Successful New Product Development through External Collaboration

The case of SMEs in the medical devices sector

Annemien J.J. Pullen

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Cover design: F.J.H. Pullen
Printed by: Wöhrmann Print Service, Zutphen

ISBN: 978-90-365-3099-6

SUCCESSFUL NEW PRODUCT DEVELOPMENT THROUGH EXTERNAL COLLABORATION

THE CASE OF SMES IN THE MEDICAL DEVICES SECTOR

Dissertation

To obtain
The degree of doctor at the University of Twente,
under the authority of the rector magnificus,
prof. dr. H. Brinksma,
on account of the decision of the graduation committee,
to be publicly defended
on Thursday the 21st of October 2010 at 15:00 hrs

by

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Dankwoord

Tijdens de uitvoering van mijn promotieonderzoek heb ik meermaals gedacht dat ik de enige was die tegen typische promotieproblemen aanliep. Ook heb ik regelmatig het gevoel gehad alles alleen te moeten doen. Waarschijnlijk herkennen veel promovendi zich hierin en sta ik in deze ervaring niet alleen. Nu het meeste werk achter de rug is en ik objectiever terug kan kijken op het proces zijn er veel mensen die mij hebben geholpen en ondersteund. Alle aanmoediging en hulp die ik heb gehad is van onschatbare waarde geweest voor het afronden van het onderzoek. Daarom wil ik hierbij iedereen die mij heeft geholpen bedanken, enkele personen in het bijzonder.

Petra, Aard en Olaf, de afgelopen 4 jaar hebben jullie op geheel eigen wijze mijn promotiecommissie gevormd en ieder je eigen waardevolle bijdrage geleverd. Daarvoor wil ik jullie bedanken.

Petra, als eerste wil ik jou bedanken. Toen je 5 jaar geleden mijn afstudeerbegeleider werd, had ik niet kunnen bedenken dat we hier vandaag samen zouden staan. Ik wil je bedanken voor het feit dat je je 5 jaar lang met hart en ziel voor mijn werk hebt ingezet. Dat vind ik geweldig. Je hebt me overal bij betrokken en me meegenomen naar allerlei interessante bijeenkomsten en conferenties in binnen- en buitenland. Ik vond het erg bijzonder om je oratie van zo dichtbij mee te maken en om nu je eerste promovenda te zijn. Het was erg gezellig om bij jou thuis of op kantoor werk en allerlei andere dingen te bespreken Tijdens het promotietraject hebben we elkaar meermaals hoofdbrekens bezorgd, maar een betere mentor had ik niet kunnen treffen. Je enthousiasme, kennis van zaken, grote betrokkenheid en vertrouwen in mijn kunnen zijn onmisbaar geweest. Petra, bedankt voor je enorme inzet en enthousiasme!

Aard, als promotor heb je een speciale rol vervuld in het promotietraject. Ondanks je drukke schema heb je mijn werk van heel kritisch en bruikbaar commentaar voorzien. Op de kritieke momenten heb je veel aandacht aan het onderzoek besteed. Vooral je verregaande theoretische kennis van verschillende stromingen en het belang dat je hecht aan praktische relevantie is heel waardevol geweest. Behalve dat, stel ik het erg op prijs dat ik de afgelopen 4 jaar naar alle conferenties die me interessant (en leuk) leken toe mocht. Dat heeft erg motiverend gewerkt en heeft ervoor gezorgd dat ik met veel interessante mensen en plaatsen kennis heb gemaakt. Bedankt voor de vrijheid die je me in het onderzoek hebt gegeven. Dat ik zelf mijn onderzoek heb kunnen ontwerpen is leerzaam en motiverend geweest.

Olaf, “neem de lezer aan de hand” is een veelgebruikte uitspraak in onze besprekingen geweest. Onze 1 op 1 werkbesprekingen waren heel intensief en uiterst waardevol. Je hebt me iedere keer laten uitleggen wat ik eigenlijk bedoel. Dat, en jouw kritische vragen hebben mij gedwongen om ècht over een stuk na te denken. Dat ik daardoor soms volkomen vertwijfeld thuiskwam is een bijkomend effect. Wat voor mij ook belangrijk is geweest is dat we de eerste paar minuten altijd even hebben bijgepraat over van alles en nog wat. Dat was erg prettig en vertrouwd.

Op deze plek zou ik ook graag al mijn collega’s van de vakgroepen NIKOS en OOHR willen bedanken voor de goede werksfeer, inhoudelijke discussies en niet te vergeten de gezelligheid. Ik zou echter enkele collega’s tekort doen wanneer ik ze hier niet met naam en toenaam zou noemen.
Koos, bedankt dat ik op de afdeling OOHR ruim 4 jaar mijn werkplek heb gehad, terwijl ik officieel bij NIKOS hoor. Ik vond het heel erg leuk om onderdeel van zowel NIKOS als OOHR te zijn. Op die manier heb ik het beste van beide afdelingen kunnen gebruiken. Ik hoop dat ik ook iets heb kunnen bijdragen. Koos, ik heb het bij OOHR enorm naar m’n zin gehad, bedankt!
Waling, je bent een bijzonder heerschap met een enorm gevoel voor humor. We hebben in de loop van de tijd een bijzondere omgangsvorm ontwikkeld waarin het een soort wedstrijd is geworden wie de snelste woordgrappen kan maken. Dat was soms bijzonder vermoeiend, maar wel erg leuk. Bedankt dat je me de afgelopen jaren scherp hebt gehouden, het was mij een waar genoegen!
Klaasjan, bedankt dat je altijd bereid bent geweest om mijn werk door te lezen en van commentaar te voorzien. Jouw kritische blik heeft voor veel verbeteringen gezorgd.
Verder wil ik Matthias, Jeroen en André bedanken voor het aanhoren van al mijn commentaar, uiteenzettingen en opmerkingen over van alles en nog wat. Ongetwijfeld zijn jullie mij vaak zat geweest, maar ik had me geen betere kamergenoten kunnen wensen!
Thijs, Joris, David, Anna, Petra, Kasia, Matthias, Jeroen, André, Marco en Remco bedankt voor alle gezelligheid en de leuke aio-uitjes. In tijden van PhD-crisis heeft dat enorm geholpen voor het moreel!
Het secretariaat van zowel NIKOS als OOHR, met in het bijzonder Hèla en Marie-Christine, bedankt voor al jullie hulp en ondersteuning!

Graag wil ik op deze plek de mensen bedanken die voor mij het allerbelangrijkst zijn, die altijd voor mij klaarstaan en waar ik altijd bij terecht kan: papa, mama, Jan, Coen, Lotte, Johanna, Hans, Frederiek en Jasmien.
Papa en mama, een beter thuis dan bij jullie is er niet. Dankzij jullie heb ik een onbezorgde jeugd,
studententijd en aio-tijd gehad. Jullie hebben mij altijd ondersteund in de keuzes die ik heb gemaakt en waar nodig, ook duidelijk, bijgestuurd (achteraf bedankt). Zonder jullie enorme inzet, ondersteuning en pep-talks was het mij niet gelukt om dit boek te schrijven!
Jan, ik ben er bijzonder trots op dat jij mijn broer bent. Bedankt voor het ontwerpen en schilderen van de voorkant van dit proefschrift. Dat maakt het een heel persoonlijk proefschrift. Ik vond het erg leuk dat je geregeld even op het Capitool langskwam om te buurten. Samen op conferentie naar LA was geweldig. Ook wil ik jou en Lotte bedanken voor het bellen van alle bedrijven. Dankzij jullie enthousiasme heeft een groot deel van deze bedrijven meegewerkt aan mijn onderzoek. Bedankt!
Coen, ik weet dat ik tijdens het afronden van het proefschrift niet altijd even gezellig ben geweest. Bedankt dat je alle stress hebt aangehoord en me serieus hebt genomen. jij hebt ervoor gezorgd dat ik in de weekenden niet alleen aan “het gepromoveer” dacht. Jouw kritische blik, relativeringsvermogen en je humor plaatsten de meeste promotieproblemen in perspectief. Daardoor kon ik ‘s maandags met herziene moed verder werken. Het is goed om te weten dat ik op jou terug kan vallen. Bedankt.

Tenslotte wil ik op deze plaats mijn oma Schreurs-Berendsen bedanken voor al haar aandacht, interesse en trots over dit promotietraject. Wat zou ze trots zijn geweest! En wat zou ze druk zijn geweest met de voorbereidingen voor vandaag! Misschien nog wel meer dan ik zelf. Ik vind het ontzettend jammer dat ze er niet meer bij is en dit ceremonieel net niet mee kan maken. Ze had het geweldig gevonden. Daarom draag ik dit boek aan haar op.

Annemien Pullen

Enschede, oktober 2010

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Introduction

1. Introduction

This dissertation deals with the issue of how small and medium sized companies organize new product development. The focus is specifically on the way companies collaborate in new product development (NPD), because collaboration is often a necessity for SMEs and, from that perspective, a prerequisite for successful new product development. The statements of NPD managers below, which are quoted from interviews with these NPD managers, indicate that external collaboration in NPD projects is common. However, these statements below also indicate that in collaborating with the goal of new product development, small and medium sized companies (SMEs) encounter numerous problems.

> *"The product entered the market two years later than planned. This was caused by miscommunication with our partner and because we did not build in a clause in the contract with this partner. The latter kept costs low, but also prevented us from the possibility to impose a fine on the partner when materials were delivered late or when payments were not made..."*
>
> *"The most difficult part in the NPD project was production. The collaboration between the materials expert and us, the mould designers and manufacturers, was incredibly important. Integrating knowledge on materials and building moulds would be a hole in the market…"*
>
> *"The biggest problem in new product development is knowledge about the materials and knowledge of the properties of specific materials. In the future we would continue to collaborate with an enthusiastic group of people. However, it is important to agree upon the goal and purpose of the collaboration: what do you give and what do you get in return? Make sure your partners have the appropriate know-how. Find the right people and filter the useful contacts from all the "spam". This needs improvements…"*
>
> *"In general it is hard for SMEs to find qualified personnel and partners and to support new employees. Actually, the main issue is that we're always running out of time and that we, as an SME, have to do everything ourselves…"*

"In future projects we need to be able to better judge whether or not companies are willing to pay and if they can afford to pay part of the project…"

The above statements of NPD practitioners from SMEs also illustrated that collaboration is highly important in new product development. However, there is room for a lot of improvement in the organization of such collaborations. Even though numerous alliances fail in practice (Duysters, Kok, & Vaandrager, 1999; Spekman, Lynn, MacAvoy, & Forbes III, 1996), the academic debate insufficiently addresses how to organize these networks in the context of NPD (Gassmann, 2006). In both practice and theory it seems there is a gap concerning successful organization of networks in terms of innovation performance for SMEs. The research described in this dissertation is addressing the issue of how SMEs should organize their external network for successful new product development.

To control for industry effects the research needs to be conducted in a single industry (Vorhies & Morgan, 2003). In order to be suitable for this research, the industry should posses some specific characteristics. First of all, a high level of collaboration between companies with the goal of new product development needs to be present. Second, there must be high levels of new product development activity and innovation in the industry. Third, the industry must be dominated by small-and medium sized companies. An industry that meets all these requirements is the medical devices sector. The sector is characterized by strict regulations and complex products. Both the strict regulations and complexity of the products are the cause of high levels of collaboration in this sector. There is a wide range of exchange of knowledge, specialized personnel, monetary resources, and materials. The sector is also characterized by short product life cycles. The complex products have a product life cycle of 18 months, whereas the average development time of a new medical device is 4 years. This forces companies to continuously improve and develop new products and leads to a lot of new product development activity. Finally, 80% of companies in this sector are SMEs.

Central in this research are the characteristics of the company, the characteristics of the network, and the outcome of new product development (i.e. the innovation performance). Earlier research has paid a lot of attention to networks, but the cases from the point of view of one single SME are very limited. In addition, earlier

research mainly focuses on the organization of the network of large companies, instead of on the organization of the network of small and medium sized companies. Combining company characteristics and network characteristics, both in relation to innovation performance in this way has not yet been conducted in previous research.

This research focuses on the challenges faced by small and medium sized companies in new product development and the importance of the external network in this situation. The next section (§1) describes the research background and research question. In this section, the theory in which the research is embedded is briefly introduced. In section 2 both the theoretical approach (§2.1) and the empirical approach (§2.2) to the research are described. Section 3 describes the medical devices sector as the setting of this research. In addition to general figures about the sector in Europe (§3.1), new product development (§3.2) and collaboration (§3.3) in this sector are described. Finally section 4 presents the outline of the thesis. To illustrate the outline of the thesis, table 1 in section 4 presents an overview of the chapters, related research steps, methodology, and related articles.

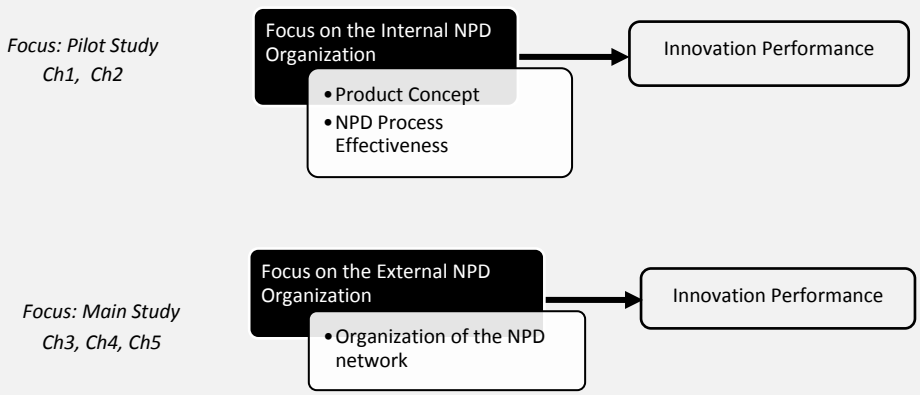
2. Research Background and Research Question

Small and medium sized companies (SMEs) must, on the one hand, innovate to compete (Cefis & Marsili, 2006; Hanna & Walsh, 2002; O'Regan, Ghobadian, & Sims, 2006) and on the other hand they need to collaborate. This need for collaboration is caused by SMEs that, due to financial, manpower and time related constraints cannot do everything themselves and therefore they need to collaborate in new product development (Hanna & Walsh, 2002; Karlsson & Olsson, 1998; Rogers, 2004; Rothwell, 1991). Especially in complex, high-tech new product development (NPD) processes that are characterized by high costs, time pressure and strict regulations, external collaboration is positively related to innovation performance (Hanna & Walsh, 2002; Ritter & Gemünden, 2003, 2004; Rothwell, 1991; Teece, 1989). In addition to the importance of external collaboration, literature shows the importance of (interaction with) the internal organization for innovation performance (among others (Balachandra & Friar, 1997; Cooper, 1984; Cooper, Edgett, & Kleinschmidt, 2004a, 2004b, 2004c; Cooper & Kleinschmidt, 1995; De Weerd-Nederhof, Bos, Visscher, Gomes, & Kekale, 2007; Ernst, 2002; Galende & Fuente, 2003; Griffin, 1997; Kahn, Barczak, & Moss, 2006; Powell, Koput, & Smith-Doerr, 1996; Sivadas & Dwyer, 2000). Figure 1 shows these two focus

areas in relation to innovation performance. The first focus area that impacts innovation performance is the internal organization, which consists of product concept issues on the one hand and NPD process effectiveness on the other hand. Product concept issues consider product functionalities that concern safety, quality, usability, treatment effectiveness and cost effectiveness of products. These product concept issues are bounded by strict sector regulations, and are therefore to a large extent similar for all companies. NPD process effectiveness considers the effectiveness of the development process in terms of speeds, flexibility and productivity. The second focus area that impacts innovation performance is the organization of external networks.

The literature clearly identifies the internal and external organization as two factors that influence innovation performance. Literature mainly addressed the internal organization, but in an increasing degree also the external organization. As indicated by the work of Chesbrough (2003) on open innovation, practice shows that the influence of the external environment is increasing. Companies are no longer individual entities, but are rather actors that operate in a shared system with other companies and stakeholders. This movement is also reflected in this research. We start off by studying the internal organization in a pilot study in chapters 1 and 2. Based on the findings from the pilot study we shift the focus to the external organization in chapters 3, 4 and 5.

Figure 1: Research Focus Areas



In examining the impact of the internal organization, sector characteristics like strict regulations are often not taken into account. When strict regulations are taken into account, the argument is that it is difficult for SMEs to distinguish themselves in terms of innovation performance based on product concept issues. To verify this assumption a pilot study was executed that examined the influence of both product concept issues and the efficiency of the NPD process on innovation performance (chapter 1) and to examine the internal organization of high performing SMEs (chapter 2). The pilot study was conducted in the highly regulated medical devices sector and showed that SMEs are less able to differentiate in terms of innovation performance through product concept issues than through efficiency of the NPD process. However, as stated before, due to limited financial and manpower resources, SMEs in general need to be efficient to be able to survive in the first place.
It seems that, due to both strict regulations and limited sizes of SMEs, they are not able to distinguish enough from competitors in terms of innovation performance by focusing on the internal NPD organization. Focusing on the external NPD organization seems to be a more successful strategy to gain competitive advantage through innovation performance. Therefore the central theme of this dissertation is the examination of the way SMEs organize their external network to achieve high innovation performance.

In contrast to most past research the focus is not on the network as a whole, but on the ego-centered network in which the perspective of the SME is taken. The ego-centered network consists of a focal actor, termed *ego* (in this case the SME), a set of *alters* who have ties to ego (in this case the external partners), and measurements on the *ties* among these alters (Wasserman & Faust, 1994).
One of the first lines of theory development which stressed the role of interaction patterns between actors to explain the sustainability of a social system was developed in the social systems perspective by Parsons (Parsons, 1937, 1964). The assumption that the interaction between actors is what adds value is further developed in structural network theory (Wasserman & Faust, 1994). In strategic management Child followed upon this, acknowledging the presence of strategic choice (Child, 1972) which implies that organizations are not just passive recipients of environmental influence but also have the power to reshape the environment. Child (1972) stipulates that a certain amount of strategic choice is present for a company to be able to organize its external network. Based on the assumption that the interaction between actors is what adds value, earlier research considered the

influence of external networks on innovation performance (among others (Ahuja, 2000; Becker & Dietz, 2004; Biemans, 1989; Branzei & Thornhill, 2006; Capaldo, 2007; Chang, 2003; Cooke & Wills, 1999; Duysters, et al., 1999; Faems, VanLooy, & Debackere, 2005; Fukugawa, 2006; Nooteboom, 1994; Pittaway, Robertson, Munir, Denyer, & Neely, 2004; Ritter & Gemünden, 2004)) and effects of single variables of the external network on innovation performance (among others (Burt, 1976, 1992b; Emden, Calantone, & Droge, 2006; Granovetter, 1973; Zaheer & Bell, 2005)). However, the question of how to organize external networks to achieve high innovation performance remains rather unclear. Therefore the central research question of this thesis is:

> *"To what extent can differences in innovation performance of SMEs in a highly regulated sector be explained by differences in the organization of their networks?"*

The research objective is to find how the NPD network between a focal SME and its external partners, that is related to high innovation performance, is organized.

3. Research Approach

To achieve the research objective as stated above, the research question is approached from both theory and practice. Both the theoretical research approach and the empirical research approach are explained in this section.

3.1. Theoretical Research Approach

In this research, the interaction between companies is considered to add value in the form of innovation performance. As described in §2, company boundaries are dissolving and companies are increasingly considered as actors operating in a shared social system. This idea is inspired by the work of Parsons (1964) who defines a social system as:

"…a social system consists in a plurality of individual actors interacting with each other in a situation, which has at least a physical or environmental aspect, actors who are motivated in terms of a tendency to the "optimization of gratification" and whose relation to their situations, including each other, is defined and mediated in terms of culturally structured and shared symbols" (Parsons, 1964).

In this definition, four dimensions are embedded: 1) interaction between actors, 2) striving for goal attainment, 3) optimization of processes and 4) maintaining patterns of culturally structured and shared symbols. These dimensions all work concurrently and all influence the outcomes of a social system. In the context of this research the outcome of the social system is innovation performance.
This research is inspired by the social systems perspective and starts with a structured literature review. Modern management literature that is inspired by the work of Parsons, is the point of departure for the structured literature review. The structured literature review focuses on the selection of network characteristics that are related to innovation performance and new product development. Both literature and earlier research present numerous variables and characteristics that are related to external networks or firm performance. However, due to the heterogeneity of the (large amount of) variables and their contents it is unclear which network characteristics are related to innovation performance. As a consequence, it seems that an adequate measurement instrument, for our purpose, to simultaneously measure the relation between the values of several network variables and innovation performance is lacking. The structured literature review resulted in the selection of the network characteristics "resource complementarity", "goal alignment", "trust", "strength of ties", "density", "network size", and "structural holes position". For measurement purposes it is inevitable to also operationalize these network characteristics. The operationalization of network characteristics and innovation performance is based on literature and validated through factor analysis **(chapter 3).** The final measurement instrument includes measures on "resource complementarity", "goal alignment", "trust", "distrust" and the newly developed measure "network position strength".

Prior to examining how exactly successful interaction between companies is organized, it is not only relevant to study the relation between innovation performance and individual network characteristics, but it is also of importance to study the relation between multiple network characteristics and innovation performance. Research often focuses on the relation between one individual network characteristic and innovation performance. For instance goal alignment versus innovation performance (Dess, 1987), resources and innovation performance (Håkansson, 1989; Lambe, Spekman, & Hunt, 2002), or structural holes versus innovation performance (Burt, 1992b). However, focusing on one or more network characteristics in solitude in relation to innovation performance

leads to a form of reductionism (Van de Ven & Drazin, 1985), as 1) real-life organizations and networks consist of multiple characteristics in combination, and as 2) ignoring the interaction between variables might lead to different research results. An additional issue in the relation between network characteristics and innovation performance is the role of product innovativeness. Product innovativeness (i.e. the level of newness of the product to the market and the firm (Booz, Allen, & Hamilton, 1982; Langerak & Hultink, 2006)) is assumed to be an important moderating or control variable in relationships between organizational characteristics and innovation performance, because the level of resources and the mix of organizational characteristics is different for radical and incremental innovation (Wheelwright & Clark, 1992). This argument has been proved to be correct for internal organizational characteristics in relation to innovation performance (Danneels & Kleinschmidt, 2001; Kleinschmidt & Cooper, 1991; Langerak & Hultink, 2006; Szymanski, Kroff, & Troy, 2007). However, the role of product innovativeness in the relation between network characteristics and innovation performance is not thoroughly examined. Examining the underlying structure of network characteristics, innovation performance and product innovativeness, indicated that only the combination of network characteristics taken together (i.e. the network configuration) has a significant effect on innovation performance **(chapter 4)**.

