisting of three main concepts (Social network, Innovation, and Innovation management practices) was developed following a review of extant literature. The central structural construct in the

model was different types of innovation (radical and incremental). The network related constructs were degree centrality, betweenness centrality, density, node diversity, tie diversity, strong ties and weak ties. The constructs related to innovation management practices that were included in the theoretical model were innovation strategy, human resource management, idea management, portfolio management and implementation.

The study aimed **to examine the relationships of the inter-organisational knowledge transfer networks on different types of innovation in SMEs.**

The following objectives were set up and met in the study:

1. Identifying gaps in the literature, understanding the current research, relevant theories and debates.

This objective has been achieved through an extensive review of literature in inter-organisational relationships, social network and innovation.

2. Developing and testing a conceptual model and hypotheses underpinned by social network and innovation theories.

The literature review provided the foundation for developing the hypotheses. To address this objective, twelve hypotheses were developed and a theoretical framework was introduced. The hypotheses were tested with empirical data collected from Hi-Tech SMEs using statistical method and a final version of the framework was provided. FsQCA method was used for further analysis and to shed more light on the relationships between innovation and network characteristics.

3. Using social network theories to understand the inter-organisational networks, knowledge transfer and its impact on innovation.

The results of the data analysis have directly contributed to this objective. In summary, the statistical analysis revealed that number of strong ties is an important factor in

improving the incremental innovation performance of a company. Also it revealed that diversity of ties, number of weak ties, density, betweenness centrality and innovation strategy play significant roles in the radical innovation performance of a company.

4. Providing implications for future research and practices.

This objective has been achieved through contribution to innovation and network literature based on the findings. Moreover, the findings had a number of implications for managers of SMEs.

9.3. Key Research Outcomes

9.3.1. Research Gaps Identified

The first objective was identifying gaps in the literature and understanding the current research. An extensive review of the literature on inter-organisational relationships, social network and innovation was conducted. The literature were reviewed and categorised based on the main concepts and arguments. Several gaps were identified:

1. The social networks studies in the context of SMEs were limited and mainly focused on large organisations.
2. There was little research in the social networks characteristics and their influence on different types of innovation.
3. There was a lack of a comprehensive tool to measure different types of innovation.
4. There was no research attempting to examine the influences of the firms' internal capabilities together with their network on different types of innovations.

9.3.2. Conceptual Framework

The second objective was developing and testing a theoretical framework and hypotheses based on social network and innovation concepts. At the beginning of the research it was

identified that in order to study the effect of inter-organisational networks on different types of innovation it is necessary to focus on different network characteristics and the internal capabilities of companies. Three types of network characteristics (structural, nodal and relational properties) and pentathlon framework were identified and hypotheses were developed based on these fundamental concepts. The theoretical model was based on the developed hypotheses. The framework was modified by collecting empirical data and testing the hypotheses. Figure 9.1 illustrates the final version of the theoretical framework.

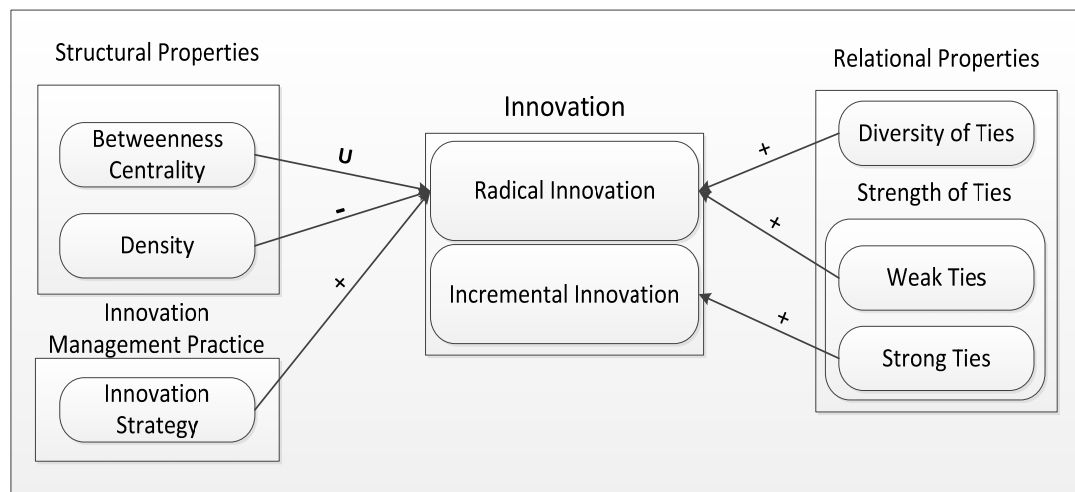


Figure 9.1: Final version of the theoretical model

The hypotheses that were not supported and the related constructs have been removed from the model. The framework shows how each of the network constructs and the innovation strategy contribute to each type of innovation. Although the hypotheses based on betweenness centrality and density were not supported, the constructs are included in the final framework. The reasons for including these constructs were discussed in the previous chapter.

Two methods of analysis were employed to analyse the impact of network characteristics together with firms' internal capabilities on their radical and incremental innovation

performances. A detailed discussion of the findings using both PLS and fsQCA was made in Chapter 8.

The third objective was to understand the inter-organisational networks, knowledge transfer and its impact on innovation. This research builds on the evidence provided by O'Reilly and Tushman (2004) regarding ambidextrous organisations. They looked at two companies' successful efforts to achieve ambidextrousness and found that efforts to build a strong social network were one of their best practices for this purpose. This research showed how different network properties can contribute to this goal which is vital for organisations' competitive advantages and long term survival. From a broader perspective the importance of social network in innovation parallels the findings of other studies that argue that a social network is a critical resource in an organisation's success (e.g. firm performance (Baum *et al.* 2000) and career success (Gabbay and Zuckerman 1998)). Another important finding is that network research that ignores the focal capabilities of a firm may miss a considerable and important amount of information in innovation. The findings showed that the internal capabilities of a firm play a significant role in enabling the company to benefit from its social network.

The findings by FsQCA analysis showed that although these individual factors are important, there is no need for a company to perform well in all the areas. This method, using a different combination of these factors revealed that there are many paths to achieve better incremental and radical innovation performance and companies need to choose the one that is closer to their abilities and fits with their resources. It shows how different configuration of the internal capabilities and network resources can lead to a better innovation performance. This also supports the findings of Zaheer and Bell (2005) suggesting that a superior network position alone is not enough and companies must also provide the internal capabilities in order to benefit from their network and enhance their performance.

The last objective was contribution to theory and practice and providing implication for future research which are discussed in the following sections. It is necessary to bear in mind that this study was conducted in the context of SMEs and therefore all the implications (theoretical and practical) that expressed here apply to SMEs.

9.4. Contribution to Knowledge

9.4.1. Contribution to Theory

This dissertation contributes to different areas of theory. A gap in the research, as explained in Chapter 1, was identified in the network and innovation literature which the research presented here attempted to address. The contribution to knowledge consists of the following:

9.4.1.1. Contribution to Innovation Literature

This research contributes to innovation literature in several ways. First, a taxonomy for innovation was introduced that provides a better understanding of different types of innovation. This classification will help future studies to focus their research on specific types of innovation (e.g. radical product innovation, incremental process innovation) and find the antecedents and barriers for each type. This will provide a better solution and guidelines for organisations and policy makers. Second, during this research a gap in the innovation measure literature was identified and a new measure was developed. The new instrument is significant from a number of perspectives. Previous innovation measures only measured different types of innovation from companies' or customers' perspectives which raises the issue of whether innovation is radical/incremental from both perspectives or only radical/incremental from the companies' perspective. This instrument is designed in a way that captures the degree of innovativeness from both parties' viewpoints. Another significance of this measurement tool was that it enables researchers to adapt this measure in different industries. This measure, by asking respondents to compare their

innovation performance with competition in the same sector, enables researchers to compare radical/incremental innovation performance of companies in different sectors. Third, the theoretical framework advanced in this study suggests how firms can leverage a variety of network resources to improve their performance to generate different types of innovations. Finally, this study helps to understand how network and innovation management practices work in complementary ways in addressing companies' resource barriers and consequently providing different avenues to improve their innovativeness.

9.4.1.2. Contribution to Network Literature

This thesis contributes to the expanding body of network research on how the knowledge resource potential of the ego network influences the focal firm's ability to generate different types of innovation. Followings are the contributions of this research to network literature:

First contribution to network literature is examining the relationship between network characteristics and different types of innovation. Previous network and innovation studies largely focused on innovation as a general concept and ignored the effect of network resources on the degree of innovation. Questions such as whether the characteristics of inter-organisational knowledge transfer networks influence a firm's generation of different types of innovation are largely unanswered. This study contributes significantly to this body of literature by examining how different network characteristics influence radical and incremental innovation.

Second, a new tool to capture inter-organisational network data was introduced. As mentioned in the first chapter, most of the previous network studies used secondary network data (e.g. alliance databases) to build the network between organisations. This study was not able to find a tool that could capture this information at inter-organisational level. To develop such a measure, this research adapted some questions from network

surveys at interpersonal level and developed some additional questions to capture structural, relational, and nodal properties of networks at the inter-organisational level. This will provide a tested instrument for future studies to adapt and develop in other network research. Developing this instrument made it possible to collect the real network data from the companies. This addressed the concerns raised by Meeus and Faber (2006) regarding the use of real network as the indicators.

Third, this study includes ties from different industries. Prior network studies (e.g. Ahuja 2000) have only considered ties with partners within the same industry and did not include the ties that companies have with partners in other industries. However, in practice company's relationships are not limited to partners in the same sector and they have knowledge transfer with partners from different sectors. This research, by studying inter-organisational ties both within and outside the industry, provides a better understanding on the impact of these relations on the innovation performance of companies.

Fourth, this study examines network properties together with the internal capabilities of companies (innovation management practices). This is important since companies without internal resources would not be able to leverage the resources in their network. The findings in this research support the argument that companies without internal capabilities will not be able to use their potential network resources in their innovation.

Fifth, the findings have implication for network literature by demonstrating that the knowledge transfer between organisations through inter-organisational networks affects radical and incremental innovation performance. This research contributes to the existing literature on networks as a source of learning for firms (e.g. (Powell *et al.* 1996)). The findings related to strength of ties are important with regards to learning theory. The findings demonstrate that weak ties increase learning benefits by providing access to

novel information on new technologies or new market opportunities. This will assist companies in learning about the opportunities that they have or their own abilities for radical innovation. On the other hand strong ties, by providing private rich customised information help the focal firm to learn about their current situation, receive feedback about their products or services and improve them accordingly.

Sixth, the findings of diversity of ties have an implication for transaction cost economy, network theory and learning theory. According to TCE companies establish relationships with other organisations to reduce the acquisition cost of what they require in the organisation. According to logic based on TCE, it is more reasonable for companies that have already established a relation with an organisation to expand the domain of the knowledge transfer to different areas. Therefore, there is no need to invest in a new relationship with a new firm. Companies, by expanding the domain of knowledge, save the cost of establishing a new relationship with a new partner. In addition to that, diversity of ties helps companies to access diverse domain of knowledge in their partners' knowledge base which is an implication for network theory. Access to diverse information will provide new learning opportunities for the focal firm which is another implication for learning theory.

Seventh, providing a guideline for analysing network data using the fsQCA method was one of the important contributions of this study. This research is one of the first studies to employ fsQCA to analyse social network data. This will provide an additional perspective for researchers to develop the research in this area.

9.4.2. Contribution to Practice

The findings have a number of implications for innovation practice. First, the portfolio of partners that a company holds must be aligned with their strategic goals. As the finding shows, a radical innovation requires a different portfolio composition compared to

incremental innovation. Therefore managers need to first specify and clearly define their goals and communicate it throughout the company and then design their portfolio of relationships accordingly. The ego network perspective adopted in this study provides a more solid foundation for managers to evaluate potential costs and benefits associated with each tie and design the firm's strategic network.

Second, companies should be aware of the fact that a network alone is not enough to improve their innovation performance and they need to improve their internal capabilities as well as their network resources (e.g. innovation management practices, absorptive capacity). Internal capabilities are the main ingredient of any innovation without which companies would not be able to absorb the knowledge and assimilate the resources for innovation generation.

Third, according to the findings of this research and previous studies (Ahuja 2000, Gilsing *et al.* 2008, Subramaniam and Youndt 2005) social networks appear to be a fundamental part of the innovation. Since innovation is a collaborative effort, the network plays an important role. Therefore, communication, knowledge transfer with partners and absorbing the transferred knowledge are key factors in innovation, regardless of their types.

Fourth, the innovation measurement instrument designed in this study can be used as a benchmark tool for companies to assess their (radical/incremental) innovation performance and compare themselves with their rival companies. This will provide them with a better understanding of their current situation and help them to find the areas that they need to change to improve their performance.

The last practical implication is the different paths that lead to better incremental and radical innovation performance. The findings in this regard showed that there is no need for companies to provide all the factors that are necessary for incremental/radical

innovation. There are different settings and configurations that companies can select based on their abilities, resources and expertise. This will enable them to achieve higher performance in different types of innovation and they can spend the rest of their resources on other activities.

9.5. Limitations and Future Research

9.5.1. Limitations

There are several limitations in this thesis that may provide a path for future research. One is the relatively small sample size. Although a large sample size would have given more power to the generalisability of the study, the difficulty in collecting data from the executive management level imposed limits on the sample size. Baruch and Holtom (2008) in their study indicated that research at organisational level or top managers level suffers from low response rates. Subramaniam and Youndt (2005) have also pointed out the difficulty of collecting empirical data from high level managers. Another reason for the low response rate was the inaccuracy of the FAME database. Not all the records in the database were up to date and therefore the letters were sent to a wrong address or to a person who was not in the company anymore. As mentioned in Chapter 5, this database was the most comprehensive database for the research purpose accessible through the university at the time. However, according to the power analysis in Chapter 6, the number of responses was well above the required minimum number for conducting the analysis. Therefore, based on these reasons the low response rate is justifiable and was not a problem.

Another limitation was collecting subjective data for innovation management practices and different types of innovations using the key informant method. This method was chosen because of the difficulty in collecting objective data on different types of innovation and management practices across multiple industries.

As explained in the methodology chapter the design of the study was cross-sectional, which means that the collected data covers only a period of two years. This approach raises the possibility of inaccurate responses due to memory loss or perceptual biases due to euphoria or disappointment over the innovation performance (Olson *et al.* 1995).

In this study the ego network approach was adapted to study the network effects. Although this perspective is highly valuable it must be remembered that an ego network is embedded in a bigger network or “whole network” and some of the behavioural properties of ego network members are influenced by other members in the whole network. The focus of this research on ego network does not include the implication for large networks.

9.5.2. Future Research

This research provides a number of opportunities for future studies. One prospect for research is differentiating partners based on their abilities and resources. This provides an opportunity to consider type of the partners and their resourcefulness in examining the effects of diversity of partners on different organisational outcomes.

Companies and especially managers of SMEs are involved in a network of both formal and informal relationships. These informal relationships can also be a valuable resource for information and build the foundation for a formal partnership between companies. Therefore, taking informal networks into account as well as formal networks can shed more light on different aspects of organisational outcome. Another prospect for future studied could be an examination of the role of intra-organisational and interpersonal networks together. Previous studies have shown the importance of these types of network in organisations.