Which combination of network characteristics (i.e. network configuration) most affects innovation performance in particular contexts Up till this moment, has not yet been clearly demonstrated in research (Pittaway, et al., 2004). Addressing multiple network characteristics simultaneously aligns with configuration theory. Configuration theory posits that for each set of network characteristics, there exists and ideal set of organizational characteristics that yields superior performance (Van de Ven & Drazin, 1985). In order to be maximally effective, organizations must have design configurations that are internally consistent and fit multiple contextual dimensions (Mintzberg, 1979). The conceptualization of fit that is most consistent with the logical arguments of configuration theories is the systems approach to fit (Doty, Glick, & Huber, 1993) which we use in this research **(chapter 5)**. Using the systems approach enables one to find the values of multiple network characteristics that in combination lead to high innovation performance in the context of this research.

In summary, the theoretical approach to answer the research question "How to explain differences in innovation performance of SMEs from a network perspective in a highly regulated sector by examining the organization of the network?" starts off with the construction of the theoretical framework (chapter 3), the examination of the underlying structure of variables (chapter 4), the operationalization of the variables (chapter 3), and the examination of the values of network characteristics within the high performing network configuration.

3.2. Empirical Research Approach

When approaching the research question empirically, one is most of all eager to understand what distinguishes highly successful and less successful companies in terms of network organization (**chapter 5)**. Data on network characteristics is gathered in Dutch small- and medium sized companies that are active in the development of new medical devices.

As explained in the previous subsection (§3.1), the systems approach (Drazin & Van de Ven, 1985) is used. The systems approach examines the impact of the network characteristics taken as a set on innovation performance by calculating the distance from an ideal profile. The ideal profile is in this research the network configuration that is related to high innovation performance. The ideal profile can be generated either theoretically or empirically. As Drazin and Van de Ven (1985), an empirical-based ideal profile is used in this research. Using an empirical based ideal profile, makes sure that the ideal profile is a faithful representation of reality. Consistent with configuration theory procedures, the 15% highest performing companies in terms of innovation performance were identified. The 15% most successful and the 85% less successful companies clearly differ in the organization of their network. The top 15% companies have a businesslike approach to collaboration. They apply open innovation in a closed business model. In contrast, the bottom 85% of companies use a more soft and friendly, trust-based approach towards collaboration.

In summary, the empirical approach to answer the research question *"To what extent can differences in innovation performance of SMEs in a highly regulated sector be explained by differences in the organization of their networks?"* is based on the systems approach and identifies the top 15% best performing companies from practice. Using the systems approach with an empirical based ideal profile, not only helps answering the research questions, but also ensures that the research objective is achieved.

4. Research Setting: The Medical Devices Sector

The context of the research is the medical devices sector[1]. As explained in the introduction of this chapter, this sector meets the set requirements to be suitable for this research. The intense competition, high rate of growth, continuing technological innovation, and customer sophistication suggest a significantly above average level of new product development activity. In addition, medical devices companies need to cooperate with external partners to share resources for the development of new products. Finally, the third met requirements is the structure of the market: the medical devices sector consist for 80% of SMEs. The medical devices sector and its characteristics are described below.

4.1. The European Medical Devices Market

80% of companies in this sector are SMEs. This are about 9200 companies, that employ a total of 434.560 people in the European Union. The European Union is the 2nd largest market for medical devices and disposables worldwide and represents 33% of the worldwide medical devices and disposables market. Over the years 2003-2007 the market increased at a rate of 5,6% per year. In the short term, due to the financial crisis, it is expected that investments in the sector will slowdown. Hospitals will most probably postpone replacements of medical devices and put off the construction of new facilities. EU manufacturers will increasingly look for ways to work together in order to reduce costs. In the long term, demand is expected to keep growing, due to the ageing population, rising labor costs, privatization of public services, environmental issues and product quality, design, and technological developments (CBI, 2009). The long term trends suggest that the market seems to be geared toward a prevention-oriented health care model in which the consumer has a growing influence. Innovative products that are convenient, user-friendly and intelligent are the future (CBI, 2009).

The European Union is also world's 2nd largest *producer* of medical devices. Production of medical devices increased between 2003 and 2007 on average by 6,9% per year. However, European producers are increasingly outsourcing

[1] According to medical device directive 93/42/EEC , a medical device is:"*…any instrument, apparatus, appliance, material, or other article, whether used alone or in combination, including the software necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of a) Diagnosis, prevention, monitoring, treatment or alleviation of a disease, b)Diagnosis, monitoring, treatment or alleviation of or compensation for an injury or handicap, c)Investigation or modification of the anatomy or of a physiological process, or, d)Control of conception. And which does not achieve its principal intended action in or on the human body by a) Pharmacological, b)Immunological or c) Metabolic means, but which may be assisted in its function by such means".*

production to low-wage countries. The EU production sector is heavily dependent on exports and due to the financial crisis demand in is dropping. Also the increased international pressure from low-wage countries and strong global players might result in a decrease of production in most EU countries. Between 2003 and 2008 imports grew at a rate of 8,2% per year. Between 2003 and 2008 exports grew by 7,7% per year (CBI, 2009).

4.2. The role of Regulations in the Medical Devices Sector

The strict regulations in the medical devices sector are to promote and protect the public health by making safe and effective medical devices available in a timely manner. The standard for demonstrating safety and effectiveness is determined in part by the risk associated with the device in question. Devices are classified according to their perceived risk using a 3-tiered system (class I, II, or III) (Kaplan, et al., 2004). The European Union system relies heavily on notified bodies (NBs), which are independent commercial organizations to implement regulatory control over medical devices. NBs have the ability to issue the CE mark, the official marking required for certain medical devices (Kaplan, et al., 2004). NBs typically function in a closed manner, providing little visibility on criteria required for approval. This dynamic allows for a high degree of variation as well as competition among NBs (Kaplan, et al., 2004).

The regulations come into expression in for example clinical trials. Clinical trials are a very unique characteristic of the sector and are obliged for every new product (Shaw, 1998). If a product concept is not approved by these clinical trials, the product may not be produced and commercialized (see figure 2). Despite all efforts of companies to meet these regulations, many product concepts are not being approved by these clinical trials which means that the product may not be produced and commercialized (Shaw, 1998) (FDA, 2004). For companies this is unfortunate as large investments (e.g. financial and time related investments) are lost. Although, formally, demonstrating safety and performance of a new device is sufficient to receive CE-marking (European Conformity), companies are under rising pressure to articulate the value of their products in terms of their incremental cost-effectiveness. There is a growing need to demonstrate that a new product is superior to an existing one in terms of “value for money” (Vallejo-Torres, et al., 2008).

The strict regulations characterize the business environment of companies in the medical devices sector (Kaplan, et al., 2004) and are the cause of the time and cost consuming product development process (Atun, Shah, & Bosanquet, 2002).

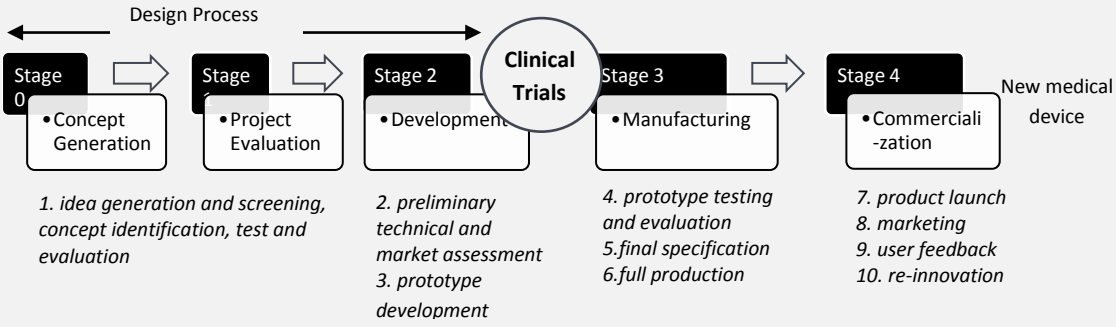
4.3. New Medical Device (Product) Development

The management of innovation and the related processes of new product development (NPD) will play a key role in the future success of the medical devices industry (A. Brown, Dixon, Eatock, Meenan, & Young, 2008). Medical technology is characterized by a constant flow of innovations, which are achieved by a high level of research and development within the industry (EUCOMED, 2007). EUCOMED estimates that between 3%-6% of total medical technology sales is spent on R&D, which is €3,8 billion annually in Europe (EUCOMED, 2007). The intense competition, high rate of growth, continuing technological innovation, and customer sophistication suggest a significantly above average level of new product development activity (Rochford & Rudelius, 1997).

The average development time for medical devices ranges from 1-2 years for incrementally new devices and 5-7 years for radically new devices, dependent on the product type, complexity, and degree of risk to the patient that dictates their regulatory defined conformance and approval route (Hourd & Williams, 2008). However, the life cycle of a specific type or variation of a device is often as short as 18-24 months, and their development is characterized by a constant flow of incremental product improvements, making early and rapid assessments of their likely cost-effectiveness is of particular importance (EUCOMED, 2007; Vallejo-Torres, et al., 2008).

The innovation cycle for new medical devices, has ten stages which are summarized below (Shaw, 1998). These ten stages of Shaw (1998) can be aligned with the five stages of the NPD process that Griffin (1997) distinguishes. Based on Griffin (1997) and Shaw (1998) figure 2 visualizes the stages in the NPD process for a medical device. In practice, medical devices companies apply all kinds of variations on this basic model, like concurrent engineering or a Stage-Gate NPD process. Because the route to commercialization of a device is complicated by regulatory and reimbursement approval requirements, most medical device companies operate some form of staged decision-making development process that is regularly viewed and decisions are taken as to whether and how to proceed (Vallejo-Torres, et al., 2008).

Figure 2: The stages in the NPD process for a medical device (based on Griffin (1997) and Shaw (1998))



4.4. Collaboration in the Medical Devices Sector

Working together to leverage resources and expertise is almost a necessity if companies hope to expeditiously bring new medical products to the market (Sanhai, 2008). Collaboration with external partners for new product development becomes increasingly important due to the strict regulations, complexity of the products and the fragmentation of the market. Mainly due to the regulations which cause a very time- and cost consuming new product development process (Kaplan, et al., 2004; Nieto & Santamaría, 2010) SMEs in the medical devices sector face the problem of a lack of financial resources and a need of qualified personnel in their NPD (Kaufmann & Tödtling, 2002; Rogers, 2004). Therefore, they need to cooperate with external partners to share resources for the development of new products (Biemans, 1989; Millson & Wilemon, 2000; Prabhakar, 2006). The rising difficulty and unpredictability of medical product development calls for a national effort to identify specific critical activities that, if carried out, would help modernize these efforts (Sanhai, 2008). One of these activities is that NPD managers need to assure coordination between their NPD teams and external organizations (Millson & Wilemon, 2002). In recent years the medical device manufacturers have been increasingly working together on a global scale to fend off competition and reduce costs (CBI, 2009).

5. Embeddedness in the Institute for Innovation and Governance Studies (IGS) of the University of Twente

The Institute for Innovation and Governance Studies (IGS) is one of the priority research institutes of the University of Twente and performs multi-disciplinary research and postgraduate research training in the field of the governance and

management of technological and social innovation. One of the four Strategic Research Orientations (SRO) in the institute is the "Management of Innovation & Entrepreneurship" SRO. The research in this dissertation is part of this Strategic Research Orientation. The Innovation & Entrepreneurship group focuses on the organization and management of innovation and entrepreneurship. Factors taken into consideration stem from operations management, organization theory, human resource management, strategy, marketing, international management and entrepreneurship. In this SRO strong collaboration exists between the departments NIKOS (The Dutch Institute for Knowledge Intensive Entrepreneurship) and OOHR (Operations, Organizations and Human Resources). Three cornerstones in the research are:

1. The interaction between characteristics of Technology, Innovation, Human Resources, and Entrepreneurship processes within and between organizations related to (innovation) performance.
2. Multi-level and multi dimensional analysis of network actors in innovation and entrepreneurship processes.
3. The research area is characterized by a multi-method approach in which qualitative and quantitative approaches are combined in a process oriented research. Furthermore, in line with the "engaged scholarship approach" (Van de Ven, 2008), the practical relevance of this area of research is considered to be a cornerstone for the academic development.

Technological developments play an important role in the selection of research settings. Selected fields of research are for example nanotechnology, information and communication technology, regenerative medicine, new construction materials & methods, and new production technologies.

On a theoretical level, the approach of innovation and entrepreneurship research is strongly influenced by (structural) contingency theory and social system theory aiming at developing new process oriented approaches. On a methodological level, the research is characterized by a multi-level approach, with the organization as primary unit of analysis. Levels of analysis are defined inside as well as outside the organization. On an empirical level, strongly rooted in the working philosophy is the idea of what recently has been labeled as "engaged scholarship" (Van de Ven, 2008), which in the tradition of NIKOS and OOHR always has meant to conduct research in direct interaction with the objects of study (firms, entrepreneurs, universities, regional intermediaries) to ensure practical relevance as well as theoretical progress.

One of the main research themes in the Strategic Research Orientation (SRO) is the theme ”Entrepreneurship in Networks: studying the role of networks in entrepreneurial processes of opportunity recognition, business concept development and exploitation of value creation” which is led by Professors Groen, Fisscher and De Weerd-Nederhof. The focus is on knowledge intensive entrepreneurship, however there is also a strong link to business development in incumbent firms based on R&D management or NPD management research. The research in this dissertation is strongly linked to this research theme in the SRO as it focuses on the management and organization of NPD networks in the highly technological research setting of the medical devices sector. Not only the subject, but also the research methodology strongly relates to the SRO. The research is based in the social systems theory, takes the perspective of the organization and is conducted in direct interaction with medical devices companies.

6. Structure of the Thesis

The thesis includes 6 chapters which are based on 5 research papers and a concluding chapter. This section presents a short introduction of all chapters. **Chapters 1 and 2** exhibit a pilot study among Spanish medical devices SMEs (chapter 1) and SMEs in multiple highly regulated sector (chapter 2). The pilot study focuses on the relation between the internal NPD organization in terms of product concept issues and the NPD process in relation to the innovation performance (chapter 1). In addition, the pilot study examined how SMEs that achieve high innovation performance shaped their internal organization (chapter 2). This pilot study was conducted to examine to what extent the internal organization is adequate to distinguish SMEs in terms of innovation performance in highly regulated sectors. As described before, the results of this pilot study showed that SMEs in highly regulated sectors, should rather focus on the organization of their NPD network to gain competitive advantage.

Chapter 3 represents research phase 2 and presents the theoretical foundation for the examination of external SME (network) characteristics in relation to innovation performance. It focuses on the selection and operationalization of network characteristics that are related to innovation performance. Since theory lacked an adequate measurement instrument to measure simultaneously multiple network characteristics, in this chapter such a measurement instrument is constructed based on theory and a pilot survey among practitioners. Using data that was gathered in medical device SMEs the measurement instrument was also validated in a factor analysis. The final measurement instrument includes measures for the

network characteristics “resource complementarity”, “trust”, “distrust”, “goal alignment”, and “network position strength”.

Research step 3 of the thesis is represented by **chapter 4**. By using multiple logistic regression on data from medical device SMEs, the underlying structure of product innovativeness, several network characteristics and innovation performance is studied. The objective of the chapter is to find out how exactly product innovativeness, individual network characteristics and combinations of network characteristics are related to innovation performance. By examining the underlying structure of the variables it becomes clear that the network configuration (i.e. the combination of network characteristics) is not simply the adding up of several individual network characteristics. The network configuration is an internally consistent combination of network characteristics that has a direct effect on innovation performance.

Chapter 5 includes research step 4. After selecting and operationalizing network characteristics in chapter 3 and examining their relation to innovation performance in chapter 4, chapter 5 shows which precise combination of network characteristics is related to innovation performance. The systems approach is used to identify the top 15% best performing companies in the dataset and their successful network configuration. Subsequently, for each case company the Euclidean distance from this successful configuration is calculated. The larger the distance from the successful configuration, the lower the innovation performance. The successful network configuration represents a “business-like”, focused approach to collaboration, in contrast to the less successful “soft and friendly” approach to collaboration.

The final chapter of the thesis, **chapter 6**, discusses the results of the preceding chapters and presents answers to the research questions as stated in §1 of this introduction. In addition both theoretical and practical implications of the research are discussed. The chapter concludes with the research limitations, suggestions for further research and a number of concluding remarks.

Table 1 below gives an overview of the structure of the thesis, the research phases, research questions and methodology. In addition Table 1 shows which research papers are related to which research phase.

Table 1: Structure of the Thesis

Chapter	Research Phase	Research Question	Methodology	Related Article
Introduction	Problem Background, Research Question, Approach and Setting, Structure of the thesis			
1	**Phase 1: Pilot Study** Relationship between internal organization and innovation performance	To what extent do differences in internal organization lead to differences in innovation performance?	• Literature study • Self-administered survey research • Case studies • Case summaries	Pullen, A.J.J., Cabello-Medina C., **De Weerd-Nederhof, P.C., Visscher, K. (2009); Development process effectiveness to achieve high innovation performance in the Spanish medical devices sector** ***Accepted to be included in the 2nd EITIM BOOK, to published 2010 by Palgrave***
2				Pullen, A.J.J., De Weerd-Nederhof, P.C., Groen, A.J., Song, M., Fisscher, O.A.M. (2009); Successful Patterns of Internal SME characteristics leading to high overall innovation performance; ***Creativity and Innovation Management;* 18(3); pp.209-223**
3	**Phase 2**: Identification of network variables in the context of new product development	Which network variables are most relevant to analyze ego-networks focused on NPD? How can network variables, in the context of NPD, be operationalized and measured?	• Literature study on network variables related to NPD • Literature study on the operationalization of Network variables • Self-administered survey research • Factor Analysis	Pullen, A.J.J., Fisscher, O.A.M., Groen, A.J., De Weerd-Nederhof, P.C. (2010); Measuring the Network – Innovation Performance: The Development of an Adequate Measurement Instrument ***In proceedings of the "R&D Management Conference 2010", 30 June-1 July 2010, Manchester, UK***
4	**Phase 3:** Examination of the underlying structure of the variables innovation performance, product innovativeness and network configuration	To what extent are network characteristics, product innovativeness and innovation performance related?	• Self-administered survey research enriched by semi-structured interviews • Multiple logistic regression analysis	Pullen, A.J.J., Groen, A.J., De Weerd-Nederhof P.C., ‚Fisscher,' O.A.M. (2010); SME product innovativeness and network characteristics for high innovation performance: What really counts in the medical devices sector ***In proceedings of the "17th International Product Development Management Conference (IPDMC)", 13-15 June 2010, Murcia, Spain***
5	**Phase 4:** Organization of the network configuration in relation to the innovation performance	Which network configuration leads to high innovation performance?	• Self-administered survey research enriched by semi-structured interviews • Social Systems Approach	Pullen, A.J.J., Groen, A.J., De Weerd-Nederhof P.C., Fisscher, O.A.M. (2010); Organizing NPD network for high innovation performance: The case of Dutch medical devices SMEs ***In proceedings of the "High Tech Small Firm Conference 2010 (HTSF)", 27-28 May 2010, Enschede, The Netherlands***
Discussion	Research Findings, Theoretical and Practical Contribution and Implications, Limitations, Suggestions for further research, Concluding remarks			

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Chapter 1

Development process effectiveness to achieve high innovation performance in the Spanish medical devices sector

Based on:

Pullen, A.J.J., Cabello-Medina C., De Weerd-Nederhof, P.C., Visscher, K. (forthcoming 2010). Development process effectiveness to achieve high innovation performance in the Spanish medical devices sector. In EITIM (eds.), *2nd EITIM Practice Book.* Basingstoke, Hampshire, UK: Palgrave Macmillan Publisher.

Abstract

Rapid development and commercialization of new products is of vital importance for small and medium sized enterprises (SME) in regulated sectors. Due to strict regulations, competitive advantage can hardly be achieved through the effectiveness of product concepts only. If an SME in a highly regulated sector wants to excel in new product development (NPD) performance, the company should focus on the flexibility, speed, and productivity of its NPD function: i.e. the development process effectiveness. Our main research goals are first to explore if SMEs should focus on their development process effectiveness rather than on their product concept effectiveness to achieve high NPD performance; and second, to explore whether a shared pattern in the organization of the NPD function can be recognized to affect NPD performance positively. The medical devices sector in Spain is used as an example of a highly regulated sector. A structured survey among 11 SMEs, of which 2 were studied more in-depth trough company visits and interviews, led to the following results. First of all, indeed the companies in the dataset which focused on the effectiveness of their development process, stood out in NPD performance. Further, the higher performing companies did have a number of commonalities in the organization of their NPD function:

1) *The majority of the higher performing firms had an NPD strategy characterized by a predominantly incremental project portfolio.*
2) *a) Successful firms with an incremental project portfolio combined this with a functional team structure*

   b) Successful firms with a radical project portfolio combined this with a heavyweight or autonomous team structure.
3) *A negative reciprocal relationship exists between formalization of the NPD processes and the climate of the NPD function, in that a formalized NPD process and an innovative climate do not seem to reinforce each other. Innovative climate combined with an informal NPD process does however contribute positively to NPD performance. This effect was stronger in combination with a radical project portfolio.*

The highest NPD performance was measured for companies focusing mainly on incremental innovation. It is argued that in highly regulated sectors, companies with an incremental product portfolio would benefit from employing a functional structure. Those companies that choose for a more radical project portfolio in highly regulated sectors should be aware that they are likely to excel only in the longer term by focusing on strategic flexibility. In their NPD organization, they

might be well advised to combine informal innovation processes with an innovative climate.

1. Introduction

Innovation is a key driver of sustainable competitive advantage and one of the key challenges for small- and medium sized companies (O'Regan, et al., 2006). Therefore, SMEs need to remain active in new product development (NPD). It is difficult for small-and medium sized companies (SMEs)[1] in regulated sectors to development new products, because heavy regulatory involvement imposes a number of difficulties on the NPD process. Products have to meet these strict regulations in terms of quality, safety, functionality, and manufacturability, which makes it difficult for SMEs to differentiate in terms of the effectiveness of the product concepts. However, there are big differences in the NPD performance of SMEs. Then, the questions are 1) how do SMEs in regulated sectors distinguish themselves in terms of innovation performance and 2) how can SMEs in regulated sectors be successful in new product development.

In this research, the Spanish medical devices sector is used as an illustration of a highly regulated sector. The medical devices development process is characterized by a heavy regulatory involvement. (Shaw, 1998). Companies in the medical devices sector are experiencing a need to develop new products more rapidly to satisfy expanding and changing customer requirements in light of new technologies and intensifying global competition (Millson & Wilemon, 2000). The ability of organizations in the medical devices sector to develop and commercialize new products fast is a major competitive advantage (Atun, et al., 2002), as speed is an important driver for new product development (NPD) performance (Calantone & Di Benedetto, 2002; Langerak & Hultink, 2005; Lynn, Abel, Valentine, & Wright, 1999; Takayama, Watanabe, & Griffy-Brown, 2002).

It is important to realize that in highly regulated sectors, such as the medical development sector, the *product concept* effectiveness of all acting companies almost per definition will be high, and variance in this performance measure will be low. This is so because all (new) product (concepts) have to comply with the same strict regulations. In this type of sectors, and especially for the SMEs in it, the effectiveness of the NPD *process* effectiveness stands a much better chance to make a difference. The development process effectiveness represent a measurement of the current NPD performance beyond the requirements imposed

[1] According to European standards, SMEs are defined as companies that have 250 or less Full Time Equivalents (Commission of the European Communities, 2003b)

by regulations of the sector. This means that it is to be expected that the SMEs we looked at in the Spanish medical devices sector would try to achieve competitive advantage in terms of speed, productivity and flexibility of their product development process, rather than in terms of manufacturability, functionality and cost of the product concept, which would be comparable for all players in the field.
According to De Weerd-Nederhof et al (2008) both the current and future NPD performance are heavily influenced by the way the NPD function is organized (i.e. the NPD configuration). The organization of the NPD function consists of the strategy, structure, climate and process of the NPD function (DeWeerd-Nederhof, Bos, Visscher, Gomes, & Kekale, 2007; DeWeerd-Nederhof, Visscher, Altena, & Fisscher, 2008). Building on this, and in light of the peculiarities faced by SMEs in highly regulated sectors, we set out to search for a shared pattern in the organization of the NPD function of Spanish SMEs in the medical devices sector, which can be related to high NPD process effectiveness, and ultimately to outperforming competitors.
Thus, our main research goals are *first* to explore differences in product concept effectiveness and development process effectiveness among SMEs in the Spanish medical devices sector, to see whether or not the current NPD performance would indeed be mainly influenced by the development process effectiveness; and *second*, to explore whether a shared pattern in the organization of the NPD function can be recognized to affect current NPD performance positively.
In the next section we first provide the theoretical framework on both the current NPD performance, and the variables that are included in the organizational configuration of the NPD function (NPD strategy, structure, climate, and process (DeWeerd-Nederhof, et al., 2007)). Next we provide the research design and methodology. We then present the research results based on a structured survey among 11 SMEs in the Spanish medical devices sector. The results are further illustrated by two real-life company descriptions. In the discussion and conclusion results are further elaborated and managerial implications are explicitly addressed.

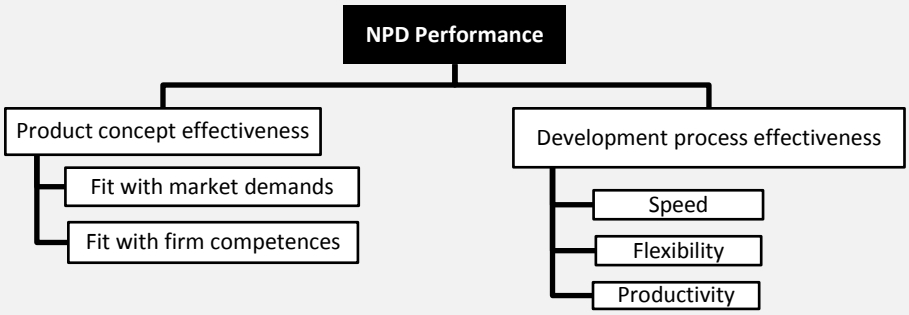
2. Theoretical Framework

2.1. NPD Performance

The NPD performance consists of the product concept effectiveness on the one hand, and the development process effectiveness on the other hand. The product concept effectiveness is used to define how well a new product concept fits with internal and external characteristics of the company. Whereas the development

process effectiveness concept is used to define how effective the development process is executed (S. L. Brown & Eisenhardt, 1995). Figure 1 shows a schematic overview of the different constructs that together build NPD performance.
The NPD performance is a dynamic concept that has both a short-term and a long-term component. The short term component is the Operational Effectiveness and refers to the effectiveness of today's work, whereas the long term component is the Strategic Flexibility which relates to the readiness to adapt to, anticipate or even create future NPD performance requirements (DeWeerd-Nederhof, et al., 2008). For this research the focus is on operational effectiveness as the aim is to measure the current NPD performance.

Figure 1: Schematic overview of the constructs that together build NPD performance



Pettigrew and Whipp (1991) studied organizational change and differences in NPD performance similarly using a content-context-process framework. Content represents the objectives, purpose, and goals of the organization (Pettigrew & Whipp, 1991). Context represents the environment of the company, and process represents the product development process of the organization. The content and context dimensions of Pettigrew and Whipp (1991) can be linked to the product concept effectiveness of Brown and Eisenhardt (1995), whereas the process that Pettigrew and Whipp (1991) describe is similar to the development process effectiveness that Brown and Eisenhardt (1995) describe.
Strict regulations are a unique characteristic of the medical devices sector, and this heavy regulatory involvement characterizes the medical devices development process (Shaw, 1998). The product concept effectiveness is highly tied to this regulatory process, which makes it difficult for companies to differentiate in terms

of this dimension. Also, Pettigrew and Whipp (1991) suggest that companies that operate in the same sector (like in the medical devices sector) share environmental characteristics such as regulations, dynamism, and fragmentation of the sector. The medical devices sector is similar to other industries in that SMEs dominate the sector. Medical devices companies often don't compete on price but rather seek to deliver products with a good quality/price-ratio. However, the processes these companies use to achieve their goals and develop new medical devices do differ as does the organization of the NPD function of these companies.

The current NPD performance of SMEs in the medical devices sector varies greatly. Since the product concept effectiveness is heavily influenced by the set regulations, we hypothesize that SMEs in the medical devices sector emphasize on development process effectiveness rather than on product concept effectiveness to achieve high NPD performance. Takeuchi and Nonaka (1986) point this out by stating that the higher the speed with which changes occur and the more the competence in the field of NPD grows, the more firms must focus their processes on speed and flexibility (Takeuchi & Nonaka, 1986). Furthermore the framework of Pettigrew and Whipp (1991) indicates that the content and context of companies in the medical devices sector does not differ, and that they can only distinguish themselves in terms of the process. This supports our previous assumption that companies can distinguish themselves more by focusing on development process effectiveness rather than through product concept effectiveness, and leads to the investigation of our proposition:

> *Proposition 1: SMEs in the medical devices sector focus on their development process effectiveness rather than on their product concept effectiveness to achieve high NPD performance.*

Our study is focusing on the importance of development process effectiveness as part of the current NPD performance. The NPD performance is influenced by the way the NPD function is organized, also called the NPD configuration. Contributing to sustained competitive advantage requires a fit of the NPD configuration with the NPD system and between the NPD system and its context (DeWeerd-Nederhof, et al., 2007). The way the NPD function is organized affects both the development process effectiveness, and (to a lesser extent as we proposed) the product concept effectiveness. Differences in development process effectiveness therefore might be explained by the difference in NPD configuration. This leads to the second proposition.

Proposition 2: SMEs in the medical devices sector that achieve high development process effectiveness share a pattern in the organization of their NPD function.

We utilize the concepts of NPD strategy, NPD structure, and NPD climate to further specify the organization of the NPD function (DeWeerd-Nederhof, et al., 2007). These concepts are further explained in the following subsections.

2.2. NPD Strategy

The NPD strategy of a firm can be defined as: "the aggregate pattern of product introductions that emerge from the firm over time" (Firth & Narayanan, 1996). The purpose of the new product strategy is to link the products to the overall objectives of the firm and to assist in the search for new products (Firth & Narayanan, 1996). SMEs with a clear strategy perform better than SMEs that lack a clear strategy (Kargar & Parnell, 1996; O'Regan, et al., 2006). Clark and Wheelwright (1993) identify three orientations of the strategy; the technology strategy, the product strategy, and the market strategy. The technology strategy refers to the acquiring, developing, and applying of technology for competitive advantage. The product strategy should contain a clear plan for the development of future products. Finally the market strategy should focus on the question what the target customers will be (Clark & Wheelwright, 1993).

Gatignon and Xuereb (1997) propose a similar typology of strategic orientation (technology orientation, competitive orientation, and customer orientation), and link this to the demand uncertainty in the market. In the medical devices sector the hospital budgets heavily influence the buying behavior of the customers. This buying behaviour is also strongly influenced by informal communication between buyers. This causes demand uncertainty in the medical devices sector (Biemans, 1989). When demand uncertainty is high the strategic orientation should be a customer orientation (Gatignon & Xuereb, 1997). In the field of NPD in Spanish firms, Varela and Benito (2005) find that firms that are market oriented get better NPD results than those that do not use this strategic orientation (Varela & Benito, 2005).

Next to the strategic orientation, the project portfolio is an important part of the NPD strategy (Wheelwright & Clark, 1992). Wheelwright and Clark (1992) view NPD strategy as the project portfolio of an organization. It must be clear which type projects are present in the organization. Wheelwright and Clark (1992) distinguish

between incremental projects (derivative projects), radical projects (breakthrough projects), and platform projects (between incremental and radical projects) (Gatignon, Tushman, Smith, & Anderson, 2002; Wheelwright & Clark, 1992). Incremental innovation projects range from cost-reduced versions of existing products to add-ons or enhancements for and existing production process (Wheelwright & Clark, 1992). Radical innovation projects involve significant changes to existing products and processes. It involves the development or application of significant new technologies or products to markets that are either non-existent or require dramatic behaviour changes to existing markets (Feller, Parhankangas, & Smeds, 2006; Wheelwright & Clark, 1992).

2.3. NPD Climate

The second aspect of the organization of the NPD function is the NPD climate. The climate is regarded as a conglomerate of attitudes, feelings, and behaviours which characterizes life in the organization, and exists independently of the perceptions and understandings of the members of the organization (Ekvall, 1996). In order to operationalize climate we use the 10 climate dimensions of Ekvall (1996) that stimulate the NPD performance. Cabra (1996) found problems with the challenge dimension by conducting factor analysis with North American samples. Further work by Isaksen, Lauer, and Ekvall (1998) and later Isaksen and Lauer (2002) found that the dynamism dimension was not discriminating. In this research we use the dimensions proposed by Ekvall (1996), excluding the dynamism dimension. In this research, a climate that stimulates innovation (innovative climate) is a climate with high levels of "challenge, freedom, idea support, trust, playfulness, debates, risk taking, and idea time" and a low level of conflicts.

2.4. NPD Structure

The third concept of the organization of the NPD function is the structure of the NPD function. This structure refers broadly to the structure of project teams and the way the people in the NPD function are organized. This work is based on efforts of (Clark & Wheelwright, 1992) who showed that effective product and process development requires teams that integrate people with multiple specialized capabilities. These teams are also referred to as cross-functional product development teams. Cross- functional development teams have become increasingly important due to complexities in the pace, diffusion and the use of multiple technologies to solve customer problems (S. T. Walsh & Linton, 2001) as well as burgeoning global competition (McDonough III, 2000). This is also in line

with the research of Sosa et al (2004) who state that complex product development requires structuring the organization into groups of cross-functional design teams to design systems and components (Sosa, Eppinger, & Rowles, 2004), and with the research of Cooper et al (2004a) who have identified the presence of cross-functional teams as a common fact in organizations they rated as best performers (Cooper, et al., 2004a)

Clark and Wheelwright (1992) have characterized a number of structures for project teams. It depends on the environment, organization size, and innovation type which project structure is best suitable (Clark & Wheelwright, 1992). They distinguish between the functional, lightweight, heavyweight, and autonomous team structure. The team structure that is used by the company needs to fit in the context. For new product development in the medical devices sector it is very important that all functional areas are involved in the development of a new product, because of the rapid changes in technology and competition. However it should be prevented that a project team gets carried away by its own ideas and fails to meet regulations, or that senior management looses the control over the team (which is likely to occur in the autonomous team structure). Therefore we expect that the heavyweight team structure is likely to be the most successful in the context of the medical devices sector. Also the success factors for cross-functional teams (McDonough III, 2000) can be found most clearly in the characteristics of the heavyweight team structure.

Another aspect of the NPD structure is the formalization of the development process (Griffin & Page, 1993). Formalization refers to the degree in which the process is subject to rules, procedures and structures previously specified (Johne, 1984). Walsh and Dewar (1987) link the degree of formalization with the organizational life cycle. They state that the more mature the organization, the more formalized the processes are (J. P. Walsh & Dewar, 1987). For new product development, it is stated that companies with a formal development process are more successful in the commercialization of new products (A. Booz & Hamilton, 1982).

We investigate both propositions based on the above literature. The next section describes the methodology we follow to 1) investigate if SMEs in the Spanish medical devices sector should focus on development process effectiveness to achieve high innovation performance, 2) explore if there is a pattern in the organization of the NPD function that these companies share and 3) what this organization of the NPD function looks like.

3. Methodology

We utilize a case based method as described by Yin (Yin, 2003) and Eisenhardt (Eisenhardt, 1989). We leveraged the international Patterns in NPD project. This project is aimed at developing knowledge in the new product development area, by describing, exploring and analyzing the organization of the innovation journey. We focus on the population of Spanish SMEs in the medical devices sector.

3.1. Sampling Process

Consistent with the case study method, we gathered data of a full population in one specific sector, to reduce extraneous variation (Eisenhardt, 1989). Data was gathered in the Spanish medical devices and disposables sector. The medical devices sector is the focus of this research because (1) differences in innovation performance of the companies depend (due to strict regulations) on management issues, and not on environmental or product concept issues, and (2) innovative capability is in this sector of vital importance (Atun, et al., 2002). Data gathering took place in the spring of 2006.

Leveraging the DUNS database we used the Spanish SIC codes (CNAE) 33100 and 33200 to identify a number of organizations. A total of 109 companies were selected. These companies were first screened on origin and number of employees. The companies with CNAE 33200 were also screened on the fact whether they were active in the medical devices sector or not. Companies with other origins than Spanish, organizations with a total number of employees of 5 or less, and organizations (with CNAE 33200) not active in the medical devices sector were deleted from the list. 57 Companies remained and were contacted to find out whether they had an NPD function. From this 35 companies remained, of which 31 companies were interested to participate in the study.

3.2. Data Description

To the NPD managers of the 31 companies that were interested to participate a questionnaire about the organization and performance of the NPD function was sent. This questionnaire was developed as part of the international 'Patterns in NPD project'. We ended up with 12 filled-in questionnaires from companies in the Spanish medical devices sector, which results in a response rate of 34,29%.

One of the companies was deleted from the sample, as the number of FTE of the particular company was 650 FTE whereas the focus of this research is on small – and medium sized companies (FTE ≤ 250). This resulted in a dataset of N=11

companies, with which the propositions were further explored. Table 1 gives general information about the companies in the dataset.

Table 1: General information of the companies in the dataset

Company #	FTE	Products	Profit	Sales	Profit/ FTE	Sales/ FTE
1	12	Interventional cardiology products	€ 113.004,31	€ 4.000.000,00	€ 9.417,03	€ 333.333,33
2	120	Products based in three main lines: Infusion, Respiratory and Bandages	€1.064.975,42	€10.000.000,00	€ 8.874,80	€ 83.333,33
3	35	Solariums, professional equipment of aesthetic and aesthetic medicine	€ 124.263,70	€ 7.000.000,00	€ 3.550,39	€ 200.000,00
4	80	Four product groups: measuring, quality & metering, industrial electric protection, and power factor protection	€5.334.493,30	€80.000.000,00	€ 66.681,17	€ 1.000.000,00
5	36	Prostheses and implants	€ 260.478,55	€ 5.000.000,00	€ 7.235,52	€ 138.888,89
6	32	Female protection slips, female hygienic bandages, and children's diapers	€ 44.271,19	€ 3.200.000,00	€ 1.383,47	€ 100.000,00
7	12	Orthopedic elastic products	€ 64.910,78	€4.000.000,00	€ 5.409,23	€ 333.333,33
8	167	Medical disposables for neurosurgery and endosurgery		€54.000.000,00		€ 323.353,29
9	80	Wide range of single use and reusable lab ware for chemical, clinical, research and industrial testing laboratories, swabs for sample collection and transport of microbiological material, sampling containers, blood collection tubes, test tubes	€ 72.800,98	€18.000.000,00	€ 910,01	€ 225.000,00
10	49	Dental equipment and optical units	€ 683.275,34	€ 9.600.000,00	€ 13.944,39	€ 195.918,37
11	60	Laboratory equipment	€ 765.986,92	€18.000.000,00	€ 12.766,45	€ 300.000,00

3.3. Measurements

NPD performance is a dynamic concept. It is divided in the current NPD performance (operational effectiveness) which refers to the effectiveness of today's work, and the future NPD performance (strategic flexibility) which relates to the readiness to adapt to, anticipate or even create future requirements (see also Figure 1){Brown, 1995 #40}{DeWeerd-Nederhof, 2008 #4}. This research focuses on the *current NPD performance*, which consists of the development process effectiveness, and the product concept effectiveness. Table 2 shows the constructs and items that together form the product concept effectiveness and the development process effectiveness. Table 2 also shows the reliability of the constructs and the literature that was used to build the constructs. All items are measurement on a 7-point Likert scale, ranging from '1 = Not at all achieved' to '7 = Very well achieved'.

Table 2: Overview and reliability statistics of the performance scale

	Current NPD performance				
	Product concept effectiveness (pce)		**Development process effectiveness (NPDpe)**		
Construct	Fit with market demands	Fit with firm competences	Speed	Flexibility	Productivity
N of Items	6	6	6	6	6
Measurement scale	7-point Likert scale	7-point Likert scale	7-point Likert scale	7-point Likert scale	7-point Likert scale
Cronbach's Alpha	α = 0,788	α = 0,747	α = 0,893	α = 0,645	α = 0,778
Based on	Customer satisfaction, timeliness, product price, quality *(Chiesa, Coughlan, & Voss, 1996)* Sales and profit impact *(Bretani & Kleinschmidt, 2004)*	R&D/Manufacturing integration *(Swink, 1999; Yam, Guan, Pun, & Tang, 2004)* R&D/Marketing integration *(Leenders & Wierenga, 2002)*	Speed relative to schedule *(Kessler & Bierly, 2002)* Development time (DT), concept to customer time (CTC), total time (TT) *(Griffin, 1997)* Speed and commitment of the NPD decision-making process, *(Griffin & Page, 1993)*	Average time and cost of redesign, enhancement *(Chiesa, et al., 1996; Thomke, 1997)* The ability to change specs late *(Thomke, 1997)*	The possibility for lower development budget *(Iansiti, 1993)* Cost relative to budget, competitors *(Kessler & Bierly, 2002)* Engineering hours, cost of materials, cost of tooling *(Clark & Wheelwright, 1993)*

Current NPD performance is measured by using all the scales of the product concept effectiveness and development process effectiveness. *Product concept effectiveness* is measured as the average score of the constructs 'fit with market demands' and 'fit with firm competences'. *Development process effectiveness* is measured as the average of the constructs 'speed', 'flexibility', and 'productivity'.
We use the development process effectiveness to determine whether a company is high or low performing. If the development process effectiveness of the company is higher or equals the average development process effectiveness of the dataset (which is 4,5), then the company is 'high performing'. Else the company is 'low performing'. Table 3 shows the scores on product concept effectiveness, and development process effectiveness of the companies in the dataset. Table 3 also shows whether the companies are high or low performing based on the above described method.

The *NPD climate* was measured by asking the respondents to indicate on a 7-point Likert scale to what extent employees have the freedom to define their own work and to what extent there is time for people to develop unplanned new ideas. This measurement of NPD climate is based on work by Isaksen and Lauer (2002), and Ekvall (1996), who developed nine items to measure activities related to the climate of the respondents' NPD function. A climate that stimulates innovation is a climate with high levels of "challenge, freedom, idea support, trust, playfulness, debates, risk taking, and idea time" (Ekvall, 1996)

Table 3: Performance scores of the companies in the dataset

Company #	Product concept effectiveness	Development process effectiveness	High/ Low performing
1	5,9	2,5	Low
2	4,3	4,0	Low
3	4,0	4,1	Low
4	5,3	4,7	High
5	4,3	3,3	Low
6	4,8	4,5	High
7	5,3	5,3	High
8	6,4	5,1	High
9	5,7	4,9	High
10	6,1	5,9	High
11	4,8	4,7	High
Average	**5,2**	**4,5**	

To measure the variable *NPD structure*, the team structure types of Clark and Wheelwright (1992) were used. In the survey, respondents were asked to indicate whether they use a functional, lightweight, heavyweight or autonomous team structure.

The level of *formalization* and *presence of cross-functional teams* was measured by presenting multiple descriptions of development processes of a business unit. Based on descriptions of the NPD system by Griffin and Page (1993), the respondents were asked to indicate which development process most closely describes the development process that is used in their business unit.

The *strategic orientation* was measured with a seven-point Likert scale ranging from '1 = strongly disagree' to '7 = strongly agree'. Respondents were asked to indicate the level of agreement with statements considering the technology strategy, product strategy, and market strategy (Clark & Wheelwright, 1993).