Future research can develop a similar study using socio-centric approach (whole network) and compare the result with this study. For example, researchers can measure global

density and examine its relation with radical innovation and compare it with local density which has been used in this research.

Another avenue for research is conducting similar research in different industries or different sectors (medium-tech and low tech) and compare the results with this research to examine how companies in different sectors are different in leveraging their network resources for different types of innovations.

Designing a longitudinal study would make a further contribution to the understanding of inter-organisational relationships and different types of innovations. The development of a time-series database would provide an additional understanding on for example the effect of the change in the portfolio of inter-organisational relationships on radical and incremental innovation performance.

The company resource profile such as human capital, technological capital, and physical resources (e.g. technological infrastructure or financial capital) is important to performance in different organisational aspects. Examining innovation barriers such as a firm's resource barriers, uncertainty and rigidity are other avenues for future studies. Researchers can explore the effect of network resources and these barriers on radical and incremental innovation performance. By exploring these possibilities, future studies can enrich our understanding of how interaction between these resources can positively or negatively affect a firm's innovation performance or different types of innovation.

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Appendices

Appendix A: Questionnaire Items Used to Measure the Concepts in Pentathlon Framework

Source: Oke, 2007. International Journal of Operations & Production Management. Vol. 27 No. 6.

Innovation Strategy: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree)

- Introduction of innovation as a fundamental part of the company's philosophy and values;
- There is clarity of corporate vision and goals relating to innovation;
- Goals for innovation are communicated effectively throughout the company;
- New initiatives are aligned with the overall business strategy;
- Top management is fully committed to support innovation activities and programmes.

Ideas Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree)

- Developing new ideas is a key strength of this business;
- Technology is a key source of new ideas for our business;
- Employees are actively encouraged to generate new ideas;
- New ideas are collected internally on a regular basis;
- New ideas are most likely to emerge from talking to customers;
- Assistance to develop new ideas is readily available.

Portfolio Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree)

- Decisions with regard to implementing new ideas are made quickly;
- Reviews of new ideas are held on a regular basis;
- There is a good balance of ideas for new products, services and processes;
- There is an effective feedback mechanism in place to monitor actual product/service performance;
- We have a process for selecting ideas to be developed;
- The process for selecting ideas is transparent and understood by all employees.

Implementation: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree)

- Projects to develop new ideas are reviewed on a regular basis;
- Project reviews for new ideas are used to improve performance of new product/service development;
- Cross-functional working is encouraged for developing new ideas;
- Project teams, which involve all parts of the company, are set up for developing new ideas;
- Developing new ideas is a well-documented process;
- We control and monitor the process effectively to constantly improve speed to market of new products.

Human Resource Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree)

-
- Employees are aware of their role with regard to innovation;
 - Innovation is a key criterion in our recruitment and selection process;
 - Human resource policies support a culture of innovation;
 - Innovation forms a key part of our training and development programmes;
 - The broad meaning of innovation (i.e. product, services and processes) is understood by all staff;
 - Innovation is reviewed in staff performance reviews.

Appendix B: Pre-Notification, Cover Letter and Reminders

Appendix B.1: Pre-Notification Letter

September 28, 2011

Dear [name of the managing director]

A few days from now you will receive in the mail a request to fill out a brief questionnaire for an important research project being conducted by the University of Bedfordshire.

It aims to help Small to Medium size Enterprises (SMEs) to improve their competitiveness and performance by means of knowledge transfer with their partners.

I am writing in advance because we have found many people like to know ahead of time that they will be contacted. The study is an important one that will help managers to develop the firms' knowledge transfer network according to their strategies and requirements to improve their innovation performance.

Thank you for your time and consideration. It is only with the generous help of people like you that our research can be successful.

Sincerely,

Meysan Poorkavoos

PhD Researcher

E-mail: Meysam.Poorkavoos@beds.ac.uk

Appendix B.2: Cover Letter

To: [name and address of the managing director]

The survey for innovation performance of SMEs

We are conducting a study that aims to help Small to Medium size Enterprises (SMEs) to improve their competitiveness and performance by means of knowledge transfer with their partners. The result of this research will help managers to develop the firms' knowledge transfer network according to their strategies and requirements to improve their innovation performance.

Even if you feel that knowledge transfer does not particularly apply to your company, we are still interested to hear from you. It will take you 20 to 25 minutes to complete the questionnaire.

We would be grateful if you would either complete the attached questionnaire yourself or arrange to have it completed by a senior member of your management team and return the completed questionnaire in the pre-paid envelope to us within two weeks. If you prefer to answer the questions online, the questionnaire is available at <http://www.bbsdirect.net/sme-innovation>.

All of your answers will be treated with strict confidentiality and will not be divulged in a disaggregated form, or used for other purposes except for this research. The result of the research will be presented in cumulative format, with no potential identifiers to a particular respondent or organization. When you return your completed questionnaire, your name will be deleted from the mailing list and never connected to your answers in any way.

If you would like to receive a free report of the survey, please attach your business card with the questionnaire.

Should you have any questions or concerns about this study, please contact me, or Professor Yanqing Duan (Yanqing.Duan@beds.ac.uk).

I look forward to hearing from you and thank you for your time and co-operation in advance.

Yours sincerely,

Meysam Poorkavoos

PhD Researcher

E-mail: Meysam.Poorkavoos@beds.ac.uk

Tel: 01234 400 400. Ext. 2128

P.S. If by some chance we made a mistake and the person is not in the company anymore, please arrange to have this completed by a senior member of your management team. Many thanks.

Appendix B.3: First Reminder

October 17, 2011

Dear [name of the managing director]

Last week a questionnaire seeking your opinions about inter-organisational knowledge transfer between your company's partners was mailed to you. Your name was drawn randomly from a list of all SMEs in the UK.

If you have already completed and returned the questionnaire to us, please accept our sincere thanks. If not, please do so today. We are especially grateful for your help because it is only by asking people like you to share your experiences that we can understand how inter-organisational relationships affect companies' innovation performance.

If you did not receive a questionnaire, or if it was misplaced, please call us at 01234 400 400 Ext. 2128 and we will get another one in the mail to you today. You can also answer the questionnaire online at <http://www.bbsdirect.net/sme-innovation> .

Sincerely,

Meysam Poorkavoos, Ph.D. Researcher
Business and Management Research Institute
University of Bedfordshire
Park Square, Luton, LU1 3JU
Meysam.poorkavoos@beds.ac.uk

Appendix B.4: Second Reminder

TO: [Name and address of the managing director]

About four weeks ago we sent you a questionnaire asking for information about inter-organisational relationships and innovation performance of your company. We don't seem to have received your response yet.

For your information, the companies that have already responded provided invaluable information on their activities in inter-organisational relationship development. The responses also show the importance of inter-organisational knowledge transfer in their innovation performance. We believe that the survey results will be very useful to SMEs.

We are writing again because of the importance that your response has to our investigation. It's only by hearing from as many responses as possible in the sample that we can be sure that the results are truly representative. Please see the attached letter for more information about the aims of the research and confidentiality of the information. Please note that you can also answer the questionnaire online at <http://www.bbsdirect.net/sme-innovation>

A few companies have written to say that they should not have received the questionnaire because they are no longer active or that they are not SME anymore. If either of these applies to you, please let us know by returning the questionnaire in the enclosed envelope with your note so that we can delete your name from the mailing list.

We hope that you will be able to fill and return the questionnaire soon, but if for any reason you prefer not to answer it, please let us know by returning the blank questionnaire with your note in the enclosed envelope.

We look forward to receiving your response.

Sincerely,

Meysam Poorkavoos
Ph.D. Researcher
Meysam.Poorkavoos@beds.ac.uk
01234 400 400. Ext. 2128.