To measure a company's NPD portfolio the respondent was asked to indicate the percentage radical, incremental and next generation projects in the portfolio (Wheelwright & Clark, 1992). The percentages had to sum up to 100%.

The questionnaire that is used to measure internal organizational characteristics in relation to current and future NPD performance is included in Appendix 1 of this thesis. The questionnaire was developed and validated in the international "Patterns in New Product Development Project" {De Weerd-Nederhof, 2008 #178}.

3.4. Data Analysis Techniques

For analysis of the data we first rely on a theoretical proposition (Yin, 1994). We are interested in a) the variance of both the product concept effectiveness and the development process effectiveness, and b) the organization of the NPD function that the companies in our dataset possibly share. The variances are calculated and compared. In addition, multiple linear regression is executed to examine which variable (product concept effectiveness or development process effectiveness) has the most influence on the current NPD performance. Data was gathered by using self-administered surveys in 11 SMEs in the medical devices sector. In line with the methodological suggestions of Eisenhardt (1989) we made summaries and analyzed each company individually. In addition to the structured survey, we studied 2 companies more in-depth: one was the highest performing company. The other was the one but lowest performing company in our dataset. Both studies 1) show if there is single respondent bias or not (see next paragraph) and 2) give background information and enlighten the results we found with the structured survey.

3.5. Single Respondent Bias

One of the problems of response in survey research is single respondent bias. We compensated this by controlling for single respondent bias. From our dataset of 11 companies we selected two companies for in-depth studies on the climate variable. The companies were selected on their scores on development process effectiveness and current NPD performance (highest scoring company and lowest scoring company). Besides the full questionnaire that was filled in by the NPD manager, at least 5 employees in both companies filled in a minisurvey that was solely focused on the NPD climate. In this way we could compare the filled in answers of the NPD manager to those of different employees in the company. For both companies we found no significant difference (Sign. p> 0,00 for both companies) between the answers of the NPD manager who filled in the full questionnaire and the answers that were given by the employees in the minisurveys (see Table 4). This excludes single respondent bias.

Table 4: Single respondent bias results

Test Statistics Casestudy 1 [b]

	NPDmanager_1 Minisurvey_1
Z	-,859[a]
Asymp. Sig. (2-tailed)	

a Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Test Statistics Casestudy 2 [b]

	NPDmanager Minisurvey_2
Z	-1,244[a]
Asymp. Sig. (2-tailed)	,214

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

4. Results

We have presented two propositions which we tested. Our first proposition was that SMEs in the medical devices sector focus on their development process effectiveness rather than on their product concept effectiveness to achieve high NPD performance. Table 5 shows the results of the variance in both the product concept effectiveness and the development process effectiveness.

We calculated the variances in both concepts to see whether the scores of the product concept effectiveness indeed vary less, or are more stable, than the scores of the development process effectiveness.

Table 5: Variances in product concept effectiveness (PCE) and development process effectiveness (NPDpe)

	N	Mean	Std. Deviation	Variance
PCE	11	5,173	,7989	,638
NPDpe_real	11	4,445	,9543	,911
Valid N (listwise)	11			

As a reminder, both product concept effectiveness and development process effectiveness are predictors of the current NPD performance (see figure 1 and table 6). Table 6 shows that development process effectiveness (npdpe) correlates stronger with the current NPD performance (oe) than product concept effectiveness (pce).

Table 6: Correlations between product concept effectiveness (PCE), development process effectiveness (NPDpe) and current NPD performance (OE)

			npdpe	oe	pce
Spearman's rho	npdpe	Correlation Coefficient	1,000	,920**	,572
		Sig. (2-tailed)	.	,000	,066
		N	11	11	11
	oe	Correlation Coefficient	,920**	1,000	,830**
		Sig. (2-tailed)	,000	.	,002
		N	11	11	11
	pce	Correlation Coefficient	,572	,830**	1,000
		Sig. (2-tailed)	,066	,002	.
		N	11	11	11

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

To examine which variable (npdpe or pce) most strongly influences current NPD performance (oe), multiple linear regression was executed. Table 7 shows the results of the regression. The standardized Beta coefficient indicates the relative importance of each independent variable. The variable npdpe (development

process effectiveness) has the highest standardized Beta value (0,630), which indicates that this variable has the most influence on the independent variable (current NPD performance (oe)).

Table 7: Results multiple regression (Method: Enter)

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	,110	,096		1,147	,285
	npdpe	,471	,016	,630	30,211	,000
	pce	,509	,019	,570	27,341	,000

a. Dependent Variable: oe

Our second proposition was that SMEs in the medical devices sector that achieve high development process effectiveness share a pattern in the organization of their NPD function. We divided the dataset in high and low performing companies based on the standards described and shown in Table 3 in the measurements section. The summaries in Table 6 show the organizational patterns of the NPD functions amongst the high performers and amongst the low performers.
At first glance, the summaries in Table 6 show a lot of variety in the organization of the NPD function. However, when taking a closer look, a number of patterns in the organization of the NPD function become apparent.

NPD Strategy
A first pattern can be found in the project portfolio of the companies. The high performing companies focus in general on incremental innovation projects, whereas the low performing companies focus more on radical innovation projects. This might be explained by the highly regulated sectors in which these companies operate. It is safer to focus on incremental innovation projects, since these types of projects can easier meet regulations than radical innovation projects. In addition, SMEs have limited amounts of resources available to meet the strict regulations and conduct clinical tests needed for radically new medical devices.

NPD Structure
The second pattern is found in the link between team structure and portfolio. The high performing companies 4, 9, 10 and 11 combine an incremental project portfolio with a functional team structure. These findings suggest that the

Table 8: Summaries of the internal organization of the companies in the dataset

Development process effectiveness	Company	Portfolio	Team_ Structure	Formalization	Climate
Low	1	Main focus on radical innovation	Heavyweight Team Structure	no formalized process	no innovative climate
	5	Main focus on incremental innovation	Heavyweight Team Structure	no formalized process	no innovative climate
	2	Main focus on radical innovation	Heavyweight Team Structure	formalized process	innovative climate
	3	Main focus on radical innovation	Functional Team Structure	no formalized process	no innovative climate
High	6	Main focus on radical innovation	Heavyweight Team Structure	no formalized process	innovative climate
	11	Main focus on incremental innovation	Functional Team Structure	no formalized process	innovative climate
	4	Main focus on incremental innovation	Functional Team Structure	no formalized process	innovative climate
	9	Main focus on incremental innovation	Functional Team Structure	no formalized process	no innovative climate
	8	Main focus on incremental innovation	Heavyweight Team Structure	no formalized process	innovative climate
	7	Main focus on radical innovation	Autonomous Team Structure	formalized process	no innovative climate
	10	Main focus on incremental innovation	Functional Team Structure	no formalized process	no innovative climate
Total N	**11**				

combination of an incremental project portfolio with a functional team structure leads to high development process effectiveness. This is also in line with the research of De Visser et al (2009) who find that "firms that manage to apply a cross-functional integration structure for their radical NPD processes and a

functional integration structure for their incremental NPD processes will be the most successful in terms of balancing derivative and breakthrough innovation performance" (De Visser, DeWeerd-Nederhof, Faems, Van Looy, & Visscher, 2009).

Furthermore our findings suggest that the combination of a radical project portfolio with a heavyweight or autonomous team structure (as seen in companies 6 and 7) can also lead to high development process effectiveness, when combined with an informal NPD process and innovative climate, or with a formal NPD process and climate that is not innovative.

NPD climate and NPD process

From the (low performing) companies 1, 3, and 5 in our dataset, it seems that lacking both a formalized NPD process and an innovative NPD climate doesn't lead to high development process effectiveness, unless combined with a functional team structure like in the high performing companies 9 and 10. In these two latter companies, the functional team structure compensates the lack of formalization to some extent. Also having both a formalized NPD process and innovative NPD climate, like in company 2, doesn't lead to high development process effectiveness. Combining a formalized NPD process with a NPD climate that isn't innovative and vice versa, seems to lead to high development process effectiveness. This can be seen in the high performing companies 4, 6, 7, 8 and 11 and is the third pattern we find.

The above results show that, companies in the Spanish medical devices sector indeed share a pattern in their NPD function. This supports our second proposition. To summarize, we found a number of patterns in the organization of the NPD function of high vs. low performing companies.

First of all, indeed the companies in the dataset which focused on the effectiveness of their development process, stood out in NPD performance. Further, the higher performing companies did have a number of commonalities in the organization of their NPD function:

1) The majority of the higher performing firms had an NPD strategy characterized by a predominantly incremental project portfolio.
2) a) Successful firms with an incremental project portfolio combined this with a functional team structure

   b) Successful firms with a radical project portfolio combined this with a heavyweight or autonomous team structure.

3) A negative reciprocal relationship exists between formalization of the NPD processes and the climate of the NPD function, in that a formalized NPD process and an innovative climate do not seem to reinforce each other. Innovative climate combined with an informal NPD process does however contribute positively to NPD performance. This effect was stronger in combination with a radical project portfolio.

What the above summarized research results mean in everyday business practice is illustrated in the following two companies. Both companies are part of our dataset of Spanish medical devices companies. Company 5 (Text Box 1) is the last but one lowest performing company, Company 10 (Text Box 2) is the highest performing company.

Text Box 1: Case illustration company 5

COMPANY 5: A LOW PERFORMER

Company 5 is a low performing company that focuses on the development, production, and commercialization of prostheses and implants. They want to offer a complete range of products to their clients (surgeons) even though a number of these products are not profitable. In addition, time is not regarded the most important. Over the years, the company has focused more and more on R&D, and they also work on their image of an innovative company. The role of senior management in this is to set an example to the employees and improve the work where possible. However, employees are not stimulated nor compensated to come up with new ideas or new developments. When employees come up with new ideas, the management listens to the ideas of the employees and approves or disapproves and gives advice about other possibilities. Most of the time these new ideas are shared only among fellow employees, as employees are not stimulated (nor compensated) to come up with innovative ideas or new developments. Conflicts between R&D and commercial functions arise when a time plan and quality are promised to customers which are not feasible in practice. Risk taking in new product development by the employees and the management is low.

The level of risk taking in company 5 is low and, as described in text box 1, the focus is on incremental new products (in line with pattern 1). The focus on incremental innovation projects is combined with a heavyweight team structure in which project teams are to a large extent autonomous and project team leaders have the authority to decide about the division of the budget and people within the

project. This type of team structure is more applicable to radical innovation projects, since these projects need more freedom to think “outside-the-box”, without being constrained by everyday company boundaries. In incremental innovation projects this heavyweight team structure is often too heavy in that in incremental innovation projects the project team should remain close to everyday company business, without getting carried away. A functional team structure is in the case of incremental innovation better applicable. However company 5 combines a focus on incremental innovation with a heavyweight team structure (conflicts with pattern 2). From text box 1 it becomes clear, that the climate in company 5 is not innovative, since employees are not stimulated nor compensated to come up with new ideas or new developments. Management decides about new product development projects, which are executed in a development process that isn’t formalized. This combination of a process that isn’t formalized and a climate that isn’t innovative conflicts with pattern 3.
Only pattern 1, a focus on incremental innovation projects, can be found in company 5. Neither pattern 2 (the presence of a functional team structure in combination with an incremental product portfolio), nor pattern 3 (the reciprocal relationship between formalization of the NPD process and the climate of the NPD function) are present in company 5. The fact that the majority of the organizational patterns that were found to positively contribute to NPD performance miss in company 5 might explain its low NPD performance.

Company 10 clearly focuses on incremental innovation projects (in line with pattern 1). Text box 2 explains that company 10 wants to exploit their current market further and new product development projects should fit with current technologies and products. This focus on incremental product development projects is combined with a functional team structure (in line with pattern 2) in which management coordinates all the work. The climate is more innovative than in case company 5, because employees in company 10 have room to discuss their ideas in organized informal product meetings (see text box 2). However the climate in company 10 is not that innovative since only incrementally new ideas are appreciated and final decisions are all made top-down. The go/ no go decision about the development project is formal. However, the development process itself is not formalized. The combination of a development process that is not formalized with a climate that is not innovative is compensated in company 10 through the functional team structure (in line with pattern 3).

Text box 2: Case illustration company 10

COMPANY 10: A HIGH PERFORMER

Our second case company, company 10, is a high performing company that focuses on dental equipment and optical units. They offer solutions to other companies (they work for) and increase patient comfort with their products. They want to concentrate on further exploitation of the markets they currently serve, instead of focusing on radically new products. They want to grow, but also stay a medium-sized company. It should be a controlled increase. Part of the products are developed for other companies and part of the products are developed for the market. Meeting the – tight - time schedules is of highest importance. The senior management coordinates all the work and ideas in a functional team structure. Every three months product meetings are organized in which from every department people from the work floor are present. In these meetings ideas are shared with the management, and are selected. The selected ideas are tested by the technical department and if the idea fits within the current technologies and products it will be further explored. However, the final decisions are made top-down. Risk taking is only accepted if it is in line with current technologies and products.

The organizational patterns 1, 2, and 3 that were found to contribute positively to NPD performance are all present in company 10. The fact that all three patterns are present in company 10, and the fact that the majority of these patterns is missing in company 5 might explain the difference in NPD performance between both companies.

5. Discussion

Our findings raise some questions about the organization of new product development in highly regulated sectors. We find that companies in the highly regulated medical devices sector that achieve high current NPD performance, mainly focus on incremental innovation projects. Does this mean that these companies have to neglect radical innovation projects? The fact that our research findings indicate that a majority of incremental projects are present can be explained by our focus on current NPD performance, which reflects the NPD performance on the short term. To be able to also achieve high future (long-term) NPD performance a company should not only be operational effective, but also strategically flexible (DeWeerd-Nederhof, et al., 2008). To achieve high future NPD performance the project portfolio should also contain projects that gain future

revenues even though they aren't profitable at first glance. This is often the case with radical innovation projects. We expect that when the focus is on future NPD performance, radical innovation projects should be more dominantly present in the project portfolio. When the focus shifts from current to future NPD performance we expect that the organization of the NPD function shifts from an operational effective organization with a focus on incremental innovation projects, to a strategically flexible organization with a focus on radical innovation projects.

With regard to the formalization of the NPD process and innovativeness of the NPD climate, we found a negative reciprocal relationship, in that a formalized NPD process and an innovative climate do not seem to reinforce each other. Innovative climate combined with an informal NPD process does however contribute positively to NPD performance. These findings conflict with theory. On the one hand, theory stated that a climate that stimulates innovation is a climate with high levels of "challenge, freedom, idea support, trust, playfulness, debates, risk taking, and idea time" (Ekvall, 1996). On the other hand, theory states that, companies with a formal development process are more successful in the commercialization of new products (Booz, et al., 1982). Now, is theory wrong, or not applicable? Theory is not wrong and is also applicable, but the theoretical approach towards these variables should be more subtle. Companies do not consist of only one variable or characteristic, but of a multitude of variables and characteristics that are all interrelated.

Finally, we focused on a highly regulated sector and found that companies in this sector can only compete on development process effectiveness. This is caused by the fact that the product concept effectiveness is to a great extent predetermined by the set regulations. The product concept effectiveness of companies in sectors that are not highly regulated is not predetermined, which means that companies in non-regulated sectors have not only the possibility to compete on development process effectiveness, but also on product concept effectiveness. Then, to what extent do our research findings also apply in non-regulated sectors?

The short-term/ long-term effects of the project portfolio on the NPD performance also apply in non-regulated sectors. Incremental innovation projects lead to higher revenues on the short term, whereas radical innovation projects lead to higher revenues on the long term. The other patterns we found (pattern nr. 2 and 3) are strongly related to the achievement of high development process effectiveness. We expect that these patterns also apply in non-regulated sectors. However only increasing the development process effectiveness in companies in non-regulated sectors has probably less effect on the NPD performance as increasing the

development process effectiveness in highly regulated companies. In non-regulated sectors, also the differences in product concept effectiveness are heavily influencing the NPD performance and need to be taken into account.

6. Conclusions

The contribution of the research outlined above is that it shows SMEs in regulated sectors how competitive advantage in terms of NPD performance could be achieved, namely by optimizing their development process effectiveness and by choosing an appropriate organization of the NPD function. The research explicitly focused on the combination of organizational variables instead of focusing only on one variable, which adds value to other scholarly work on the same topic.

In line with our theoretical proposition, we find that small- and medium sized companies in the Spanish medical devices sector can indeed improve the performance of their NPD function by focusing on the speed, flexibility, and productivity of their NPD function. Furthermore we find that, companies with high current NPD performance in terms of development process effectiveness have a number of commonalities in the organization of their NPD function. These companies either combine an incremental project portfolio with a functional team structure, or they combine a radical project portfolio with a heavyweight or autonomous team structure. It should be noted that most of the firms with high development process effectiveness employed an NPD strategy focusing on incremental innovation. Further, a reciprocal relationship between formalization of the NPD processes and the climate of the NPD function was found, in that a formalized NPD process and an innovative climate do not seem to reinforce each other. Innovative climate combined with an informal NPD process does however contribute positively to NPD performance, especially for the minority of firms in the set with an NPD strategy focusing more on radical innovation. .

One should keep in mind that the research was a pilot study and that the dataset consisted of 11 companies. The conclusions need to be interpreted accordingly. To generalize the findings and draw firm conclusions, additional data is needed. Nevertheless, this pilot study does add to our understanding of the relation between the internal organization and NPD performance, which was the goal of the pilot study.

It should be noted however, that as was explained in the theoretical framework section, the NPD performance is a dynamic concept that has both a short-term (Operational Effectiveness) and a long-term (Strategic Flexibility) component. For this research the focus is on operational effectiveness as the aim is to measure the

current NPD performance. Although the results of our study might lead one to believe that in highly regulated sectors the only way to innovate is in incremental steps, this is somewhat misleading because of the short term –operational effectiveness view employed in the research. For radical innovation to lead to competitive advantage indeed also some organizational characteristics have been found, but the beneficial effect on both development process and product concept effectiveness might be subject to considerable time delay, especially in the medical devices sector.

For further research we strive to conduct longitudinal research in this field. The data of this research was gathered at one point in time, but since new product development is dynamic, longitudinal research might be interesting. Furthermore, it could be worthwhile to test our research findings in other countries and other strictly regulated sectors. We specifically looked at the context of the Spanish medical devices sector, but since the strict regulations for new medical devices are comparable in most countries, our findings might be applicable in other countries. Also, there are a number of other sectors that have similar characteristics in terms of regulations. Although further research is needed, we expect to find a similar pattern in the internal organization of the NPD function of successful companies in other highly regulated sectors for a larger dataset. Suggestions for other sectors are the biotechnology (Senker, 1991) and commercial space sector (Carayannis & Samanta Roy, 2000).

7. Managerial Implications

So, what do the research findings mean in everyday business practice? It not possible to give a full recipe for successful new product development, but we can demonstrate the value of certain ingredients, and, just as importantly, warn for the excessive use of some other ingredients. There are several myths about the organization of new product development that are among CTO's and managers of new product development. In this research we tackled four of these myths.

Myth 1: First focus on the quality, safety, and manufacturability of the product, then take a look at your NPD process.

We have shown that, in a regulated sector, the quality, safety, and manufacturability standards are predetermined through regulations. High quality, safety, and manufacturability of products are a precondition, regardless of the company, and not leading to competitive advantage. As a manager, you should focus on your NPD process. The development speed should be high (don't waste

time), the development process should be flexible (be able to change fast if specifications change), and the development process should have high productivity (don't exceed costs nor budgeted hours).

Myth 2: The more innovative, the better.
Managers are often confronted with the idea that radical innovation is just it. We have shown that taking little steps in the innovativeness of new products is – at least in regulated sectors - more successful. Managers should take a look at the portfolio of different innovation projects in their companies. How is the balance between incremental and radical innovation projects? If the portfolio mainly contains radical innovation projects and lacks incremental innovation projects, they should try to shift this balance by attracting more incremental innovation projects. However, keep in mind that the pursuit of radical innovations should not be fully abandoned, since they are needed for future profits.

Myth 3: Project teams should be autonomous and not restricted by organizational procedures.
There is not one best way to structure your NPD teams. The best way to organize projects heavily depends on the type of development projects. As a manager you should take a look at your project portfolio and at the team structure you use. In an incremental project portfolio, the projects are not so new and unknown that you need self-steering project teams. Rather, project teams are required that remain close to the company and do not get carried away. For incremental innovation, you should create project teams in which members remain on their current locations, in which different functions coordinate ideas through detailed specifications, in which occasional meetings are organized to discuss issues that cut across groups, and in which the responsibility passes sequentially from one function to the next. The more radically new the project is, the more the final project responsibility shifts towards the project leader and the more responsibilities the project team should get in general.

Myth 4: The NPD climate should be innovative and the NPD process should be formal.
We have shown that the innovativeness of the climate and the formalization of the NPD process do not reinforce each other. It is either-or, not both. This means that, there are two roads to success: you, as a manager, either work on an innovative climate, or you work on an well formalized NPD process. Considering the NPD

climate, questions you need to pose to yourself are: how much time, freedom, support, and trust do employees get to develop new ideas? Are employees challenged? Are employees allowed to take risks? If you answer most of these questions positively, the climate in your NPD function can be considered innovative. If you answer most of these questions negatively, you haven't got an innovative climate. Considering the formalization of the NPD process ask yourself if your organization follows a formally documented NPD process or not. For high current NPD performance either an innovative climate or a formalized process should be present.

Acknowledgement

The research described in this article is part of the European research project 'Patterns in New Product Development: consistent NPD configurations for sustained innovation', which was founded at the University of Twente, the Netherlands. 'Patterns in NPD' is funded by RADMA and the University of Twente (The Netherlands).

The company studies could be conducted thanks to the enthusiastic cooperation of the NPD managers, CEOs and employees of two Spanish medical devices companies in the Barcelona and Valencia region in Spain.

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Chapter 2

Successful Patterns of Internal SME characteristics leading to high overall innovation performance

Based on:

Pullen, A.J.J., De Weerd-Nederhof, P.C., Groen, A.J., Song, M., Fisscher, O.A.M. (2009). Successful patterns of internal SME characteristics leading to high overall innovation performance, *Creativity and Innovation Management*, 18(3), pp.209-223.

Abstract

Small and medium-sized enterprises (SMEs) struggle with the paradox of developing new products and technologies on the one hand and minimizing costs on the other hand. These SMEs must be innovative to survive and grow. However, compared to large firms, SMEs have several problems in their innovation process, which negatively influence their overall innovation performance. This research explores successful patterns of internal SME characteristics that lead to high overall innovation performance. Cluster analyses were conducted to find patterns in the internal characteristics of SMEs with high overall innovation performance. We find that companies that focus on incremental innovation and that achieve high overall innovation performance indeed share a pattern in their internal organization, when controlling for innovation type. The paper adds to the current body of knowledge by comparing high- and low-performing companies based on competence differences. Because real-life organizations consist of multiple organizational characteristics, we also contribute to management practice by simultaneously addressing multiple organizational characteristics for the successful organization of innovation.

1. Introduction

For small and medium-sized enterprises (SMEs[1]), new product development (NPD) is of high importance if they want to survive and grow. However, while SMEs need to innovate, they must also minimize costs (Hanna & Walsh, 2002). Compared to large firms, SMEs have a number of typical problems with regard to their innovation process. They are confronted more with financial constraints, they have more manpower bottlenecks in terms of too few or inadequately qualified personnel, and they often do not have other products (cash cows) to compensate for a lack of sales and profits (Kaufmann & Tödtling, 2002; Nooteboom, 1994). On the other hand, SMEs also have some advantages with regard to innovation. SMEs are usually less bureaucratic and generally have greater incentives to be successful than large firms (Michael & Palandjian, 2004; Nooteboom, 1994). The problems that SMEs face in their innovation processes lead to low innovation performance. However, high innovation performance is an important denominator of competitive advantage for SMEs (O'Regan, et al., 2006). Therefore SMEs must find a way to achieve high innovation performance. One way to do this is by arranging the internal organization in such a way that a fit between the internal organization and the environment of the SME is created (DeWeerd-Nederhof, 1998; DeWeerd-

[1] SMEs are companies that have (according to European Standards) 250 or fewer full time employees. (Commission of the European Communities, 2003a)

Nederhof, et al., 2007). However, what the exact architecture of such an internal organization is still remains rather vague.

In researching the relationship between innovation performance and the organizational characteristics, many authors focus on one or two organizational characteristics (Meyer, Tsui, & Hinings, 1993a). For example, Miles and Snow (1978) focus on business strategy types, and Clark and Wheelwright (1992) focus on team structures. This narrow focus unfortunately leads to a form of reductionism (Van de Ven & Drazin, 1985). This form of reductionism can be overcome by simultaneously addressing the multiple internal characteristics of (holistic) organizations (Meyer, et al., 1993a; Miller & Friesen, 1984). Only by simultaneously addressing the multiple internal characteristics of (holistic) organizations can relationships between performance and these organizational characteristics be fully understood (Van de Ven & Drazin, 1985). Therefore in this study we address multiple internal characteristics simultaneously.

The level of resources and the mix of organizational characteristics (the pattern) is different for radical and incremental innovation (Wheelwright & Clark, 1992). Therefore in this research we distinguish between radical and incremental innovation and focus on patterns of internal characteristics.

Parry et al. (2009) examine the impact on perceived cycle time of six variables that reflect a business unit's NPD strategy, NPD environment, product strategy, and NPD processes on a data set of 164 U.S. companies. They consider the pattern of relationships among these six factors. In particular, they define theoretical and empirical ideal profiles and examine the impact of deviations from these profiles on perceived cycle time {Parry, 2009 #353}. We build on the research of Parry et al. (2009) and include eight additional countries in the analyses. Furthermore we compare the differences in innovation performance across companies.

The main objective of this paper is to search for successful patterns of internal characteristics of the SME to explain differences in overall innovation performance. Our contribution lies in the comparison we make between high- and low-performing companies based on differences in internal characteristics. Because real-life organizations consist of multiple organizational characteristics, we also contribute to management practice by simultaneously addressing multiple organizational characteristics for the successful organization of innovation.

The next section of this paper consists of a literature review on internal SME characteristics that culminates in a number of testable hypotheses. The third section describes the methodology and the data set that is used to test the hypotheses. After presenting the results in the fourth section, we provide a

discussion and then end the paper with conclusions and suggestions for further research.

2. Theoretical Framework

In this section we describe the definition of innovation that is used as well as the internal SME characteristics that are the independent variables of this research. At the end of this section, we present the research hypotheses.

2.1. Innovation Performance

Wheelwright and Clark (1992) use three categories of commercial development projects: derivative (incremental), breakthrough (radical), and platform projects. Studies have confirmed that radical and incremental innovation projects do indeed need different strategies and structures (Ettlie, Bridges, & O'Keefe, 1984); different technology adoption models (Dewar & Dutton, 1986); and different environmental, organizational, and process factors (Koberg, Detienne, & Heppard, 2003). Therefore in this research we distinguish between radical and incremental innovation.

When we use the term *innovation*, we refer to the innovation concepts formulated by Afuah (1998) and Garcia and Calantone (2002). They state that, in the field of high technology, innovation is invention + commercialization (Afuah, 1998; Garcia & Calantone, 2002).

The performance that is achieved at the end of the NPD process is the innovation performance at the firm level. It can be defined as the sum of the successes of a firm's innovations (Salomo, Strecker, & Talke, 2007). Innovation performance can be measured with three items: the existence of a strong emphasis on research and development (R&D), the introduction of many new products/services over time, and significant changes in products/services (Miller & Friesen, 1982). An alternate way to measure innovation performance is presented by Cooper and Kleinschmidt (1995). They present a number of measures for innovation performance at the firm level: success rate, percent sales, profitability relative to spending, technical success rating, sales impact, profit impact, success in meeting sales objectives, success in meeting profit objectives, profitability relative to competitors, and overall success. Of these performance measurements, the percent sales (represented by new or modified products) most clearly indicates whether a company is successful in NPD at the firm level (Cooper & Kleinschmidt, 1995). We adopt this operationalization of innovation performance in this research.

2.2. Internal SME Characteristics

Internal characteristics of an organization are important for the innovation performance of that organization. The combination of these characteristics is of particular interest as organizations consist of multiple variables that are represented in their coherence and the way they influence each other. Ernst (2002), Cooper et al. (2004a, 2004b, 2004c), and Kahn et al. (2006) compare the internal characteristics of best- and worst-performing companies in NPD. As a result they all present a framework of success factors for NPD. The categorization of internal characteristics that the authors use in their frameworks differs, but the success factors are to a great extent similar. Table 1 shows these frameworks as they are represented by the original authors. For the sake of comparison we only adjusted the sequence in which the main concepts in the frameworks were represented. As the frameworks all underline the importance of strategy, process (including market research), and organization (including what Cooper et al. (2004a,

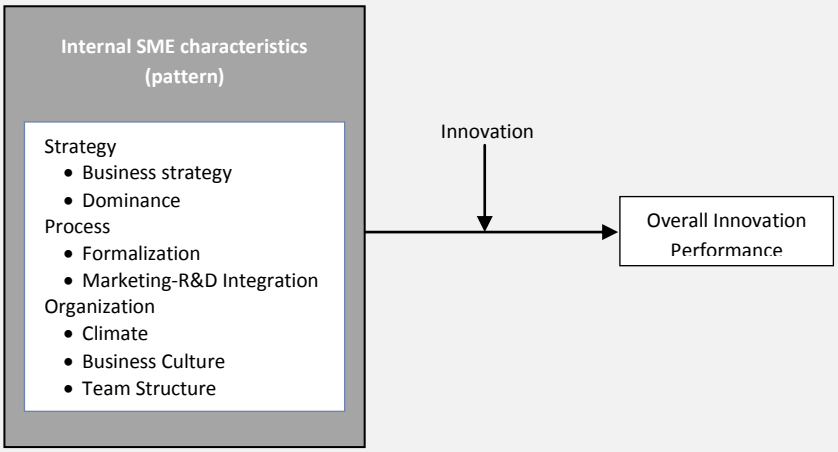
Table 1: Comparison of frameworks of internal NPD success factors

Ernst (2002)	Cooper et al. (2004a, 2004b, 2004c)	Kahn et al. (2006)
Strategy	Strategy	Strategy
Clear objectives	Clear goals	Strategic plan
Long term goals	Portfolio management	Long term goals
Overall strategy	Resource availability	Resource availability
	Resources	Portfolio management
	Effective allocation	Formal & systemic
		Ranking of projects
		Alignment portfolio & strategy
Process	Process	Process
Quality of planning	Formalization	Formalization
Continuous commercial assessment	Quality of execution	Strict rules and procedures
Quality of market research	Market research	
	Clear product definition	
		Market research
		Clear product definition
		Link marketing and R&D
Culture	People	People
Free time & skunk works	Culture & climate	Cross-functional teams
Resource availability	Top management support	Team structure
	Team structure	NPD training
Organization		
Cross-functional teams		
Team structure		
Role of senior management		
Senior Management Support		

2004b, 2004c) and Kahn et al. (2006) categorize as people), we used these variables in this research to analyze the internal characteristics of the SME that influence innovation performance.

To search for successful patterns of internal SME characteristics to explain differences in innovation performance, we used the conceptual model shown in Figure 1. This figure represents the relation between the independent variables (the internal SME characteristics) and the dependent variable (overall innovation performance). The internal SME characteristics are further specified as *Strategy*, *Process*, and *Organization* based on the frameworks shown in Table 1. These concepts are further explained in the following subsections. Each independent variable (internal characteristic) is described by (1) defining the variable, (2) explaining the relation between the variable and innovation performance, and (3) further specifying the relation between the variable and the different innovation types. In this way we structurally build the hypotheses.

Figure 1: Conceptual Framework



Strategy

This section defines the variables that together make up the *Strategy* construct and links them to innovation performance. These variables are *business strategy* and *dominance*.

Business strategy represents defining and planning a focus for the NPD efforts of a small business unit, division, product line, or individual project (Kahn, et al., 2006).

Table 2: Definitions of strategy types

Prospector	We continuously search for market opportunities and regularly experiment with potential responses to emerging environmental trends. Therefore, we often are the creators of change and uncertainty to which our competitors must respond.
Analyzer	We attempt to maintain a stable, limited line of products or services, operating routinely and efficiently through the use of formalized structures and processes. At the same time, we monitor a carefully selected set of promising new product and market developments in different industries.

It is an agglomeration of decisions through which a strategic business unit aligns its managerial processes (including its capabilities) with its environment (Miles, Snow, Meyer, & Coleman Jr., 1978).

Having a clear strategy in NPD is vital as "undertaking product innovation without a strategy is like running a war without a military strategy" (Cooper, 2000). In relation to innovation performance, business strategy is found as one of the most important drivers of innovation performance (Cooper, 1984; Cooper & Kleinschmidt, 1995). The best performers tend to have clearly identified strategies in place to guide their NPD efforts (Cooper, et al., 2004b).

Miles and Snow (1978) developed a business strategy typology which consists of three strategic types of organizations: defenders, analyzers, and prospectors. There is a fourth strategic type (the so-called reactor), but this form is a strategic failure, in that inconsistencies exist among its strategy, technology, structure, and process (Miles, et al., 1978). Even though some researchers argue that the validity of the Miles–Snow typology is unconfirmed and that the typology itself is too narrow and limited (Zahra & Pearce II, 1990), the typology is well known and often used. Combining the Miles–Snow typology with other internal characteristics (as we did in this research) overcomes the issue of the typology being too limited. Ettlie et al. (1984) link innovation type and business strategy. They find that a more traditional strategy tends to promote incremental innovation while a more aggressive technology strategy promotes radical innovation. In the Miles–Snow typology this implies that an analyzer strategy is most suitable for incremental innovation. The analyzer strategy tries to improve its efficiency by improving or enhancing its products. In contrast, for radical innovation, the prospector strategy is most suitable, as the prospector strategy is most strongly focused on market opportunities and emerging trends. Table 2 shows the definitions of both the analyzer and prospector strategies. The defender and reactor strategy are omitted,

as in theory these two types are linked neither to successful incremental innovation nor to successful radical innovation.

SMEs with high dominance rarely have to change their practices to keep up with the market and competitors and can control and manipulate their environment (Bantel, 1998). Dess and Beard (1984) characterize the environment in terms of instability (or dynamism) and munificence. Instability is the rate of environmental change and the unpredictability of environmental change. Munificence is the extent to which the environment can support sustained growth (Dess & Beard, 1984). In relation to innovation performance, having a certain amount of dominance (power or authority) is important for an SME to be able to execute the necessary actions to achieve the goals that are set in the strategy (Simon, 1976).
We assume that companies that focus on radical innovation are ahead of their competitors and the market. The technologies that are used are so fundamentally new that they can control their environment with it and have high dominance. On the other hand, companies that focus on incremental innovation have to enhance their products to keep up with the market.

In summary, we hypothesize that for successful incremental innovation SMEs should combine an analyzer business strategy with a low level of dominance. For successful radical innovation we argue that SMEs should follow a prospector business strategy, combined with high levels of dominance.

Process
The variables that together make up the *Process* construct are *formalization* and *marketing–R&D integration*. This section describes these variables and links them to innovation performance.
Formalization of the NPD process is defined as "a system of rules covering the rights and duties of positional incumbents; a system of procedures for dealing with work situations" (J. P. Walsh & Dewar, 1987). The Product Development and Management Association best practices studies find that 60% of successful organizations use a formal process (Griffin, 1997). Ernst (2002) summarizes these findings. He states that "the existence of a formal NPD process, which is comprehensive and characterized by professionalism throughout the process, especially in terms of evaluation and selection of new ideas and development and market introduction, has a positive effect on the success of new products" (Ernst, 2002). In addition, in their three-part series, Cooper et al. (2004c) find similar

results. They indicate that putting a formal NPD process in place is clearly a strong practice among better performers. Also the framework of Kahn et al. (2006) shows that the best-performing companies (they call it level four companies) use a formal process (Kahn, et al., 2006).

Ettlie et al. (1984) distinguish between innovation types. They find that high levels of formalization are positively related to the development of incremental new products, while low levels of formalization are needed for successful radical product development (Ettlie, et al., 1984).

Marketing–R&D integration is defined as the degree to which there is communication, collaboration, and a cooperative relationship between marketing and R&D (Leenders & Wierenga, 2002). It involves a cross-functional process in which the functional areas of marketing on the one hand and R&D on the other hand are cooperating. "Interfunctional coordination and collaboration between R&D and marketing is crucial to the success of the new product development process" (X.M. Song, Neeley, & Zhao, 1996). Leenders and Wierenga (2002) elaborate on this by saying that NPD involves a cross-functional process in which different functional areas have to cooperate to be successful. For the success of a new product, it is especially important that market information reach the NPD function along the entire NPD process (Ernst, 2002; Mumford, 2000). Cooper et al. (2004) turn this the other way around by stating that a lack of solid market and customer information is a major cause of new product failure (Cooper, et al., 2004c).

In this research it is assumed that the more radical the innovation is, the less important market information is, because radical innovation deals with the emergence of a new dominant paradigm instead of dealing with complementary assets (Cesaroni, Di Minin, & Piccaluga, 2005). Thus we argue that SMEs that aim for high incremental innovation performance should have high levels of formalization and marketing–R&D integration. In contrast, we argue that for successful radical innovation SMEs should combine low levels of both formalization and marketing–R&D integration.

Organization

The variables *climate*, *culture*, and *team structure* together form the *Organization* construct. The definition of these variables and their relation to innovation performance are described in this section.

The climate that Cooper et al. (2004a) refer to is the organizational climate as defined by the attitude of the individuals concerning the organization—its degree

of trust, conflict, morale, rewards equity, leader credibility, resistance to change, and scapegoating as seen by the individuals (Burton, Lauridsen, & Obel, 2004). It is regarded as an attribute of the organization, a conglomerate of attitudes, feelings, and behaviors that characterizes life in the organization (Ekvall, 1996). More precisely, climate is shared perceptions, both formal and informal, of organizational policies, practices, and procedures (Reichers & Schneider, 1990). In an entrepreneurial climate, employees have (1) the possibility to use a set portion of their workday for independent work developing their own ideas (free time) and (2) support for work on unofficial projects (skunk works) (Cooper & Kleinschmidt, 1995; Ernst, 2002).

In relation to innovation performance, climate is an enabler of creative processes that lead to new ideas in organizations. It is an intervening variable which affects the results of the operations of the organization (Eisenhardt, 1989; Ekvall, 1996). Organizational climate interacts with the organizational context to influence innovation performance (Nystrom, Ramamurthy, & Wilson, 2002). One of the resources that should be available in order to improve innovation performance is idea time and freedom for employees (Mumford, 2000). These are the key elements of an entrepreneurial climate (Cooper, et al., 2004a; Cooper & Kleinschmidt, 1995). An entrepreneurial climate translates into ideation, free time, skunk works, and available resources (bootstrapping) (Cooper & Kleinschmidt, 1995). In all NPD, regardless of innovation type, the presence of an "entrepreneurial climate" is needed (Cooper, et al., 2004a; Cooper & Kleinschmidt, 1995) in order to achieve high innovation performance.

Organizational culture is defined as the shared beliefs and values held by an organization's members (Smart & St.John, 1996). Or, according to Burton et al. (2004, p. 70), "culture is a pattern of knowledge, belief, and behavior that includes social forms." Culture is a common set of shared meanings or understandings about the group/organization and its problems, goals, and practices (Reichers & Schneider, 1990).

In relation to innovation performance, organizational culture is regarded as the context in which innovation takes place (Prajogo & Sohal, 2001). The more innovative this context is, the higher the innovation performance. According to Prajogo and Sohal (2001) this implies that the propensity for innovation is inherent in the members of the organization. Cameron and Ettington (1988) defined four types of culture divided on a two-dimensional scale. On the horizontal axis the scale ranges from an internal, short-term orientation to an external, long-term

orientation. On the vertical axis the scale ranges from flexibility and spontaneity to stability, control, and predictability. Cameron and Ettington distinguish between the clan culture (internal orientation and flexibility), the adhocracy culture (external orientation and flexibility), the hierarchy culture (internal orientation and stability), and the market culture (external orientation and stability). Smart and St. John (1996) use the four culture types of Cameron and Ettington (1988) and link them to organizational performance. They find that different culture types are related to higher levels of performance on different effectiveness dimensions. When looking at the four different types of culture and taking the different innovation types into account, it is expected that radical innovation projects require an adhocracy culture. These projects are external and long-term oriented and focused on flexibility and spontaneity. Incremental innovation projects are more short-term oriented and focused on stability, control, and predictability. Therefore it is expected that companies with a focus on incremental innovation use a hierarchy culture to achieve high innovation performance. Based on Cameron and Ettington's model, only the adhocracy and hierarchy cultures are considered in this research.

Culture should not be confused with climate. Culture refers to the deep structure of organizations, which is rooted in the values, beliefs, and assumptions held by organizational members. In contrast, climate portrays organizational environments as being rooted in the organization's value system, but tends to present these social environments in relatively static terms. Climate is often considered to be relatively temporary, whereas culture is more stable over time (Denison, 1996). Culture exists at a higher level of abstraction than climate, and climate is a manifestation of culture. Organizational culture deals with beliefs, perceptions, and behavior, whereas organizational climate has been built up from measures or qualitative assessments of individual perception (Pettigrew, 1990).

The team structure we refer to in this research is the structure of cross-functional product development teams. Cross-functional teams are project teams that consist of different capabilities and disciplines. These cross-functional teams are important for NPD as effective product and process development requires the integration of specialized capabilities (Clark & Wheelwright, 1992). The rapid change and diffusion of technology and burgeoning global competition have intensified the need for complex and highly novel product innovations. In this context, the use of cross-functional teams has become very important (McDonough III, 2000). Firms interested in improving both proficiency in their development process and the survival rate of new products should promote cross-functional integration (Thieme,

Song, & Shin, 2003). This is also in line with the research of Sosa et al. (2004), who state that complex product development requires structuring the organization into groups of cross-functional design teams to design systems and components, and with the research of Cooper et al. (2004), who have identified the presence of cross-functional teams as a common factor in organizations they rated as best performers (Cooper, et al., 2004a). Clark and Wheelwright (1992) have identified a number of structures for cross-functional project teams: (1) functional team structure, (2) lightweight team structure, (3) heavyweight team structure, and (4) autonomous team structure. Which project structure is most suitable depends on the environment, organization size, and innovation type (Clark & Wheelwright, 1992).

In their research Ettlie et al. (1984) find structural differences for incremental and radical innovation. They find that incremental innovation depends more on traditional structures and radical innovation depends more on informal structures (Ettlie, et al., 1984). In addition, Clark and Wheelwright (1992) write that, when companies push to develop new products quickly, without distraction from other tasks (but without losing sight of organizational procedures), a lightweight team structure is most suitable. Furthermore, they find that radical innovation projects require team members to have freedom to generate ideas that are different from current practices, as is possible in the autonomous team structure. In line with the research of Clark and Wheelwright (1992) and Ettlie et al. (1984), we hypothesize that the lightweight team structure can be found in incremental innovation and the autonomous team structure in radical innovation.

We therefore hypothesize that successful incremental innovation requires a combination of an entrepreneurial climate, a hierarchy culture, and a lightweight team structure. In addition we hypothesize that SMEs should combine an entrepreneurial climate with an adhocracy culture and autonomous team structure to achieve high radical innovation performance.

Table 3: Organizational pattern typology overview

	Selected References	Theoretical organizational pattern 1 *Organizing for radical innovation*	Theoretical organizational pattern 2 *Organizing for incremental innovation*
Strategy	Miles & Snow (1978)	Prospector	Analyzer
Dominance	Bantel (1998)	High level	Low level
Formalization	Griffin & Page (1996)	No formalized processes	Formalized processes
Marketing-R&D integration	Leenders & Wierenga (2002)	Low level	High level
Climate	Ekvall (1996) and Cooper & Kleinschmidt (1995)	Entrepreneurial	Entrepreneurial
Culture	Cameron & Ettington (1988)	Adhocracy	Hierarchy
Team structure	Clark & Wheelwright (1992)	Autonomous	Lightweight

2.3. Successful Patterns

From the literature discussed above we selected the theories we believe are the most determinative in their field. With the help of these selected references, we constructed two internal patterns that lead to high innovation performance. Both the selected references and the patterns are shown in Table 3 below.