P.S. If by some chance we made a mistake and the person is not in the company anymore, please arrange to have this completed by a senior member of your management team. Many thanks.

Appendix C: Questionnaires of the Study

Appendix C.1: Questionnaire (First version)

Business School
University of Bedfordshire
Park Square
Luton, LU1 3JU

2011-01-06

Dear Mr. [name of the managing director],

The survey for innovation performance of SMEs

We are conducting a study which aims to help SMEs to improve their competitiveness and performance by means of knowledge transfer with their partners. The result of this research will help SMEs to choose the right partners for knowledge transfer to improve their innovation performance according to their business strategy.

Even if you feel that knowledge transfer does not particularly apply to your company, we are still interested to hear from you. It will take you about ten minutes to complete.

We would be very grateful if you could return the completed questionnaire in the pre-paid envelope to us. All of your answers will be treated with strict confidentiality and will not be divulged in a disaggregated form, or used for other purposes except for this research. We look forward to hearing from you. If you would like to receive a free report of the survey, please attach your business card with the questionnaire. Thank you for your time and co-operation in advance.

Yours sincerely,

Meysam Poorkavoos

PhD Researcher

E-mail: Meysam.Poorkavoos@beds.ac.uk

Tel: 01234 400 400. Ext. 2128

Section A – General Business Information

-Where precise figures cannot be provided **your best estimates are acceptable**

1. What are the main services/products offered by your company?

2. How long has your company been in business?

3. How many employees do you have?

1-9 10-20 21-50 51-150 151-250

>250

4. How much did you invest in your internal R&D in 2009?

5. How much was your total sale in 2009?

6. For the employees of your company please ESTIMATE the proportion that hold a degree, e.g. BA/BSc, or higher degree, e.g. MA/PhD:

Section B – Product, Service and Process Innovation

Definition of innovation:

Innovation is defined as **new** or **improved goods or services** and/or the **processes** used to produce or supply all goods or services that the business has introduced, regardless of their origin. These may be new to the business, new to the market or new to the industry.

Goods, Services and Process Innovation

7. How would you rate your organization's performance to generate the following types of innovations in the products/services or processes you have introduced in the last two years?

(1 = weaker than competition; 4 = similar to competition; 7= stronger than competition).

During the 2 year period 2009 - 2010

Incremental innovation									
1	We improve or revise existing products or services	1	2	3	4	5	6	7	N/A
2	We add new products or services to our existing ranges	1	2	3	4	5	6	7	N/A
3	We introduce new ranges of products or services not previously offered by this company	1	2	3	4	5	6	7	N/A
4	We reposition existing products or services	1	2	3	4	5	6	7	N/A
5	We change the way we make or deliver products or services	1	2	3	4	5	6	7	N/A
Radical innovation									
6	We develop products or services that offer greater advantages to customers than any other product or service currently available	1	2	3	4	5	6	7	N/A
7	We develop products or services that better meet the needs of customers than any other product or service currently available	1	2	3	4	5	6	7	N/A
8	We have launched products or services that are the first of their kind in the world	1	2	3	4	5	6	7	N/A
9	We develop products or services that require Customers to substantially alter their behaviour	1	2	3	4	5	6	7	N/A

8. How would you rate the innovation performance of your company?
(choose between 1 to 7, 1= not innovative at all- 7=very innovative)

Section C - Inter-organisational relationships

Definition: Inter-organisational relationships refer to all types of knowledge transfer between companies which contribute to their innovation. This knowledge transfer relationship can range from informal relationships between managers of the company to formal relationship with **customers, suppliers** or **partners**.

- **Please write your answers to the following questions in the table on the next page.**

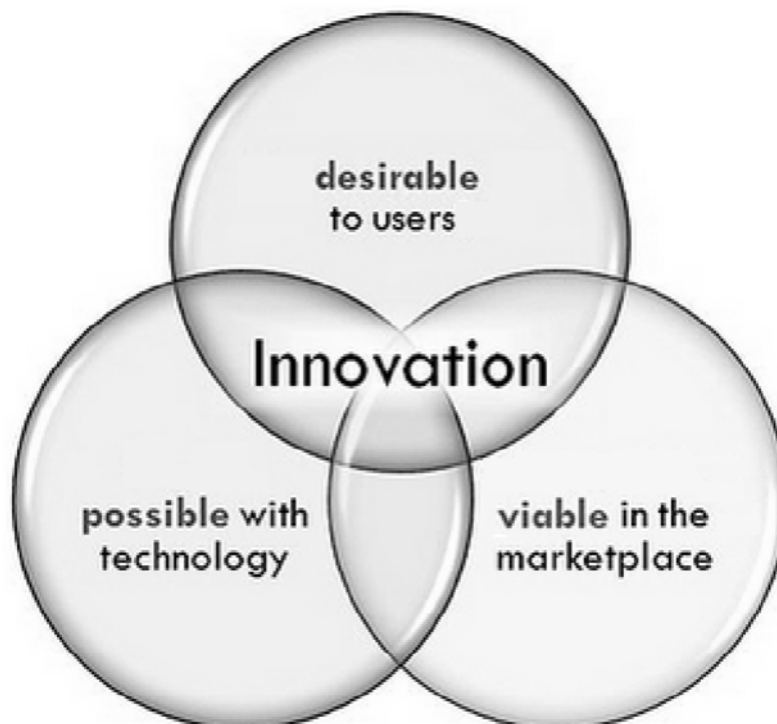
9. Please write the name of the companies, universities, institutes or laboratories that you have had an **inter-organisational relationship** with in 2009. If it is not possible to provide the real name of your partners you can write Firm A, Firm B and so on in each row.

10. For each of the companies you have provided please fill in the rest of the table according to the following guidelines

- a. **Business type:** what is their main business (consultancy, university...).
- b. **Formal/informal:** The relation with your partner is formal (e.g. formal alliance, partnership, joint venture or etc) or informal.
- c. **Type of the knowledge:** Companies in their relationship usually transfer different types of knowledge e.g. technological knowledge, managerial knowledge, market knowledge, R&D knowledge etc. Please specify what types of knowledge your partners transfer to you.
- d. **How often do you make a contact with this company:** (e.g. Once in a week, more than once in a week, once in a month, once in a year).
- e. **How long have you been in knowledge transfer relationship with this company?** (e.g. 5 years, 10 months).
- f. **Where is your partner located?** (local, regional, national, international)
- g. **Medium:** What kind of medium do you use **mainly** for your communications with this firm (e.g. email, face to face, telephone, video conference, ...)

Appendix C.2: Questionnaire (Final version)

THE SURVEY FOR INNOVATION PERFORMANCE OF SMEs



University of Bedfordshire

**Business and Information Systems
Research Centre**

2011

Please return your completed questionnaire in the enclosed envelope to:
**Meysam Poorkavoos, Business School, University of Bedfordshire,
Park square, Luton, LU1 3JU**

Section A: General Business Information

Before you start, please take a moment to read these instructions:

- a. Questions requiring **ONE** answer have **CIRCLES** next to each answer option.
- b. Questions allowing **MORE THAN ONE** response have **BOXES** next to each answer option - mark as many boxes as apply to you.
- c. Some questions ask you to write in your answer in your own words, into the box provided.
- d. If it is not possible to provide precise figures please use your estimates.

Q1 What are the main services/products offered by your company?

Q2 How long has your company been in business?

- Less than 5 years
- 6 to 10 years
- 11 to 15 years
- 16 to 20 years
- More than 20 years

Q3 Please answer the following questions about performance of your company in 2011:

	<i>Very weak</i>	<i>Weak</i>	<i>Medium</i>	<i>Strong</i>	<i>Very strong</i>
How would you rate the profitability of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How would you rate sales growth of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How would you rate market share of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How would you rate overall performance of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q4 To what extent do you agree with following sentences (in 2011):

	<i>Strongly disagree</i>	<i>Disagree</i>	<i>Neither agree nore disagree</i>	<i>Agree</i>	<i>Strongly agree</i>
Your company has achieved the start up goals:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your company has provided secure job to employees:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
You are satisfied with the company's performance:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q5 How many employees did you have in 2010?

- 1-9
- 10-50
- 51-150
- 151-250
- more than 250

Q6 For the employees of your company please **ESTIMATE** the proportion that had a professional qualification or higher education degree in 2010:

- 0% - 20%
- 21% - 40%
- 41% - 60%
- 61% - 80%
- 81% - 100%

Q7 How much was your total sale in 2010?

- Less than 1 million
- 1 to 5 million
- 6 to 10 million
- 11 to 15 million
- 16 to 20 million
- 21 to 25 million
- more than 26 million

Q8 What is the percentage of the total sale that you invested in R&D in 2010?

Section B: Product, Service and Process Innovation

How would you rate your organisation's performance in the following activities in 2011 compared to similar companies in same sector?

Q9	<i>Much weaker</i>	<i>Weaker</i>	<i>Similar</i>	<i>Stronger</i>	<i>Much stronger</i>
We often improve or revise existing products or services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We add new products or services to our existing ranges	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We make changes that reinforce our prevailing product/service lines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We often reposition existing products or services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We exploit the potential of the established design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We often change the way we make products or deliver services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new or significantly improved processes for producing or supplying products (goods or delivering services) which are new to our firm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop products or services that offer greater advantages to customers than any other products or services currently available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop products or services that better meet the needs of customers than any other product or service currently available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop products or services that require customers to substantially alter their behaviour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new products/services to an existing market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new products/services to a new market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop new product/services that require significantly new technology or ideas that were not existed in the market before	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We create new major product/service programs leading to expansion of current markets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop Innovations that make our prevailing product/service lines obsolete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new or significantly improved processes for producing or supplying products (goods or delivering services) which are new to our industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q10 Please indicate the degree to which you agree or disagree with each of the following statements. in 2011, Compared to our competitors, our business tends to be: (scale is 1= strongly disagree and 5 = Strongly agree)?

	1	2	3	4	5
One of the first to market with innovative new product and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
More effective than our competitors at taking existing ideas and making them into something better	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Better than our competitors at developing products and services to meet customer needs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Perceived by customers to be more innovative than our competitors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Be at the leading edge of innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q11 Innovation Strategy: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Introduction of innovation as a fundamental part of the company's philosophy and values	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is clarity of corporate vision and goals relating to innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Goals for innovation are communicated effectively throughout the company	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New initiatives are aligned with the overall business strategy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Top management is fully committed to support innovation activities and programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q12 Ideas Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Developing new ideas is a key strength of this business	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technology is a key source of new ideas for our business	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees are actively encouraged to generate new ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New ideas are collected internally on a regular basis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New ideas are most likely to emerge from talking to customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Assistance to develop new ideas is readily available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q13 Portfolio Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Decisions with regard to implementing new ideas are made quickly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reviews of new ideas are held on a regular basis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a good balance of ideas for new products, services and processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is an effective feedback mechanism in place to monitor actual product/service performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have a process for selecting ideas to be developed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The process for selecting ideas is transparent and understood by all employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q14 Implementation: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Projects to develop new ideas are reviewed on a regular basis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project reviews for new ideas are used to improve performance of new product/service development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cross-functional working is encouraged for developing new ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project teams, which involve all parts of the company, are set up for developing new ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing new ideas is a well documented process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We control and monitor the process effectively to constantly improve speed to market of new products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q15 Human Resource Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Employees are aware of their role with regard to innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation is a key criterion in our recruitment and selection process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Human resource policies support a culture of innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation forms a key part of our training and development programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The broad meaning of innovation (ie. product, services and processes) is understood by all staff	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation is reviewed in staff performance reviews	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q16 To what extent is being innovative important to your company?

Not at all important
 Not important
 Indifferent
 Important
 Very Important

Definition of inter-firm relationship:

Inter-firm relationships refer to all types of knowledge transfer relations between companies. These relationships are formal and can be with any type of organisations, customers, suppliers, partners, universities or laboratories.

Q17 To what extent is inter-firm relationships important to your company?

Not at all important
 Not important
 Indifferent
 Important
 Very Important

Q18 Are you satisfied with the overall level of inter-firm relationships that your company has?

Very dissatisfied
 Dissatisfied
 Neither satisfied nor dissatisfied
 Satisfied
 Very Satisfied

Section C: Inter-firm relationships

Definition of partner:

In this study partner is defined as companies, universities, institutes or laboratories that your company have had an inter-firm relationship.

Definitions of different form of interorganisational relationships:

Joint Venture: An entity that is created when two or more firms pool a portion of their resources to create a separate jointly owned organisation.

Network: A hub and wheel configuration with a local firm at the hub organizing the interdependencies of a complex array of firms.

Consortia: Specialized joint ventures encompassing many different arrangements. Consortia are often grouping of firms oriented towards problem solving and technology development, such as R&D consortia.

Alliance: An arrangement between two or more firms that establishes an exchange relationship but has no joint ownership involved.

Trade Association: Organisations (typically nonprofits) that are formed by firms in the same industry to collect and disseminate trade information, offer legal and technical advice, furnish industry-related training, and provide a platform for collective lobbying.

Interlocking Directorate: An interlocking directorate occurs when a director or executive of one firm sits on the board of a second firm or when two firms have directors who also serve on the board of a second firm.

	Partner 1	Partner 2	Partner 3	Partner 4	Partner 5	
Q19						
A. Think about your partners that you had an inter-firm relationship in 2010 and list their initials here.						
B. What is their main business?						
C. How often did you make contact with this company in 2010?	Daily	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Weekly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Monthly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Quarterly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Annually	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D. How long was your company in a relationship with this company up until 2010?						
E. Where is your partner located	Local	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Regional	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	National	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	International	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F. Type of the partner	Supplier	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Client or customer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Competitor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Consultant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Other (please specify)					
G. What form of inter-organisational relationship did you have with this partner in 2010?	Alliance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Joint venture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Consortia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Trade Association	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Interlocking Directorate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)						

Q20

	Partner 6	Partner 7	Partner 8	Partner 9	Partner 10
A. What is the initial of any other partners that you had inter-firm relationship in 2010 that were not named in the last above?					
B. What is their main business?					
C. How often did you make contact with this company in 2010?					
Daily	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Weekly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Monthly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quarterly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Annually	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D. How long was your company in a relationship with this company up until 2010?					
E. Where is your partner located					
Local	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regional	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
International	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F. Type of the partner					
Supplier	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Client or customer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Competitor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Consultant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)					
G. What form of inter-organisational relationship did you have with this partner in 2010?					
Alliance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Joint venture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Consortia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Trade Association	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Interlocking Directorate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)					

Q21 With the partners that you have mentioned in Q19 and Q20, what types of knowledge did you transfer in 2010 (check all that apply)?

- Technological Knowledge (eg. providing technical solutions etc.).....
- Managerial Knowledge (eg. project management, co-ordinating etc.).....
- Market Knowledge (eg. market research, visioning etc.).....
- Training (eg. staff training etc.)
- Others (please specify) _____

Q22 When you received information from your partners that you have mentioned in Q19 and Q20, how was it provided to you (Check all that apply)?

- Face to face conversation.....
- Written document.....
- Telephone
- Electronic mail.....
- Electronic Discussion.....
- Video conferencing
- Others (please specify) _____

Q23 This question aims to collect information about the relation between your partners. Please report from best of your knowledge which of the partners that you have mentioned in Q19 and Q20 had knowledge transfer with each other in 2010? (For example if partner 1 has knowledge transfer with partner 3 you can report it by marking the cell on second row and forth column).