This table shows the variables described in the previous section and linked to innovation performance. Organizational pattern 1 includes the values of the variables that theory suggests lead to high overall innovation performance when the focus is on radical innovation. Organizational pattern 2 shows the values of the variables for the organization of incremental innovation. It is important to keep in mind that, for this research, the combination of these variables is important. We look at patterns of internal characteristics in relation to innovation performance and not at the individual organizational characteristics in relation to innovation performance. The hypotheses that are tested in this research are:

> *H1a: For SMEs with a focus on incremental innovation, innovation performance will be high when their internal organization is in line with pattern 2.*

> *H1b: For SMEs with a focus on radical innovation, innovation performance will be high when their internal organization is in line with pattern 1.*

High innovation performance, as included in the hypotheses, means that the achieved innovation performance is higher than the average innovation performance of the subset of companies.

3. Methodology

The research described in this paper is survey research. Data collection is carried out with the specific aim of testing the adequacy of the concepts developed in relation to the phenomenon, of hypothesized linkages among the concepts, and of the validity boundary of the models (Forza, 2002). The research is part of the international research project "Patterns in New Product Development" which aims to develop new knowledge in the field of NPD.

3.1. Sampling Process

Europe and Australia

In Europe and Australia, companies were selected based on sector (first two digits of SIC codes). Table 4 shows the different data sets that were used to select companies and the responses in each country. Publicly available information, mainly Web based, was then used to determine the possible suitability of these companies. Firms were contacted by telephone to ensure their suitability in terms of number of staff engaged in NPD, which needed to be at least five full-time employees (FTEs); 1,480 companies were found that met this criterion. Of these, 423 companies indicated their willingness to participate in this study and a questionnaire was sent to them. The contact person was asked to distribute the questionnaire to a manager who has been involved in developing new products in their organization or who has knowledge of overall new product programs in their organization. Follow-up phone calls and e-mails were used to increase the response rate.

Table 4: Sampling data from Europe and Australia

Country	Sampling frame	First selection	Suitable	Willing to participate	# Firms participating
Belgium	EPO	67	46	11	3
Denmark	Nnerhverv	145	145	36	31
Finland	Voitto	60	60	15	13
Netherlands	EPO	178	119	34	14
	FME	2500	200	29	23
	Chamber of Commerce	200	121	21	13
Norway	Diagnose	551	154	125	8
Portugal	Convenience sample			11	11
Spain	DUNS	109	35	31	19
Turkey		600	600	110	52
Total		4410	1480	423	187

United States

Sampling in the United States consisted of 500 randomly selected firms from all nonservice firms listed in the World Business Directory. A presurvey letter requesting preapproval for participation was sent to all 500 firms. A total of 186 firms agreed to participate and provided a contact person, while 36 companies declined to participate, 42 letters were returned due to invalid contact person or address, and 236 companies did not respond. The questionnaire was sent to 422 firms (the 186 firms that agreed to participate and the 236 non-responding firms from the presurvey). Just as in the other countries, the contact person was asked to distribute the questionnaire to a manager who has been involved in developing new products in their organization or who has knowledge of overall new product programs in their organization. To increase the response rate, four follow-up mailings were sent to the companies.

3.2. Data Description

Europe and Australia

Of the 423 European and Australian companies that received questionnaires, 187 returned filled-in questionnaires, resulting in a response rate of 44.21%. The European data set includes 130 SMEs from eight different European countries. The range of the number of FTEs in the companies is shown in Table 5 and is based on

the categorization on European Standards (Commission of the European Communities, 2003a).

United States

Of the 422 U.S. companies that received questionnaires, 164 returned usable questionnaires. For the United States, the response rate was 38.86%. The U.S. data set includes 69 SMEs. The range of the number of FTEs in these companies is shown in Table 5.

Table 5: Full Time Equivalent (FTE) categorization per country

		Full Time Equivalent (FTE)			
		2-9 FTE	10-49 FTE	50-250 FTE	**Total**
Country	Belgium	0	0	1	1
	Denmark	2	9	9	20
	Finland	0	2	2	4
	Netherlands	1	14	18	33
	Norway	0	1	5	6
	Portugal	0	1	9	10
	Spain	4	5	5	14
	Turkey	11	17	14	42
	US	0	28	41	69
Total		18	77	104	199

The sample of 199 companies was divided in two subsamples based on the innovation type they focus on (radical or incremental). Companies were asked to indicate the percentage of radical, platform, and incremental innovation projects in their portfolio. We used Table 6 to divide the companies in the two subsamples. This resulted in two subsets: one for radical innovation (N=13) and one for incremental innovation (N=100) (see Table 7). The N=86 missing items are companies that 1) focus on platform innovation, 2) have a mixed portfolio with no clear focus, or 3) that have an equal focus on incremental, platform, and radical innovation.

Table 6 Rules for dividing the datasets in subsets

Rule	Subset
=> 50 % incremental	Incremental subsample
=> 50 % radical	Radical subsample

Table 7 Data frequency in innovation type subsets

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	=> 50% radical	13	6,5	11,5	11,5
	=> 50% incremental	100	50,3	88,5	100,0
	Total	113	56,8	100,0	
Missing	System	86	43,2		
Total		199	100,0		

From table 7 can be seen that the subset for radical innovation includes N=13 companies. With this modest amount of cases a cluster analysis can, unfortunately, not be conducted. This means that we can only test Hypothesis 1a, which focuses on incremental innovation. Therefore we continue to test Hypothesis 1a.

3.3. Measurements

Overall innovation performance was measured as a scale variable using the percent sales performance measurement of Cooper and Kleinschmidt (1995). They find that, out of 10 performance measurements, this measurement most clearly indicates whether a company is successful in NPD at the firm level (Cooper & Kleinschmidt, 1995).

Measurements for Strategy

To measure the nominal variable business strategy, the business strategy types of Miles and Snow (1978) were used. Companies were asked to indicate whether they consider themselves to be analyzers, prospectors, defenders, or reactors. In addition to the business strategy types, the level of dominance of the SME in its environment was measured as in Bantel (1998) and then translated into a nominal

variable. SMEs were asked to what extent they must change their practices to keep up with the market and competitors and to what extent they can control and manipulate their environment to their own advantage.

Measurements for Process

The level of formalization was measured on a nominal scale by presenting multiple descriptions of development processes of a business unit. The respondents were asked to indicate which development process most closely describes the development process that is used in their business unit. To analyze marketing–R&D integration, the respondents were asked to indicate on 7-point Likert scales to what extent both departments share information, to what extent conflicts between both departments are constructive, and to what extent both departments are more like teammates than competitors.

Measurements for Organization

The presence of an entrepreneurial climate (nominal variable) was measured by asking the respondents to indicate on a 7-point Likert scale to what extent employees have the freedom to define their own work and to what extent there is time for people to develop unplanned new ideas. To measure the nominal variable business culture, the business culture types of Cameron and Ettington (1988) were used. Respondents were asked to indicate whether they have a clan, adhocracy, hierarchy, or market business culture. To measure the nominal variable team structure, the team structure types of Clark and Wheelwright (1992) were used. In the survey, respondents were asked to indicate whether they use a functional, lightweight, heavyweight, or autonomous team structure.

3.4. Data Analysis Techniques

To test the hypothesis, simultaneous analysis of multiple variables is needed. We chose to conduct cluster analyses in both subsets as this enables a holistic view and analyses of the data. In cluster analysis a sample of entities is classified into a smaller number of mutually exclusive subgroups based on the similarities between subgroups (Forza, 2002). From the various types of cluster analyses that are available, the two-step cluster analysis was selected because in this type of cluster analyses both continuous and categorical variables can be processed at the same time (Norusis, forthcoming 2009). Dolnicar (2003) presents a review of unquestioned standards in using cluster analysis. With regard to sample size she finds that in 20% of studies she reviewed, the datasets were smaller than N=100.

The median sample size is 293. Sample sizes themselves are not problematic. The methodological problems occur when sample sizes are too small for the number of variables used. As a rule of thumb, the minimal sample size should be 2^k (k represents the number of variables). For a sample size of N=100, as in this study, a maximum of 6 to 7 variables may be included {Dolnicar, 2003 #404}.

The independent variables were business strategy, dominance, formalization, marketing–R&D integration, (entrepreneurial) climate, business culture, and team structure, while the dependent variable was innovation performance. To examine whether innovation performance of the found clusters differs significantly, analyses of variance (ANOVA) tests were conducted.

4. Results

From the data set, 100 companies have a focus on incremental innovation projects. A two-step cluster analysis was conducted on these companies in order to test hypothesis 1a.

First, we find that companies in our data set that focus on incremental innovation indeed share a pattern in their internal organization. In our data set we can distinguish between two groups, also called clusters as they are the outcome of the cluster analysis (see Table 8).

Table 8: Cluster distribution of incremental innovation

	N	% of Combined	% of Total
Cluster 1	56	62.9%	56.0%
Cluster 2	33	37.1%	33.0%
Combined Cluster	89	100.0%	89.0%
Excluded Cases	11		11.0%
Total	100		100.0%

Cluster 1 includes 56 companies, which is 62.9% of the incremental data set. Cluster 2 includes 33 companies (37.1%). The mean innovation performances of both clusters are shown in Table 9. The innovation performances of both clusters are significantly different ($p < 0.05$) as shown by the ANOVA results displayed in Table 10. The innovation performance of cluster 1 is significantly higher than the

innovation performance of cluster 2. The innovation performance of cluster 1 is also higher than the average innovation performance of the incremental data set.

Table 9: Scores on innovation performance per cluster for incremental innovation

TwoStep Cluster Number	Mean	N	Std. Deviation
Cluster 1	74.82	56	15.541
Cluster 2	64.76	33	20.813
Total	71.09	89	18.231

Table 10: ANOVA test results of the innovation performance per cluster for incremental innovation

	Sum of Squares	df	Mean Square	F-statistics	Sig.
Between Groups	2103.006	1	2103.006	6.740	.011
Within Groups	27146.275	87	312.026		
Total	29249.281	88			

Second, as a result of the cluster analysis, we find the organizational pattern that is dominant in the cluster. Companies that focus on incremental innovation and that achieve high innovation performance have an organizational configuration that combines an analyzer or prospector business strategy with an adhocracy business culture. Furthermore, they have a high level of marketing–R&D integration. Half of the companies have high dominance in their environment, and the other half have low dominance. Most of the time they do not use formalized processes. The team structure they use is the functional team structure. In 52 out of 56 companies in this cluster, an entrepreneurial climate is present. Based on theory we expected that the organizational pattern that leads to high innovation performance would include an analyzer strategy, with a low level of dominance, a high level of marketing–R&D integration, formalized processes, a hierarchy culture, a lightweight team structure, and an entrepreneurial climate. Table 11 shows that there are differences between theory and practice in the areas of business

strategy, formalization, business culture, and team structure. We will discuss these differences in the next section.

In addition our results indicate the differences between the organizational pattern that leads to high innovation performance and the less successful organizational pattern in terms of innovation performance. The differences can be found in the areas of business strategy, dominance, marketing–R&D integration, and (entrepreneurial) climate. Cluster 1 is dominated by analyzer and prospector business strategies. The other cluster is dominated solely by an analyzer business strategy. The companies in cluster 2 mainly have low dominance in their environment and low
marketing–R&D integration, instead of high scores for both variables as in cluster 1. Finally, 30 out of the 33 companies in cluster 2 do not have an entrepreneurial climate.

Table 11: Comparison of a successful internal organization for incremental innovation from both theory and practice

	Theoretical organizational pattern *Organizing for incremental innovation*	**Organizational pattern in practice** *Organizing for incremental innovation*
Business Strategy	Analyzer	Prospector/ Analyzer
Dominance	Low level	High/Low level
Formalization	Formalized processes	No formalized processes
Marketing-R&D Integration	High level	High level
(Entrepreneurial) Climate	Entrepreneurial	Entrepreneurial climate
Business Culture	Hierarchy	Adhocracy
Team structure	Lightweight	Functional

5. Discussion

In this study we show that SMEs that achieve high innovation performance and focus on incremental innovation projects share a configuration in their internal organization. The configuration that was found to lead to high innovation performance in practice gives an indication of the internal organization that might be recommended for incrementally focused SMEs. In this configuration an analyzer or prospector business strategy is combined with an adhocracy business culture, a

high level of marketing–R&D integration, no formalized processes, a functional team structure, and an entrepreneurial climate.

The results indicate that the main differences between theory and practice can be found in the variables business strategy, formalization, business culture, and team structure. Even though theory suggested that the best-performing (incrementally focused) companies use formalized processes, this is different in practice. This might be explained by the fact that in incremental innovation the amount of risk and uncertainty is lower. Companies know what they are doing: it becomes more a matter of routine. Either the analyzer or prospector strategy is used instead of only the analyzer strategy. The strong presence of the prospector strategy can be explained by the size of the companies in the data set. SMEs that want to achieve high innovation performance cannot afford to be expectant or passive with regard to market opportunities. More strongly put, a company has to be the creator of change in its market. With regard to team structure for incremental innovation, a project steering committee is possibly too heavy for the type of work to be done and the size of the company. In incremental innovation the development process is well known and each functional department knows its role. Therefore the functional team structure is more applicable. Instead of the hierarchy culture, an adhocracy business culture is present because the adhocracy culture better fits the prospector strategy than the hierarchy culture does. The hierarchy culture is internally focused and aims for stability and control. This does not fit the prospector strategy. In contrast, in the adhocracy culture, the orientation is external and on the long term. It has an innovation-oriented and entrepreneurial focus, which fits the prospector strategy.

The literature from which the theoretical organizational pattern and the hypotheses were constructed mainly focus on one variable. In this research we focused on multiple variables at the same time, because in practice companies combine multiple organizational characteristics that are interrelated. This explains the differences between the theory and our results.

6. Conclusions and Further Research

This research adds to the current body of knowledge in that it compares high- and low-performing SMEs based on competence differences. It also presents companies with a clear indication of how to configure their internal organization to achieve high innovation performance for incremental innovation. By taking a holistic view, the disadvantages of reductionism have been overcome.

In line with theory, we indeed found a clear pattern in the internal organization of incrementally focused SMEs that achieve high innovation performance. However, the internal pattern we found differs from the pattern that was suggested by theory. This can be explained by (1) the fact that most theory is focused on large firms whereas our research focuses on SMEs and (2) the fact that most theory focuses on one variable and thus implies that these theories are not applicable in practice.

Furthermore we find that incrementally focused SMEs that achieve high innovation performance combine an analyzer or prospector business strategy with an adhocracy business culture. They also have a high level of marketing–R&D integration. Most of the time they do not use formalized processes. They use a functional team structure in an entrepreneurial climate.

We have overcome some reductionism, because we used the interaction approach in clustering the companies. Using the systems approach to explore the interrelations between the variables in further research would be another step forward in overcoming reductionism.

For further research it might also be interesting to conduct cross-country and cross-industry analyses. The Patterns in NPD database is a very rich database with data from a variety of countries and sectors, but for our research the sample size was too small to control for both countries and industries. Due to the small number of companies in our dataset that focus on radical innovation projects we were not able to test our hypotheses 1b. However, further research into the internal configuration used by successful radically focused companies is also of interest to establish whether a distinction between innovation types really matters and is necessary (as suggested in theory).

Because we collected data at one point in time, and as NPD is dynamic and changes over time, longitudinal analysis of research results might be worthwhile as well. This research focused on the internal configuration of SMEs, but as SMEs often collaborate in NPD with external partners, the external configuration also influences the overall innovation performance. By taking the external characteristics of the SME into account, the relation between the overall innovation performance and organizational characteristics (internal and external) would become even clearer.

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Chapter 3

The Development of an adequate Measurement Instrument for the Simultaneous Measurement of Network Characteristics and Innovation Performance

Based on:

Pullen, A.J.J., Fisscher, O.A.M., Groen, A.J., De Weerd-Nederhof, P.C. (2010). *Measuring the network-innovation performance: The development of an adequate Measurement Instrument.* In Conference Proceedings of the "R&D Management Conference 2010", 30 June- 1 July 2010, Manchester, UK

Abstract

Especially in the context of small and medium sized companies (SME) collaboration for new product development purposes is an important research issue. However the academic debate does not address how to organize these external networks. In addition, the vast amount of network characteristics and the heterogeneous content of network characteristics makes it difficult to thoroughly examine the organization of NPD networks. An adequate measurement instrument to simultaneously measure the relation between the values of several network characteristics and innovation performance is lacking. This research focuses on the interaction between actors: the social capital. Therefore, in this research, based on the social systems perspective, we develop such a measurement instrument to measure the relationship between the organization of the external network and innovation performance.

We started with an in-depth literature review in network and innovation literature to select the most relevant network characteristics in relation to new product development (NPD). In addition a panel review with 15 middle managers of small and mediums sized medical devices companies was conducted. The resulting measurement instrument was tested and validated in SMEs in the Dutch medical devices sector. Through factor analysis 6 reliable constructs were distinguished: Innovation Performance, Resource Complementarity, "Fairness" Trust, "Reliability" Distrust, Lack of Goal Alignment and Network Position Strength. The latter is a fully new measurement construct.

This research contributes to theory by addressing the lack of an adequate measurement instrument to study the relationship between the innovation performance of an SME and multiple network characteristics simultaneously. Furthermore, this research contributes to practice as it offers practitioners an instrument to assess the effectiveness of their companies' NPD network in relation to their innovation performance.

1. Introduction

New Product Development (NPD) in small- and medium sized organizations (SMEs[1]) often takes place in collaboration with other organizations, because SMEs need partners in developing new products (Karlsson & Olsson, 1998; Rogers, 2004). The innovativeness of SMEs stems from their capabilities to interact with the

[1] Small- and medium sized companies are companies that have (according to European Standards) 250 or less full time employees ((Commission of the European Communities, 2003a)

environment and not only from their technological and scientific expertise (Yli-Renko & Autio, 1998). Compared to large firms, SMEs have a number of typical problems with regard to their innovation process, especially in the shift from the development stages to the commercialization stages (Hanna & Walsh, 2002). They are more confronted with financial constraints, they have more manpower bottlenecks in terms of too few or inadequately qualified personnel and they often don't have the possibility to substitute for the lack of sales and profits through other products (cash cows) (Karlsson & Olsson, 1998; Kaufmann & Tödtling, 2002; Rogers, 2004; Roper, 1997). On the other hand, SMEs also have some advantages with regard to new product development which makes them very suitable as network partner. SMEs are usually less bureaucratic, and generally have greater incentives to be successful than large firms (Michael & Palandjian, 2004). Often, they also have highly specialized qualifications, adaptability, flexibility, internal consistency, and the willingness to undertake risk (Rogers, 2004; Roper, 1997).

The way firms organize their network leads to a certain amount of social capital (Cooke & Wills, 1999). From alliance literature we know, that numerous external alliances fail in practice (Duysters, et al., 1999; Spekman, et al., 1996). Since alliances are a type of collaboration ,we assume that the high alliance failure rate has its effect on the failure rates of collaboration. In spite of the high failure rate, the academic debate does not address how to organize these networks in the context of new product development (NPD) (Gassmann, 2006).

A problematic issue in examining the organization of NPD networks is the vast amount of network characteristics. These characteristics are described and operationalized in literature, but, due to their heterogeneous and (sometimes) contradicting meaning, cannot be analyzed simultaneously. In addition, many network characteristics are not linked or related to NPD and innovation performance. Actually, it seems that an adequate instrument to simultaneously measure the relation between the values of several network characteristics and innovation performance is lacking. Only by simultaneously addressing multiple (network) characteristics of organizations can relationships between performance and these organizational characteristics be fully understood (Van de Ven & Drazin, 1985). To improve innovation performance not only one network variable, but a combination of network characteristics that together build the network for NPD should be considered. Therefore the objective of this research is to develop an adequate measurement instrument to measure the relationship between several network characteristics in combination and innovation performance.

In order to build such an adequate measurement instrument, first an in-depth literature review on network characteristics that are related to innovation performance is conducted (§2). Based on the frame of reference of the research (§2.1) and the literature review, network characteristics are selected (§2.2) and operationalized (§2.3) to be included in the measurement instrument. Next, a pilot test among practitioners in the medical devices sector is conducted (§3), to examine the:

- *Clarity* of the instrument: identify possible lack of clarity in the measurement instrument
- *User friendliness* of the instrument: identify difficulties for respondents in using the measurement instrument
- *Applicability and relevance* of the subjects covered in the instrument for SMEs that collaborate in NPD.

Finally, after pilot testing the measurement instrument, the validity and reliability of the measurement instrument are analyzed by using exploratory factor analysis (§4).

The paper continues in section 2 with the frame of references which sets the boundaries of the research, which is followed by the literature review. Section 3 describes the results of a pilot test of the measurement instrument with practitioners. Section 4 presents the context of the medical devices sector in which the measurement instrument is tested. Section 5 examines the validity of the developed measurement instrument by using exploratory factor analysis. Finally, section 6 discusses the results which is followed by a summation of research limitations and suggestions for future research in section 7.

2. A Theoretical Examination of NPD related Network Characteristics

The first part of the research is described in this section and includes the literature review. In order to conduct the literature review, first the frame of reference and the focus of the review is explained. Then, the network characteristics that are selected from literature are presented. The final and most extensive part of this section defines the network characteristics, explains their relation to innovation performance and new product development and presents their operationalization.

2.1. Boundaries in examining NPD related network characteristics

To set the boundaries of the literature review, the frame of reference should be made clear. As stated before, the objective of this paper is to develop an adequate

measurement instrument to measure the relationship between the organization of the SME's external network and its innovation performance. Networks are often defined as patterned relationships between actors such as individuals, groups or organizations (Groen, 2005). Inspired by the social systems perspective, Groen (2005) argues, that many (small) firms beyond their individual scope cooperate with other organizations, large and small, to exploit new technologies in networks. A social system was originally defined by Parsons as:

"…a social system consists in a plurality of individual actors interacting with each other in a situation, which has at least a physical or environmental aspect, actors who are motivated in terms of a tendency to the "optimization of gratification" and whose relation to their situations, including each other, is defined and mediated in terms of culturally structured and shared symbols" (Parsons, 1964).