Partner Name	Partner 1	Partner 2	Partner 3	Partner 4	Partner 5	Partner 6	Partner 7	Partner 8	Partner 9	Partner 10
Partner 1										
Partner 2										
Partner 3										
Partner 4										
Partner 5										
Partner 6										
Partner 7										
Partner 8										
Partner 9										
Partner 10										

Thank you for taking the time to complete and submit this survey. Your insight and information are very valuable for this research. If there are any further comments or observations you would like to make relating to the issues raised by the questionnaire, please feel free to outline them below.

Should you have any further questions or concerns about this survey or any of its questions, please contact Meysam Poorkavoos at 01234 400 400. Ext. 2128 or Meysam.Poorkavoos@beds.ac.uk.

Please return your completed survey in the provided envelop, or to:

Meysam Poorkavoos,

Business School, University of Bedfordshire,

Park square, Luton, LU1 3JU.

Appendix C.3: Questionnaire (Online version)

The survey for innovation performance of SMEs

Thanks for your participation in the survey for innovation performance of SMEs. This study aims to help SMEs to improve their competitiveness and performance by means of knowledge transfer with their partners. The result of this research will help managers to develop the firms' knowledge transfer network according to their strategies and requirements to improve their innovation performance.

All of your answers will be treated with strict confidentiality and will not be divulged in a disaggregated form, or used for other purposes except for this research. The result of the research will be presented in cumulative format, with no potential identifiers to a particular respondent or organization.

If you need assistance or have any question please contact: Meysam Poorkavoos, Meysam.Poorkavoos@beds.ac.uk.

Before you start, please take a moment to read these instructions:

- a. Questions requiring ONE answer have CIRCLES next to each answer option - click on a circle to select your answer.
- b. Questions allowing MORE THAN ONE response have BOXES next to each answer option - click on as many boxes as apply to you. If you change your mind about an answer, clicking on the box again will remove the tick.
- c. Some questions ask you to type in your answer in your own words, into the box provided.
- d. Click on 'Next' to move forward to the next page in the questionnaire.
- e. It is possible to change any answer you have made, including going back to pages you have already completed, by clicking on 'Previous'.
- f. Some pages have several questions - please scroll down to answer all the questions.
- g. At the bottom of each page there is a progress bar showing you how far through the survey you are.

1. Would you like to receive a free report of the survey? Yes No

2. Please enter your company name here (we will use this to check your name off of the mailing list) :

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Reset

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The survey for innovation performance of SMEs

Section A: General Business Information

-If it is not possible to provide precise figures please use your estimates.

3. What are the main services/products offered by your company?

A

4. How long has your company been in business?

- Less than 5 years 6 to 10 years 11 to 15 years 16 to 20 years More than 20 years

5. Please answer the following questions about performance of your company in 2011 compared to your competitors:

	very weak	Weak	Medium	Strong	Very strong
How would you rate the profitability of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How would you rate sales growth of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How would you rate market share of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How would you rate overall performance of your company:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. To what extent do you agree with following sentences (in 2011):

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Your company has achieved the startup goals:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your company has provided secure job to employees:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
You are satisfied with the company's performance:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. How many employees have you had in 2010?

- 1-9 10 - 50 51-150 151-250 >250

8. What percentages of the employees had a professional qualification or higher education degree in 2010?

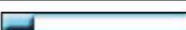
- 0% - 20% 21% - 40% 41% - 60% 61% - 80% 81 - 100%

9. How much was your total sale in 2010?

- Less than 1 million 6 to 10 million 16 to 20 million more than 26 million
 1 to 5 million 11 to 15 million 21 to 25 million

10. What is the percentage of the total sale that you invested in R&D in 2010?

123

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The survey for innovation performance of SMEs

Section B: Product, Service and Process Innovation

11. How would you rate your organisation's performance in the following activities in 2011 compared to similar companies in same sector?

	<i>Much weaker</i>	<i>Weaker</i>	<i>Similar</i>	<i>Stronger</i>	<i>Much stronger</i>
We often improve or revise existing products or services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We add new products or services to our existing ranges	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We make changes that reinforce our prevailing product/service lines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We often reposition existing products or services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We exploit the potential of the established design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We often change the way we make products or deliver services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new or significantly improved processes for producing or supplying products (goods or services) which are new to our firm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop products or services that offer greater advantages to customers than any other products or services currently available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop products or services that better meet the needs of customers than any other product or service currently available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop products or services that require customers to substantially alter their behaviour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new products/services to an existing market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new products/services to a new market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop new product/services that require significantly new technology or ideas that were not existed in the market before	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We create new major product/service programs leading to expansion of current markets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We develop Innovations that make our prevailing product/service lines obsolete	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We introduce new or significantly improved processes for producing or supplying products (goods or services) which are new to our industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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- 12. Please indicate the degree to which you agree or disagree with each of the following statements. in 2011, Compared to our competitors, our business tends to be: (scale is 1= strongly disagree and 5 = Strongly agree)?**

	1	2	3	4	5
One of the first to market with innovative new product and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
More effective than our competitors at taking existing ideas and making them into something better	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Better than our competitors at developing products and services to meet customer needs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Perceived by customers to be more innovative than our competitors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Be at the leading edge of innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- 13. Innovation Strategy: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):**

	1	2	3	4	5
Introduction of innovation as a fundamental part of the company's philosophy and values	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is clarity of corporate vision and goals relating to innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Goals for innovation are communicated effectively throughout the company	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New initiatives are aligned with the overall business strategy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Top management is fully committed to support innovation activities and programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- 14. Ideas Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):**

	1	2	3	4	5
Developing new ideas is a key strength of this business	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technology is a key source of new ideas for our business	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees are actively encouraged to generate new ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New ideas are collected internally on a regular basis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New ideas are most likely to emerge from talking to customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Assistance to develop new ideas is readily available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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15. Portfolio Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Decisions with regard to implementing new ideas are made quickly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reviews of new ideas are held on a regular basis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a good balance of ideas for new products, services and processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is an effective feedback mechanism in place to monitor actual product/service performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have a process for selecting ideas to be developed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The process for selecting ideas is transparent and understood by all employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. Implementation: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Projects to develop new ideas are reviewed on a regular basis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project reviews for new ideas are used to improve performance of new product/service development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cross-functional working is encouraged for developing new ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Project teams, which involve all parts of the company, are set up for developing new ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing new ideas is a well documented process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We control and monitor the process effectively to constantly improve speed to market of new products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. Human Resource Management: Please indicate the degree to which you agree or disagree with each of the following statements. (scale is 1= strongly disagree and 5 = Strongly agree):

	1	2	3	4	5
Employees are aware of their role with regard to innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation is a key criterion in our recruitment and selection process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Human resource policies support a culture of innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation forms a key part of our training and development programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The broad meaning of innovation (ie. product, services and processes) is understood by all staff	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation is reviewed in staff performance reviews	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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- Not at all important* *Not important* *Indifferent* *Important* *Very important*
18. To what extent is being innovative important to your company?

Definition of Inter-firm relationships:

Inter-firm relationships refer to all types of knowledge transfer relations between companies. These relationships are formal and can be with any type of organisations, customers, suppliers, partners, universities or laboratories.

- Not at all important* *Not important* *Indifferent* *Important* *Very important*
19. To what extent is inter-firm relationships important to your company?

- Very dissatisfied* *Dissatisfied* *Neither satisfied nor dissatisfied* *Satisfied* *Very satisfied*
20. Are you satisfied with the overall level of inter-firm relationships that your company has?

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Section C: Inter-firm relationships

Definition of Inter-firm relationships:

Inter-firm relationships refer to all types of knowledge transfer relations between companies. These relationships are formal and can be with any type of organisations, customers, suppliers, partners, universities or laboratories.

Definition of partner:

In this study partner is defined as companies, universities, institutes or laboratories that your company have had an inter-firm relationship.

This section aims to collect information about your partners.

21. How many partners did you have in 2010 (if you had more than 10 partners please enter 10)?

22. Please enter initials of your partner companies in 2010.

1.
2.
3.
4.
5.

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23. What is the main business of each of your partners?

- 1. Company1
- 2. Company2
- 3. Company3
- 4. Company4
- 5. Company5

24. Please indicate how long was your company in a relationship with this company up until 2010?

	<i>Less than 6 months</i>	<i>6 months to 12 months</i>	<i>1 year to 5 years</i>	<i>More than 5 years</i>
1. Company1	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Company2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Company3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Company4	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Company5	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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25. Where is your partner located?

	<i>Local</i>	<i>Regional</i>	<i>National</i>	<i>International</i>
1. Company1	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Company2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Company3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Company4	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Company5	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

26. How often did you make contact with this company in 2010?

	<i>Daily</i>	<i>Weekly</i>	<i>Monthly</i>	<i>Quarterly</i>	<i>Annually</i>
1. Company1	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Company2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Company3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Company4	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Company5	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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27. What is the type of your partners?

	<i>Supplier</i>	<i>Client/Customer</i>	<i>Competitor</i>	<i>Consultant</i>	<i>Others</i>
1. Company1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Company2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Company3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Company4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Company5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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Definitions of different form of interorganisational relationships:

Joint Venture: An entity that is created when two or more firms pool a portion of their resources to create a separate jointly owned organisation.

Network: A hub and wheel configuration with a local firm at the hub organizing the interdependencies of a complex array of firms.

Consortia: Specialized joint ventures encompassing many different arrangements. Consortia are often grouping of firms oriented towards problem solving and technology development, such as R&D consortia.

Alliance: An arrangement between two or more firms that establishes an exchange relationship but has no joint ownership involved.

Trade Association: Organisations (typically nonprofit) that are formed by firms in the same industry to collect and disseminate trade information, offer legal and technical advice, furnish industry-related training, and provide a platform for collective lobbying.

Interlocking Directorate: An interlocking directorate occurs when a director or executive of one firm sits on the board of a second firm or when two firms have directors who also serve on the board of a second firm. Interlocking directorates serve as a mechanism for interfirm information sharing and cooperation.

28. What form of interorganisational relationship did you have with your partner in 2010?

	<i>Joint venture</i>	<i>Network</i>	<i>Consortia</i>	<i>Alliance</i>	<i>Trade Association</i>	<i>Interlocking Directorate</i>	<i>Others</i>
1. Company1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Company2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Company3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Company4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Company5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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29. With th partners that you have mentioned, what types of knowledge did you transfer in 2010 (Check all that apply)?

- Technological knowledge (eg. providing technical solutions)
- Managerial knowledge (eg. project management, co-ordinating)
- Market knowledge (eg. market research, visioning)
- Training (eg. staff training)

Others (please specify)

30. When you received information from your partners that you mentioned before, how was it provided to you (check all that apply)?

- Face to Face conversation
- Written document
- Telephone
- Electronic mail
- Video conferencing

Others (please specify)



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31. This question aims to collect information about the relation between your partners. Please report from best of your knowledge which of your partners had knowledge transfer with each other in 2010? (For example if partner 1 has knowledge transfer with partner 3 you can report it by clicking on the cell on second row and forth column).

Partner 1=Company1, Partner 2=Company2, Partner 3=Company3, Partner 4=Company4, Partner 5=Company5,

Partner 6=(no reply), Partner 7=(no reply), Partner 8=(no reply), Partner 9=(no reply), Partner 10=(no reply)

Partner Name	Partner 1	Partner 2	Partner 3	Partner 4	Partner 5	Partner 6	Partner 7	Partner 8	Partner 9	Partner 10
Partner 1	X									
Partner 2	X	X								
Partner 3	X	X	X							
Partner 4	X	X	X	X						
Partner 5	X	X	X	X	X					
Partner 6	X	X	X	X	X	X				
Partner 7	X	X	X	X	X	X	X			
Partner 8	X	X	X	X	X	X	X	X		
Partner 9	X	X	X	X	X	X	X	X	X	
Partner 10	X	X	X	X	X	X	X	X	X	X

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32. Thank you for taking the time to complete and submit this survey. Your insight and information are very valuable for this research.

If there are any further comments or observations you would like to make relating to the issues raised by the questionnaire, please feel free to outline them below.

Should you have any further questions or concerns about this survey or any of its questions, please contact Meysam Poorkavoos at 01234 400 400. Ext. 2128 or Meysam.Poorkavoos@beds.ac.uk.

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Many thanks for the time you have taken to complete this questionnaire.

**Your submission has been successfully posted to:
Meysam Poorkavoos, researcher at the University of
Bedfordshire Business School.**

Appendix D: Interview Protocol and Interview Questions

Appendix D.1: Interview Protocol

The Interview Protocol

Thank you very much for agreeing to be interviewed. This research aims to understand how knowledge transfer in SMEs helps them to be innovative and competitive. This study collect information about inter-organisational knowledge transfer between partners and how this knowledge transfer together with other factors contribute to the innovation performance of the companies. The results of this research will help SMEs to manage their network with their partner in a way to help them to be more innovative and establish relations with more suitable partners. In addition to this it will help SMEs to understand what are the important resources and factors that help them to be more innovative.

Knowledge transfers between SMEs range from formal relationships (e.g. alliance, joint venture, customer supplier relationships) to informal relationships like an informal conversation between managers of two different companies. But since this research is concerned about innovation so we are interested on those knowledge transfers which contribute to innovation activities of the company.

We further confirm that the information we collect will be treated with strict confidentiality and anonymity. It will not be divulged in disaggregated form, or used for other purpose except for this research.

Would you have any objections to the interview being tape-recorded? This would help me to analyse interview result afterwards. It also helps to preserve the accuracy of the collected data.

Appendix D.2: Interview Questions

Interview date and time:	
Interviewee:	Job title:
Firm:	Address:
Tel:	
E-mail:	

1. Could you please say what main services/products are offered by your company?
2. Does being innovative is important for your company?(to what extend)
3. What are the resources for Ideas for change products/services or processes (enhance existing knowledge)?
4. What are the resources for Ideas for new products/services or processes (acquire new knowledge)?
5. What are other factors that help your company to be innovative (apart from formal networking) (like going to events or using forums)
6. What are the main barriers for innovation in your company?
7. In terms of innovation do you think radical innovation is more important for your business or incremental innovation? Why?
8. What are the factors that can help a firm to do a radical innovation?
9. What are the factors that can help a firm to do an incremental innovation?

-(Researcher explains what is weak and strong partner)
10. How important is the knowledge that is being transferred from your weak partners in developing your new products or making changes in your current products? What about Strong partners?
11. How important is different types of partners for developing new products or services (or improving it or both of them)?
12. How important is different types of knowledge that is being transferred with a partner?(is it more important for new products or more important for improving your products or both)

13. To what extent do you agree with the following sentence
14. Do you think having higher number of partners will increase your innovation performance or it will waste your resources?
15. How well is your company in networking?
16. Are you satisfied with your innovation performance or it needs to be improved?
17. Do you think inter-organisational networking is important for your company?
18. What are your plans for future to make your company more innovative?