Four dimensions are embedded in this definition:

1. Interaction between actors (social network)
2. Striving for goal attainment (scope)
3. Optimization of processes (scale)
4. Maintaining patterns of culturally structured and shared symbols (skill & value)

All four dimensions work concurrently and influence the outcomes of a social system in a structured, though not deterministic, way (Groen, 2005).

The second foundation of the social systems perspective lies in its assumed relation between action and capitals (Groen, Wakkee, & DeWeerd-Nederhof, 2008b). Groen (2005) builds on the work by Parsons when developing a multi level framework for knowledge intensive entrepreneurship in networks. In this framework it is assumed, that each of the four dimensions of the social system produces its own type of processes, and within those processes its own type of capital. Every action can be decomposed into four types of capital (social, strategic, economic and cultural capital) as input. At the same time, each action also produces an effect on each of these four capitals (Groen, et al., 2008b). *Social capital* relates to the network connections of an actor that directly or indirectly give access to other actors. *Strategic capital* is the set of capacities that enables actors to decide on goals and to control resources and other actors to attain them. *Economic capital* is the set of mobile resources that are potentially usable in exchange relationships between the actor and its environment in processes of acquisition, disposal or

selling. Finally, *cultural capital* relates to the pattern maintenance function, which refers to the integrated structure of a social system (Groen, et al., 2008b). Sufficient capital is needed on each of the four dimensions to create sustainable enterprises (Groen, 2005).

This research focuses on the interaction between actors: the social capital. To develop an adequate measurement instrument, we start off by selecting the NPD related network characteristics that are relevant in the context of this research. We select network characteristics from literature that have to meet certain requirement in the setting of this research. The first requirement is that we select literature that focuses on *SMEs* in networks, since they have a number of typical problems in their NPD process as explained in the introduction. Second, because we take the perspective of the SME to analyze its network, we adopt the *ego-centered network perspective*. In an ego-centered network, the network consists of a focal actor, termed ego, a set of alters who have ties to ego, and measurements on the ties among these alters (Wasserman & Faust, 1994). This implies that we select network characteristics from literature that are relevant in an ego-centered network perspective. Third, it is a requirement that all selected network characteristics are *related to innovation performance*, because we look specifically at networks that are focused on new product development. In this research the definition of innovation proposed by Afuah (1998) is used, which states that in the field of high technology innovation is invention + commercialization (Afuah, 1998). We use this definition, because we are interested in the organization of NPD networks that not only lead to a successful development process, but also to successful commercialization of the new product. Therefore we need a measure of innovation performance that takes into account the fact that the new product needs to be in the market for a certain period of time, before it becomes visual in the sales figures of the company. In addition, since we want to know how a focal SME should organize its NPD process in terms of the external network in order for the newly developed product to be successful in the market, we need a measure of innovation performance which is not bound to a certain *time span* and which is also *applicable at the project level*.

In summary, based on this frame of reference, we build our measurement instrument from network literature and innovation literature that a) focuses on SMEs, b) has an ego-centric network perspective, c) focuses on networks for NPD purposes, d) takes into account the time span and e) considers individual NPD projects.

After selecting relevant network characteristics, we will use the multi level framework of Groen (2005) by linking each relevant NPD network characteristics to one of the four capitals (strategic, economic, social, and cultural).

2.2. Selection of NPD related network characteristics

Literature on external collaboration and new product development was reviewed to identify network characteristics that are used in literature and prior research and that are relevant in this research context. Articles were selected by using the key words "network variables", "network characteristics", "new product development", and "innovation". In addition to these key words, articles were selected that were published from 1975 onwards, and that were published in the English language. We did not put any restriction on the theoretical embeddedness of the selected papers, since we wanted to have a complete overview of as many characteristics as possible.

The main problem we encountered in the literature study was that different researchers use different labels for network characteristics that in fact measure the same variable. The other way around, there are also several network characteristics that are labeled the same across different research even though they measure different concepts. In addition, sometimes network characteristics have the character of a construct consisting of items, sometimes they have the character of items. To overcome this problem, we looked at the lowest level of operationalization: the item-level.

From the literature we extracted a total of 54 items that all fitted in the frame of reference. This list of 54 items was given to a panel of both senior researchers and PhD students. They were requested to assess each item and categorize them according to similarity. 50 out of 54 items were grouped in the same way by all panel members. The categorization of only 4 out of 54 items needed discussion. The categorization of items resulted in 7 groups of items. These 7 groups represent our selected network characteristics and are listed in Table 1.

Table 1 shows that the network characteristics we extracted from literature and that fit in our frame of reference are: "goal alignment", "resource exchange", "trust", "density", "structural holes position", and "network size". As aimed for, these network characteristics can all be included in the multi level model of Groen (2005), which is based on social systems theory, in which they together represent

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Table 1: Selection of network characteristics from literature

Network characteristic	Definition	Authors
	Social Capital	
Density	The number of actual links in the network as a ratio of the number of possible links	Tichy et al (1979); Burt (1992); Nahapiet and Ghoshal (1998); Borgatti et al (1998); Kerssens-Van Drongelen and Groen (2004); Inkpen and Tsang (2005); Liao and Welsch (2005); Burt (1992); Coleman (1988); Gilsing et al (2008)
Structural holes position	The extent to which an actor can broker connections in its network	Burt (1992); Haythotnthwaite (1996); Borgatti et al (1998); Kerssens-Van Drongelen and Groen (2004); Zaheer & Bell (2005)
Network size	The number of alters that an ego is directly related to. (In the case of an ego-network, this is equal to the number of actors in the group).	Tichy et al (1979); Borgatti et al (1998); Koka and Prescott (2002); Kerssens-Van Drongelen and Groen (2004)
	Strategic Capital	
Goal alignment	The degree to which network members share a common understanding and approach to the achievement of network tasks and outcomes	Tichy et al (1979); Leana and Van Buren III (1999); Inkpen and Tsang (2005); Bourgeois III (1980); Dess (1987)
	Economic Capital	
Resource exchange	The physical and organizational resources of the company that are exchanged and/or combined with those of its counterparts	Tichy et al (1979); Burt (1992); Haythornthwaite (1996); Grant (1991); Håkansson (1989); Lambe et al (2002)
	Cultural Capital	
Trust	The belief that the results of somebody's intended action will be appropriate from our point of view	Nahapiet and Ghoshal (1998); Leana and Van Buren III (1999); Inkpen and Tsang (2005); Liao and Welsch (2005); Gulati & Sytch (2008)

all four capitals (see Table 1). In this categorization *social capital* is represented by "density", "structural holes position", and "network size", *strategic capital* is represented by "goal alignment", *economic capital* is represented by "resource exchange", and finally "trust" represents *cultural capital*.

The next section presents the definitions of all selected network characteristics and describes their relation to innovation performance.

2.3. Defining and operationalizing NPD related network characteristics

This section presents the definitions of the network characteristics, their relation to innovation performance and their operationalization. In this section, also the operationalization of innovation performance is presented.

Density

Density is the number of actual links in the network as a ratio of the number of possible links in the network (Borgatti, Jones, & Everett, 1998; Burt, 1992a; Haythornthwaite, 1996; Inkpen & Tsang, 2005; Kerssens-VanDrongelen & Groen, 2004; Liao & Welsch, 2005; Nahapiet & Ghoshal, 1998; Rowley, 1997; Tichy, Tushman, & Fombrun, 1979). As density increases, communication across the network becomes more efficient. Furthermore as interorganizational linkages become more dense, behaviors become more similar across the network, and the likelihood that shared behavioral expectations will be established increases (Rowley, 1997). Irrespective of one's position, high density inhibits the existence and utilization of diversity, and hence of novelty value, while at low levels it does not support absorption sufficiently (Gilsing, Nooteboom, Vanhaverbeke, Duysters, & Van den Oord, 2008). Gilsing et al (2008) find that in respect to both density and centrality Burt and Coleman complement instead of contradict each other. Gilsing et al (2008) find that a central position (Burt) is important for novelty value and density (Coleman) is of importance for understanding and absorptive capacity (Gilsing, et al., 2008). The density of a network may give insights into such phenomena as the speed at which information diffuses among the nodes, and the extent to which actors have high levels of social capital and/or social constraint (Hanneman & Riddle, 2005).

Structural Holes Position

When ego occupies a structural holes position in the network, ego is able to broker connections between alters in his network (Burt, 1992a; Haythornthwaite, 1996). In an ego network, ego is connected to every other actor (by definition). If these others are not connected directly to one another, ego may be a "broker" if ego falls on the paths between the others (Hanneman & Riddle, 2005). Firms occupying the favored network position of bridging structural holes are likely to perform better because of the their superior access to information (Burt, 1992b; Zaheer & Bell, 2005). Actors in a network rich in structural holes will be able to access novel information from remote parts of the network, and exploit that information to their advantage (Burt, 1992b, 2001, 2004). Consequently, networks rich of

structural holes are more likely to yield new information, which can lead then to the discovery of entrepreneurial opportunities (Arenius & De Clerq, 2005).

Network Size

The *size* of the network is determined by the number of alters that an ego is directly related to (Borgatti, et al., 1998; Kerssens-VanDrongelen & Groen, 2004; Koka & Prescott, 2002; Tichy, et al., 1979).

Even though "density", "structural holes position", and "network size" can be calculated by using the software program UCINET (Borgatti, Everett, & Freeman, 2002), the resulting scores and measurement scale have not been validated. The input that is needed by UCINET is a matrix in which binary values indicate whether actors (external partners) are connected or not (0 means not connected, 1 means connected). This implies that the scores for "density", "structural holes position", and "network size" are strongly related and might even belong to the same "higher level" network characteristic. To measure "density", "Structural holes position", and "network size, we constructed a 10 x 10 matrix in which ego was asked to indicate which actors in his network are directly connected. This measure is based on the nonredundancy measure as developed by McEvily and Zaheer (1999). The measure for nonredundancy of McEvily and Zaheer is an ego-centered network measure based on an instrument designed and developed specifically for use in the small firm context. In this measurement respondents are asked to mark in a 5 x 5 matrix their most important external sources of advice. McEvily and Zaheer find that there is no bias towards listing 5 actors, because 50% of the firms report fewer than 5 actors (McEvily & Zaheer, 1999). This is also the case in our dataset. However a considerable amount of companies in our dataset (20%) report between 5 and 10 actors with whom they cooperate in new product development. In addition, since one of the network characteristics we want to measure is network size, we need the correct number of actors in the ego-network. Therefore, we expanded the matrix to a 10 x 10 matrix to make sure all actors are included and an accurate measure for "density", "structural holes position", and "network size" is used.

Goal Alignment

Goal alignment is the degree to which every pair of individuals has clearly defined expectations about each other's behavior in the relation (Tichy, et al., 1979), or the degree to which network members share a common understanding and approach

to the achievement of network tasks and outcomes (Inkpen & Tsang, 2005). This is also called associability, which is the willingness and the ability of individuals to define collective goals that are then enacted collectively (Leana & Van Buren III, 1999). When partners have contradicting or inconsistent goals, inter-partner conflicts may arise. This is not conducive to the flow of knowledge between the partners and the alliance.

Value, in terms of innovation performance, can be created through cooperation and knowledge sharing (Inkpen & Tsang, 2005). When the objectives and strategies of an alliance are clearly stated, a foundation of common understanding and the means to achieve the collaborative purpose is established among the partners. Subordinating cooperation to strategic goals can provide longer-term horizons for the alliances, compared with circumstantial cooperative outsourcing, even when an alliance is structured to deal with specific projects of a pre-determined duration (Suarez-Villa, 1998).

To conduct his research on goal alignment Dess (1987) reviewed a number of questionnaire items used by previous researchers (Bourgeois, 1980; Child, 1975; Khandwalla, 1976) to develop an initial listing of 'company objectives'. The 'company objectives' instrument consisted of 15 items, on a 5-point scale ranging from '1=Not at All Important' to '5=Extremely Important'. We include the items of Dess (1987) that concern the company objectives goals in our measurement instrument. The measurement of goal alignment requires three steps (Dess, 1987): 1) calculation of the mean standard deviation of the score of both ego and its external partners for each item, 2) the summation of the standard deviation for all items to yield an aggregate firm score and 3) the firm score needs to be subtracted from a constant number to give the numerical values a positive relationship to the variable being measured, because the standard deviation measures dispersion instead of consensus (Dess, 1987).

Resource Exchange

In relationships between companies the physical and organizational resources of the company are exchanged and combined with those of its counterparts in order to achieve the set goals (Haythornthwaite, 1996; Tichy, et al., 1979). The resources of the two units are affected, both in terms of how they are used and how they develop (Gadde, Huemer, & Håkansson, 2003). The resources that are exchanged between companies are also termed “bonds” (Håkansson & Laage-Hellman, 1984). Six types of bonds can be distinguished (Johanson & Mattsson, 1991): technical (product and process adjustments), planning or temporal (logistical coordination),

knowledge (knowledge about the counterpart), socio-economic (personal confidence and liking), and legal (special credit agreements, long term contracts). For technical development, the technical and knowledge-based bonds are the most important (Håkansson & Laage-Hellman, 1984). Grant (1991) also distinguishes between six major categories of resources: financial, physical, human, technological, reputation, and organizational resources (Grant, 1991).

Lambe et al (2002) distinguish between resources that are developed and resources that are used in external collaboration: idiosyncratic and complementary resources. Idiosyncratic resources are developed during the life of the collaboration, are unique, and facilitate the combining of resources contributed by the partner firms. Complementary resources are defined as the degree to which firms in an alliance are able to eliminate deficiencies in each other's portfolio of resources by supplying distinct capabilities, knowledge, and other entities (Lambe, et al., 2002). Lambe et al (2002) find that both resource types should be present as they affect the success of the external collaboration. The resource types of both Grant (1991) and Johansson and Mattsson (1991) can be idiosyncratic (unique to the relation) or complementary.

Firms are encouraged to innovate by searching out new resources, or new ways of using existing resources, as the basis for future organizational rents (Galunic & Rodan, 1998; Håkansson, 1989; Oerlemans, Meeus, & Boekema, 1998). Such resources will fuel the firm's innovative activities by providing the external information necessary to generate new ideas. Equally, the innovative work of the firm will benefit from access to new knowledge necessary to resolve design and manufacturing problems (Tsai, 2001). Simply having resources is not enough to produce innovative output. It is also the way these resources are utilized in the innovation process, which determines whether innovative outputs are produced in an effective and efficient way (Oerlemans, Meeus, & Boekema, 2001). In fact, the innovation effects of resource exchange in NPD collaborations can be located at two levels. First, the adaptation of external resources leads to an extension of firms' technological capabilities of developing new products. Second, the implementation of additional capacities from outside raises the probability of realizing innovations (Becker & Dietz, 2004).

To measure idiosyncratic and complementary resources Lambe et al (2002) adopted their measures from previous research and adapted them to their research context. A 7-point scale ranging from "not true at all" to "very true", captures the degree to which the partners have developed idiosyncratic resources. A 7-point scale ranging from "strongly disagree" to "strongly agree", taps the

degree to which the partners enhance their ability to achieve business goals by pooling their distinct capabilities (complementary resources). We include the scale for resource exchange of Lambe et al (2002) in our measurement instrument.

Trust

Trust represents an organization's expectation that another firm will not act opportunistically when dealing with that organization (Gulati, 1995). It is defined as the belief that the results of somebody's intended action will be appropriate from our point of view (Nahapiet & Ghoshal, 1998). Trust is necessary for people to work together on common projects, even if only to the extent that all parties believe they will be compensated in full and on time (Leana & Van Buren III, 1999). Trust that builds up over time may in itself lead to unforeseen benefits, even when the expected gains are not fully realized over a given time period. Trust and the temporal, qualitative and community dimension of an alliance are important factors in determining commitment, over and above any strict cost-benefit accounting, particularly among small and medium sized producers (Suarez-Villa, 1998). Some element of trust will be required for any transaction in which simultaneous exchange is unavailable to the parties (Ring & Van de Ven, 1992) as in new product development.

Rempel and Holmes (1986) were among the first researchers that focused on trust and that developed a measurement for trust. They distinguish between cognitive, behavioral and emotional trust (Rempel & Holmes, 1986). In studying the relation of interpersonal and interorganizational trust on performance, Zaheer et al. (1998) build on the research of Rempel and Holmes (1986) and define trust as follows: "Trust is the expectation that an actor (1) can be relied on to fulfill obligations, (2) will behave in a predictable manner, and (3) will act and negotiate fairly when the possibility for opportunism is present (Zaheer, McEvily, & Perrone, 1998). They distinguish between reliability, predictability and fairness as dimensions of trust. More recently Gulati and Sytch (2008) investigated the formation of trust between firms, as we do. They specifically focus on relational trust, which is the expectation that another organization can be relied on to fulfill its obligations, to behave in a predictable manner, and to act and negotiate fairly, even when the possibility of opportunism is present (Gulati, 1995; Zaheer, et al., 1998). To measure interorganizational trust, they adapted the trust measures of Zaheer et al. (1998) (who, in turn, based their measures on the research of Rempel and Holmes (1986)). The measure for interorganizational trust of Gulati and Sytch (2008) has a Cronbach's alpha of $\alpha = 0.85$ (Gulati & Sytch, 2008). In our measurement

instrument we adopt the trust measures of Gulati and Sytch (2008), since their measurement specifically focuses on interorganizational trust rather than on interpersonal trust. In addition, their measurement is the most recent measurement of trust, which is based on, and which is tested and improved over time by acknowledged scholars in the field of research on trust.

Innovation Performance

Miller and Friesen (1982) measure innovation performance using three factors: the existence of a strong emphasis on R&D, the introduction of many new products/ services over time, and significant changes in products/ services. Cooper and Kleinschmidt (1995) presented a number of measures for innovation performance at the firm level. For this research a measure of innovation performance which is not bound to a certain time span and which is also applicable at the project level is needed. Atuahene-Gima, Slater, and Olsen (2005; 2007) present a measure for product innovation performance which focuses on whether the product development objectives were achieved. They base their scale on earlier research by Narver and Slater (1990) and Griffin and Page, (1993) (Atuahene-Gima, Slater, & Oslon, 2005). The product innovation performance construct includes 5 items that are measured on a 7-point Likert scale (1=low and 7=high). We adopt the product innovation measure of Atuahene-Gima, Slater, and Olsen (2007).

As indicated in the above description of operationalizations of the network characteristics, prior research has spend time and effort in measuring network characteristics. However, all the above described measurement scales have not been examined simultaneously in relation to innovation performance. Drazin and Van de Ven (1985) argue, that focusing on one or more network characteristics in solitude in relation to innovation performance leads to a form of reductionism (Van de Ven & Drazin, 1985), as 1) real-life organizations and networks consist of multiple characteristics in combination, and 2) the interaction between the variables is ignored which might lead to different research results. This form of reductionism can be overcome by addressing the characteristics of organizations in combination (Miller & Friesen, 1982). Focusing on multiple network characteristics in combination leads to new insights in the external organization of new product development (NPD) and, as we assume, also asks for adaptations in the measurement scales used so far. Therefore we combined the above described individual measurement scales into one measurement instrument, which we pilot tested with practitioners and of which we assessed the reliability. Our

measurement instrument combines the different measurement scales (multiple network characteristics and innovation performance) from literature and adds a measurement for structural network characteristics. The next section described the pilot test of our measurement instrument.

3. Data Gathering in The Medical Devices Sector

This section describes the research methods that are used to develop the measurement instrument. In addition the context of the research, the data gathering process and the sample are described.

3.1. The medical devices sector as research context

To rule out possible confounding effects due to unmeasured industry characteristics we focus on one sector (Langerak & Hultink, 2006). The measurement instrument (i.e. the questionnaire) was tested by practitioners from the medical devices sector[2]. This sector was selected, because collaboration with external partners for new product development becomes increasingly important due to the complexity of the products and the fragmentation of the market. In the sector there are numerous SMEs that need and cooperate with external partners to share resources for the development of new products. In addition the sector is characterized by very strict regulations. Both the quality and safety of products are very important and guaranteed by very strict regulations. These regulations are the cause of the time and cost consuming product development process (Atun, et al., 2002). Clinical trials are a very unique characteristic of the sector and are obliged for every new product (Shaw, 1998). If a product concept is not approved by these clinical trials, the product may not be produced and commercialized (see figure 2).

[2] According to medical device directive 93/42/EEC (European Commission DG Enterprise, 1994), a medical device is:*…any instrument, apparatus, appliance, material, or other article, whether used alone or in combination, including the software necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of*

- *Diagnosis, prevention, monitoring, treatment or alleviation of a disease*
- *Diagnosis, monitoring, treatment or alleviation of or compensation for an injury or handicap*
- *Investigation or modification of the anatomy or of a physiological process*
- *Control of conception*

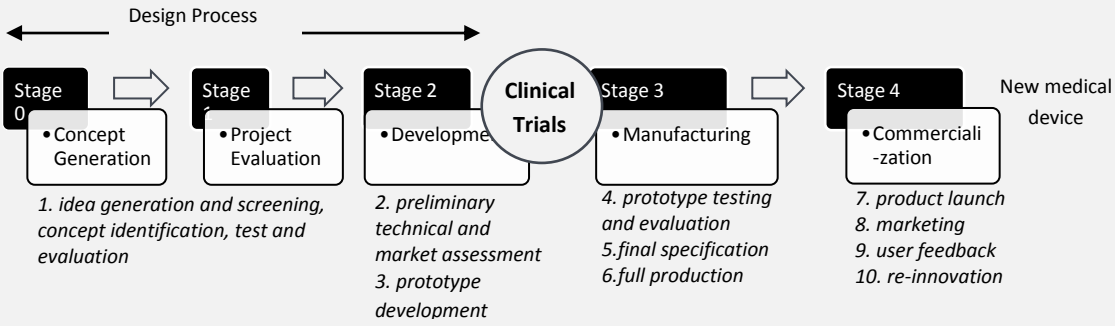
And which does not achieve its principal intended action in or on the human body by

- *Pharmacological*
- *Immunological or*
- *Metabolic means*

But which may be assisted in its function by such means.