Appendix E: FsQCA Solutions (Complex, parsimonious and intermediate)

Appendix E.1: Solutions for Incremental Innovation

TRUTH TABLE ANALYSIS

Model: finc = f(fstrategy, fidea, fportfolio, fimplement, fhr, fdcent, fstrong)

Rows: 15

Algorithm: Quine-McCluskey

True: 1

--- COMPLEX SOLUTION ---

frequency cutoff: 2.000000

consistency cutoff: 0.981493

	raw coverage	unique coverage	consistency
	-----	-----	-----
fstrategy*fidea*fportfolio*fimplement*~fstrong	0.608792	0.044402	0.973349
fstrategy*fidea*fportfolio*fimplement*fhr	0.545213	0.037764	0.981152
~fstrategy*~fportfolio*~fimplement*~fhr	0.374834	0.096179	0.955622
~fdcent~fstrong			
fstrategy*fidea*fportfolio*~fhr*fdcent*~fstrong	0.260511	0.010473	1.000000
fstrategy*fidea*fimplement*fhr*fdcent*~fstrong	0.266854	0.008408	0.985831
fstrategy*~fidea*fportfolio*~fimplement*~fhr	0.327777	0.014014	1.000000
~fdcent~fstrong			
fstrategy*~fidea*~fportfolio*~fimplement*~fhr	0.177312	0.006638	0.994210
fdcent~fstrong			
fstrategy*fidea*~fportfolio*fimplement*~fhr	0.087329	0.011506	1.000000
*fdcent*fstrong			

solution coverage: 0.810297

solution consistency: 0.958639

TRUTH TABLE ANALYSIS

Model: finc = f(fstrategy, fidea, fportfolio, fimplement, fhr, fdcent, fstrong)

Rows: 15

Algorithm: Quine-McCluskey

True: 1-L

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2.000000

consistency cutoff: 0.981493

	raw coverage	unique coverage	consistency
	-----	-----	-----
fportfolio	0.759994	0.239563	0.925620
~fstrategy*~fdcent	0.416286	0.082756	0.928289
fstrategy*fdcent	0.383095	0.030535	0.945051

solution coverage: 0.876383

solution consistency: 0.892042

TRUTH TABLE ANALYSIS

Model: finc = f(fstrong, fdcent, fhr, fimplement, fportfolio, fidea, fstrategy)

Rows: 33

Algorithm: Quine-McCluskey

True: 1

0 Matrix: 0L

Don't Care: -

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2.000000

consistency cutoff: 0.981493

Assumptions:

fstrong (present)

fstrategy (present)

	raw coverage	unique coverage	consistency
	-----	-----	-----
fimplement*fportfolio*fidea*fstrategy	0.657767	0.185573	0.975284
~fdcent*~fhr*~fimplement*~fportfolio*~fstrategy	0.374834	0.096179	0.955622
fdcent*~fhr*fportfolio*fidea*fstrategy	0.270394	0.010473	1.000000
fstrong*fdcent*fimplement*fidea*fstrategy	0.119044	0.004130	1.000000
fdcent*fhr*fimplement*fidea*fstrategy	0.295177	0.008408	0.987173
fdcent*~fhr*~fimplement*~fportfolio	0.181295	0.006638	0.994337
*~fidea*fstrategy			
~fdcent*~fhr*~fimplement*fportfolio	0.327777	0.014014	1.000000
*~fidea*fstrategy			

solution coverage: 0.811624

solution consistency: 0.958704

Appendix E.2: Solutions for Radical Innovation

TRUTH TABLE ANALYSIS

Model: frad = f(strategy, fidea, fportfolio, fimplement, fhr, fbcent, ftiedv, fdensity, fweak, fnodedv)

Rows: 13

Algorithm: Quine-McCluskey

True: 1

--- COMPLEX SOLUTION ---

frequency cutoff: 2.000000

consistency cutoff: 0.909489

	raw coverage	unique coverage	consistency
	-----	-----	-----
fstrategy*fidea*fportfolio*fimplement*fhr *~fbcent*~fdensity*~fweak*~fnodedv	0.436498	0.114574	0.900409
fstrategy*fidea*fportfolio*fimplement*~fhr *~fbcent*ftiedv*~fweak*~fnodedv	0.381913	0.035129	0.925360
fstrategy*~fidea*~fportfolio*~fimplement *~fhr*~fbcent*ftiedv*~fdensity*~fweak*~fnodedv	0.292740	0.035489	0.945867
~fstrategy*~fidea*~fportfolio*~fimplement *~fhr*~fbcent*ftiedv*~fdensity*~fweak*~fnodedv	0.216538	0.019096	0.961600
fstrategy*~fidea*fportfolio*~fimplement*~fhr *~fbcent*~ftiedv*~fdensity*fweak*~fnodedv	0.175824	0.016754	0.980905
fstrategy*fidea*fportfolio*fimplement*~fhr *~fbcent*~ftiedv*~fdensity*~fweak*~fnodedv	0.046478	0.022158	1.000000
fstrategy*fidea*fportfolio*~fimplement*~fhr *~fbcent*ftiedv*~fdensity*fweak*~fnodedv	0.213655	0.006666	0.976936
fstrategy*fidea*fportfolio*fimplement*fhr *~fbcent*ftiedv*~fdensity*fweak*~fnodedv	0.240677	0.026482	0.991834
fstrategy*fidea*~fportfolio*fimplement*fhr *~fbcent*ftiedv*~fdensity*fweak*~fnodedv	0.117997	0.013691	1.000000

solution coverage: 0.697352

solution consistency: 0.895029

 TRUTH TABLE ANALYSIS

Model: frad = f(fstrategy, fidea, fportfolio, fimplement, fhr, fbcent, ftiedv, fdensity, fweak, fnodedv)

Rows: 13

Algorithm: Quine-McCluskey
 True: 1-L

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2.000000

consistency cutoff: 0.909489

	raw	unique	
	coverage	coverage	consistency
	-----	-----	-----
fstrategy	0.938029	0.404251	0.758154
fnodedv	0.556116	0.022338	0.886814
solution coverage: 0.960367			
solution consistency: 0.750000			

 TRUTH TABLE ANALYSIS

Model: frad = f(fnodedv, fweak, fdensity, ftiedv, fbcent, fhr, fimplement, fportfolio, fidea, fstrategy)

Rows: 32

Algorithm: Quine-McCluskey

True: 1

0 Matrix: 0L

Don't Care: -

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2.000000

consistency cutoff: 0.909489

Assumptions:

fweak (present)

ftiedv (present)

fstrategy (present)

	raw coverage	unique coverage	consistency
	-----	-----	-----
fnodedv*~fdensity*ftiedv*~fbcent*~fhr *~fimplement*~fportfolio*~fidea	0.240317	0.019096	0.965268
~fdensity*ftiedv*~fbcent*~fhr*~fimplement *~fportfolio*~fidea*fstrategy	0.311115	0.033688	0.947859
~fnodedv*ftiedv*~fbcent*~fhr*fimplement *fportfolio*fidea*fstrategy	0.405152	0.037110	0.929339
~fnodedv*~fdensity*~fbcent*fhr*fimplement *fportfolio*fidea*fstrategy	0.477752	0.123581	0.907287
fnodedv*~fdensity*fbcent*~fhr*fimplement *fportfolio*fidea*fstrategy	0.061791	0.036030	1.000000
fnodedv*fweak*~fdensity*~fbcent*~fhr *~fimplement*fportfolio*~fidea*fstrategy	0.210413	0.013511	0.977406
fnodedv*fweak*~fdensity*ftiedv*~fbcent *~fhr*~fimplement*fportfolio*fstrategy	0.214556	0.005585	0.977030
fweak*~fdensity*ftiedv*~fbcent*fhr*fimplement *fportfolio*fidea*fstrategy	0.264817	0.025401	0.976096
fnodedv*fweak*fdensity*ftiedv*~fbcent*fhr *fimplement*~fportfolio*fidea*fstrategy	0.117997	0.013691	1.000000
solution coverage: 0.735183			
solution consistency: 0.898899			