If a product is approved, the product can be produced and commercialized. Unfortunately many product concepts are not being approved by these clinical trials, and at this moment there is little knowledge about success or failure of a product before clinical trial (FDA, 2004). Mainly due to these regulations SMEs in the medical devices sector face the problem of a lack of financial resources, and the need for highly qualified and specialized personnel (which is often scarcely available) in their NPD process. The NPD process of a medical device is shown in Figure 2.

Figure 2: The stages in the NPD process for a medical device (based on Griffin (1997) and Shaw (1998))



3.2. Data gathering and sample

The measurement instrument was pilot tested with 15 middle managers in medical device companies that all participated in the Medical Device Summer School organized by Management Forum in July 2009. The companies that participated were all from the European Union. All companies but one were SMEs. Medical devices that were developed in these companies were all complex products in that they are all classified as class II or III medical devices according to the medical devices directive Meddev 2.4/1 Rev.8 of the European Commission (European Commission DG Enterprise, 2001).

To test the validity and reliability of the measurement instrument (i.e. the questionnaire), data was gathered in Dutch medical devices companies. The data gathering took place during the autumn and winter of 2009. 751 Dutch medical devices companies were contacted through a telephone pre-survey to examine their suitability as research subject. To be suitable for the research companies

needed to actively participate in the development of new medical devices and have less than or equal to 250 Full Time Equivalents. In this telephone pre-survey also key respondents were identified. From the 751 Dutch medical devices companies, a total of 105 suitable companies were identified. From these 105 companies, a total of 97 companies indicated that they were willing to cooperate with the research. They received a personalized letter explaining the purpose of the study, along with the developed questionnaire by e-mail. The questionnaire could be filled-in electronically and returned by e-mail. Non-respondents received reminder telephone calls and a second questionnaire. Respondents were new product development managers, R&D Managers, CTO's and CEO's. These efforts yielded 60 usable responses, giving a response rate of 61,9% percent (see Table 2).

Table 2: Response rate of the sample for validity and reliability tests

		Frequency	Percent	**Cumulative Percent**
Valid	filled-in questionnaire	13	13,4	13,4
	filled-in questionnaire + interview	47	48,5	**61,9**
	withdrawn participation	37	38,1	100,0
	Total	97	100,0	

4. Pilot Test of the Measurement Instrument

The measurement instrument was pilot tested with 15 middle managers in medical device companies that all participated in the Medical Device Summer School organized by Management Forum in July 2009. The first draft of the measurement instrument (i.e. the questionnaire) including the constructs as listed in table 2 was administered to 15 respondents. To discuss the questionnaire with the respondents we first asked each respondent to fill in the questionnaire. Right from the beginning respondents were struggling with the introductory questions that asked them to describe the most recently finished new product development project and that asked them to describe the 10 partners with whom they collaborated in this project. These questions even caused some respondents to refuse to fill in the rest of the questionnaire. No problems were encountered in filling in the questions on innovation performance and network characteristics.

After the respondents filled in the questionnaire we discussed the questionnaire with them. We found that the difficulties the respondents encountered at the start of the questionnaire and the unwillingness of some respondents to finalize the questionnaire were caused by two questions. The first question asked respondents

to describe the most recently completed NPD project. This question could not be answered by most respondents since this information was confidential to the organization. The same holds for the second question that caused problems. This question asked respondents to give the company name, size, country of residence and industry of 10 external partners with whom the company collaborated in the most recent NPD project. The names of the external partners were for all companies extremely confidential which (in some cases) even caused unwillingness to continue filling in the questionnaire. Both of these questions were only included in the questionnaire to make it easier for respondents to keep a specific project in mind in filling in the questionnaire. Discussions with the respondents made clear that this was not necessary. If we still wanted to include these questions we should according to the respondents add the option "confidential" as an answering alternative. However, the respondents made clear that if the information was not directly needed for the research it was better to remove the confidential questions. Respondents who did their best to fill in the full questionnaire but who left a number of blanks, were asked why they left some answers open. The problem was that these respondents just did not had all the necessary information to fill in the questionnaire because of their function in the company. Discussion with the entire respondent group resulted in the conclusion that the questionnaire should best be filled in by a sales/marketing person or the head of the NPD department.

Based on the discussions with the respondent group we made some changes to the questionnaire. The option "confidential" was added to the question that asked to describe the most recent NPD project. Furthermore, the question that asked for the company names of the external partners was removed. The questions regarding innovation performance and network characteristics were not altered at all since the respondents indicated that they encountered no problems in filling in these questions. This resulted in a measurement instrument that included 24 items, grouped in 6 network characteristics and innovation performance.

5. Validity and Reliability of the Measurement Instrument

Table 3 on the next page shows the means, standard deviations and correlations of the items that are included in the factor analyses.

Table 3: Means, Standard Deviations and Correlation Coefficients of Variables

				Correlation Coefficient																							
		mean	stdev	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Q8.1_MarketShare_Objective	3,59	1,949	1,000	,686**	,633**	,468**	,442**	,244	,326*	,265*	,212	,058	,045	-,029	,018	-,019	,098	,104	-,082	,119	,137	,239	,139	,100	,078	,192
2	Q8.2_Sales_Objective	3,71	1,820	,686**	1,000	,559**	,617**	,718**	,052	,171	,109	-,013	-,080	-,090	-,020	,011	-,023	,200	,071	,020	,231	,189	,288*	,150	,064	,019	,170
3	Q8.3_ReturnAssets_Objective	3,47	1,924	,633**	,559**	1,000	,801**	,703**	,127	,220	,343**	,122	,028	-,006	,011	-,017	-,022	,274*	,241	,060	,308*	,084	,186	,118	-,058	-,128	,028
4	Q8.4_ReturnInvestment_Objective	3,61	2,000	,468**	,617**	,801**	1,000	,819**	,166	,163	,302*	,079	-,037	-,056	,069	,072	-,017	,326*	,396**	,186	,319*	,076	,275*	,308*	-,058	-,108	,021
5	Q8.5_Profitability_Objective	4,05	1,951	,442**	,718**	,703**	,819**	1,000	,027	,048	,162	,017	-,044	-,200	-,041	,045	-,073	,263*	,300*	,240	,362**	,131	,308*	,227	-,131	-,115	-,051
6	Q19.1_CreatedUniqueCapabilities	4,63	1,929	,244	,052	,127	,166	,027	1,000	,682**	,593**	,519**	,524**	,481**	,472**	,388**	,313*	,123	,368**	,139	,236	,139	,190	,318*	-,078	,148	,068
7	Q19.2_TogetherDevelopedKnowledge	4,75	1,728	,326*	,171	,220	,163	,048	,682**	1,000	,521**	,397**	,498**	,473**	,508**	,416**	,458**	-,003	,282*	,159	,090	,242	,238	,296*	-,146	,082	,026
8	Q19.3_TogetherInvestedInBuildingBusiness	4,24	1,851	,265*	,109	,343**	,302*	,162	,593**	,521**	1,000	,605**	,373**	,560**	,317*	,486**	,508**	,074	,283*	,150	,307*	-,005	,108	,408**	-,166	-,045	,000
9	Q19.4_TogetherInvestedInRelationship	4,27	1,779	,212	-,013	,122	,079	,017	,519**	,397**	,605**	1,000	,478**	,608**	,346**	,240	,398**	,030	,289*	-,001	,245	-,071	,054	,306*	-,264*	-,080	-,135
10	Q19.5_IfEndedKnowledgeWasted	4,07	2,067	,058	-,080	,028	-,037	-,044	,524**	,498**	,373**	,478**	1,000	,587**	,538**	,316*	,510**	,055	,296*	,221	,245	,101	,090	,272*	-,033	,206	,104
11	Q19.6_IfPartnerSwitchInvestmentsWasted	4,32	1,978	,045	-,090	-,006	-,056	-,200	,481**	,473**	,560**	,608**	,587**	1,000	,484**	,444**	,579**	,009	,229	,061	,173	-,015	,099	,399**	-,087	,166	,091
12	Q20.1_ContributeDifferentResources	5,19	1,537	-,029	-,020	,011	,069	-,041	,472**	,508**	,317*	,346**	,538**	,484**	1,000	,503**	,594**	,332*	,330*	,216	,190	,201	,156	,400**	-,177	,037	-,044
13	Q20.2_ComplementaryStrengths	5,47	1,466	,018	,011	-,017	,072	,045	,388**	,416**	,486**	,240	,316*	,444**	,503**	1,000	,626**	,127	,332*	,235	,124	,212	,257*	,452**	-,168	,042	,000
14	Q20.3_SeparateAbilitiesCombined	5,69	1,545	-,019	-,023	-,022	-,017	-,073	,313*	,458**	,508**	,398**	,510**	,579**	,594**	,626**	1,000	,007	,316*	,319*	,242	,141	,135	,295*	-,159	,186	,031
15	Goal_Differences	9,0854	4,66216	,098	,200	,274*	,326*	,263*	,123	-,003	,074	,030	,055	,009	,332*	,127	,007	1,000	,132	,192	,021	,131	,056	,080	-,198	-,072	-,068
16	Q25.1_TreatYouFairly	5,36	1,679	,104	,071	,241	,396**	,300*	,368**	,282*	,283*	,289*	,296*	,229	,330*	,332*	,316*	,132	1,000	,700**	,619**	,428**	,617**	,651**	-,227	,098	-,097
17	Q25.2_ConfidentialityOfInformation	5,54	1,633	-,082	,020	,060	,186	,240	,139	,159	,150	-,001	,221	,061	,216	,235	,319*	,192	,700**	1,000	,560**	,488**	,509**	,412**	-,086	,165	,078
18	Q25.3_PartnersAlwaysEvenHanded	4,73	1,910	,119	,231	,308*	,319*	,362**	,236	,090	,307*	,245	,245	,173	,190	,124	,242	,021	,619**	,560**	1,000	,393**	,452**	,434**	-,091	-,009	,046
19	Q25.4_Inv_ProfitAtYourExpense	4,31	1,869	,137	,189	,084	,076	,131	,139	,242	-,005	-,071	,101	-,015	,201	,212	,141	,131	,428**	,488**	,393**	1,000	,507**	,378**	,007	,153	,181
20	Q25.5_Inv_CannotCompletelyRelyOnPromises	4,68	2,004	,239	,288*	,186	,275*	,308*	,190	,238	,108	,054	,090	,099	,156	,257*	,135	,056	,617**	,509**	,452**	,507**	1,000	,530**	,137	,201	,249
21	Q25.6_Inv_HesitantVagueSpecifications	4,02	1,987	,139	,150	,118	,308*	,227	,318*	,296*	,408**	,306*	,272*	,399**	,400**	,452**	,295*	,080	,651**	,412**	,434**	,378**	,530**	1,000	-,091	-,115	,038
22	Inv_Density	,6176	,40839	,100	,064	-,058	-,058	-,131	-,078	-,146	-,166	-,264*	-,033	-,087	-,177	-,168	-,159	-,198	-,227	-,086	-,091	,007	,137	-,091	1,000	,298*	,860**
23	Network_Size	3,38	2,215	,078	,019	-,128	-,108	-,115	,148	,082	-,045	-,080	,206	,166	,037	,042	,186	-,072	,098	,165	-,009	,153	,201	-,115	,298*	1,000	,488**
24	Ties_Brokered_normalized	,6105	,41084	,192	,170	,028	,021	-,051	,068	,026	,000	-,135	,104	,091	-,044	,000	,031	-,068	-,097	,078	,046	,181	,249	,038	,860**	,488**	1,000

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

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

To examine the underlying structure of the different network characteristics and innovation performance in combination we conducted factor analysis. An exploratory factor analysis was conducted because the measures for structure-related network characteristics were not directly extracted from earlier research, and because none of the measures were earlier combined in one questionnaire. For both the dependent variable (i.e. innovation performance) and the independent variables (i.e. the network characteristics) principal component analyses were conducted.

The factor analysis with the dependent variable resulted in one single factor. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0,713 which is good (see Table 4). Bartlett's test of spericity was X^2 (10) = 261,963 (p<0,001). From factor analysis it was found that innovation performance is represented by one factor that consists of 5 items. The factor has high reliability as the Cronbach's α = and explains 76,56% of the variance (see Table 5).

Table 4: KMO and Bartlett's Test (for the dependent variable)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,713
Bartlett's Test of Sphericity	Approx. Chi-Square	261,963
	Df	10,000
	Sig.	,000

Table 5: Component matrix (for the dependent variable)

	Component
	Innovation Performance
Q8.1_MarketShare_Objective	,797
Q8.2_Sales_Objective	,876
Q8.3_ReturnAssets_Objective	,897
Q8.4_ReturnInvestment_Objective	,894
Q8.5_Profitability_Objective	,906
Eigenvalue	3,828
% Variance explained	76,56
Cronbach's α	0,923
# items	5

Extraction Method: Principal Component Analysis.

For the independent variables (i.e. the network characteristics) principal component analysis (PCA) was conducted on 19 items with orthogonal rotation (varimax). The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0,613 which is moderate. Bartlett's test of spericity was X^2 (231) = 587,863 (p<0,001). The factor analysis resulted in five factors. Two items had negative factor loadings, which indicate that we had to use the inverse of these items. In addition one factor (factor 4) initially received reliability of 0,417 which does not meet the criterion of Hair et al. (2006). According to Hair et al. (2006) a factor must meet the criterion of Cronbach's α > 0,6 in order for a factor to be reliable (Hair, Black, Babin, Anderson, & Tatham, 2006). This factor included the three structural network characteristics. Reliability tests indicated that one of the items ("network size") had to be removed from the analysis. Factor 2 (the factor that includes trust-related items), did receive high reliability, but reliability tests showed that the reliability could even be improved by removing one item from the scale. Based on the criterion of Hair et al. (2006), we removed these two items and repeated the principal component analysis with the remaining 17 items. This second factor analysis is described in detail below.

The principal component analysis (PCA) that was conducted on the 17 items with orthogonal rotation (varimax) resulted in a Kaiser-Meyer-Olkin (KMO) measure of 0,743 which is good (and an improvement considering the first factor analysis). Bartlett's test of sphericity X^2 (136) = 640,758 (p<0,001), indicated that correlations between items were sufficiently large for PCA (see Table 6).

Table 6: KMO and Bartlett's Test (for the independent variables)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,743
Bartlett's Test of Sphericity	Approx. Chi-Square	640,758
	Df	136,000
	Sig.	,000

An initial analysis was run to obtain eigenvalues for each component (factor) in the data. Five components (factors) had eigenvalues over Kaiser's criterion of 1 and in combination explained 76,38 % of the variance. Table 6 shows the factor loadings after rotation and the factor reliabilities.

Items with loadings greater than 0,40 on a factor are considered significant. As can be seen in Table 7 there are three items (Q20.1, Q20.2 and Q20.3) that load on more than one factor. There is some disagreement in literature about what to do when items load on multiple factors. Kline (2000) suggests to drop the items that load on multiple factors, because they are difficult to interpret (Kline, 2000). However Hair et al. (1995) argues that the meaning of an item must be taken into account when assigning labels to a factor (Hair, Anderson, Tatham, & Black, 1995). In line with Hair et al. (1995) Pett et al. (2003) suggest placing the item with the factor it is most closely related to conceptually instead of dropping the item. They argue that reliability tests of the factors will show the internal consistency of a factor and will also indicate whether or not reliability of a factor will increase by dropping an item (Pett, Lackey, & Sullivan, 2003). As Hair et al. (1995) and Pett et al. (2003) we do not drop the items with multiple (significant) factor loadings, rather we assign the item to the factor it is most closely related to and use reliability tests for internal consistency. All five constructs had high reliabilities, and high Eigenvalues.

The items that cluster on the same components (factors) suggest that component 1 represents “Resource Complementarity”. In constrast to the research of Lambe et al (2002) we find that resource complementarity is one-dimensional instead of two-dimensional. Component 2 represents “fairness trust” and component 3 represents “reliability distrust”. Our findings suggest that the network characteristics “trust” is not one-dimensional as suggested by Gulati and Sytch (2008), but multidimensional. Component 4 represents a network characteristic we labeled “Network Position Strength”. This is a new construct which includes two items that are related to the structure of the network. Finally, component 5 represents the inverse measure of goal alignment, we labeled “lack of goal alignment”. These new insights will be discussed more deeply in the discussion section.
All components (factors) had high reliabilities: Resource Complementarity has a Cronbach’s α=0,922, “Fairness” Trust has a Cronbach’s α=0,928, “Reliability” Distrust has a Cronbach’s α=0,749, Network position strength has a Cronbach’s α= 0,906.

Table 7: Rotated component matrix (for the independent variables)

	Component				
	1	2	3	4	5
	Resource Complementarity	"Fairness" Trust	"Reliability" Distrust	Network Position Strenth	Lack of Goal Alignment
Q19.1_CreatedUniqueCapabilities	,807				
Q19.2_TogetherDevelopedKnowledge	,784				
Q19.3_TogetherInvestedInBuildingBusiness	,810				
Q19.4_TogetherInvestedInRelationship	,798				
Q19.5_IfEndedKnowledgeWasted	,735				
Q19.6_IfPartnerSwitchInvestmentsWasted	,836				
Q20.1_ContributeDifferentResources	,683				,505
Q20.2_ComplementaryStrengths	,590	,439			
Q20.3_SeparateAbilitiesCombined	,695	,418			
Goal_Differences					,861
Q25.1_TreatYouFairly		,897			
Q25.2_ConfidentialityOfInformation		,933			
Q25.4_Inv_ProfitAtYourExpense			,797		
Q25.5_Inv_CannotCompletelyRelyOnPromises			,857		
Q25.6_Inv_HesitantVagueSpecifications			,771		
Inv_Density				,934	
Ties_Brokered_normalized				,942	
Eigenvalue	6,39	2,16	1,95	1,47	1,01
% Variance explained	37,61	12,71	11,49	8,63	5,93
Cronbach's α	0,922	0,928	0,749	0,906	X
# items	9	2	3	2	1

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

The final measurement instrument, which is based in the social systems perspective, to measure multiple network characteristics simultaneously in relation to innovation performance includes the five network characteristics "resource complementarity" (*economic capital*), "fairness trust" and "reliability distrust" (*cultural capital*), "lack of goal alignment" (*strategic capital*) and "network position strength" (*social capital*) which together represent the dimensions of the social system as defined by Parsons (1964) and explained in §2.1. The measurement instrument is included in Appendix 2 of this thesis.

6. Discussion

We began by observing that especially in the context of SMEs collaboration for new product development purposes is an important research issue (Groen, 2005; Karlsson & Olsson, 1998; Rogers, 2004; Yli-Renko & Autio, 1998) since numerous alliance fail in practice (Duysters, et al., 1999; Spekman, et al., 1996). However the academic debate does not address how to organize these external networks (Gassmann, 2006). In addition, the vast amount of network characteristics and the heterogeneous content of different network characteristics makes it difficult to thoroughly examine the organization of NPD networks. An adequate measurement instrument to simultaneously measure the relation between the values of several network characteristics and innovation performance is lacking. Therefore, in this research, based on the social systems perspective, we developed such a measurement instrument to measure the relationship between the organization of the external network and the innovation performance.

To develop the measurement instrument, we used the multi-level framework of Groen (2005; 2008) and filled each of the four capitals of which the social system consists with the most relevant and NPD related network characteristics. After an in-depth literature research, pilot test, and reliability analysis of the proposed measurement instrument we found, that an adequate measurement instrument to simultaneously measure multiple network characteristics in relation to innovation performance should include the network characteristics "lack of goal alignment" (*strategic capital)*, "resource complementarity" *(economic capital)*, "fairness trust" and "reliability distrust" (*cultural capital)*, and "network position strength" *(social capital)*.

In addition to developing an adequate measurement instrument, we also found some interesting differences between theoretically well-established constructs and their empirical validity. First, when measured in combination with other network characteristics, the measures for idiosyncratic and complementary resources (Lambe, et al., 2002) were found to be one-dimensional rather than two-dimensional as suggested in literature. It might very well be, that in practice companies consider idiosyncratic resources (i.e. resources that are developed in and tight to a specific relation) as complementary. It implies that the common denominator in both complementary and idiosyncratic resources is that they both complement the resources present in the company.

In addition, we found that the measure of trust as developed primarily by Rempel and Holmes (1986) and later adapted and improved by Zaheer et al. (19980 and Gulati and Sytch (2008) is two-dimensional instead of one-dimensional as suggested by literature. The first factor (dimension) includes the 2 positive trust-items we term “Fairness Trust”. “Fairness” trust covers, what Zaheer et al. (1998) describe as the relational aspect of trust. It can be described as the expectation that a partner will negotiate fairly. The second factor includes the 3 items that are associated with negative trust we term “Reliability Distrust”. This second dimension of trust is strongly related to the reliability aspect of trust that Zaheer et al. (1998) introduce. It can be described as the expectation that a partner can be relied on to fulfill its obligations. As described earlier, Zaheer et al. (1998) distinguish in their definition of trust between 3 aspects of trust “fairness”, “reliability”, and “predictability”. However in both their research and in the research of Gulati and Sytch (2008) the measurement of trust is found to be one-dimensional. Our research shows that trust is not only theoretically multidimensional, but also empirically. This means that, in practice, companies can have both “fairness” trust and “reliability” distrust towards their collaboration partners.

Next to the development of the measurement instrument as a whole, and the new insights about earlier developed measurements described above, the final important result of the research is the fact that we developed and validated a brand new measure and construct: Network Position Strength. “Network position strength” examines the strength of ego’s position in its ego network. From factor analysis we find that “network position strength” includes the items density and structural holes position. Prior research considered these items as individual constructs, but we showed that in fact they belong to a higher level construct and contribute by making this construct measurable. This might explain why earlier research finds contradicting results in the relation between these items in isolation and innovation performance. The matrix form of the measure is based on McEvily and Zaheer (1999). However with our matrix a larger extent of the network is captured and not only one of the items (density or structural holes position), but the higher level construct “network position strength” itself is measured. The Crombach’s α of 0,906 indicates the high reliability of the newly developed measurement.

7. Limitations and Further Research

Our study has some limitations that suggest a number of directions for future research. Our sample consisted of small and medium sized companies from one sector: the medical devices sector. A cross-industry study in multiple sectors for generalizability of the research findings is suggested. We expect to find the same findings in other sectors that are dominated by small and medium sized companies. In addition, since our sample is modest in size, additional data might be gathered in future research for generalizability purposes.

Another suggestion for further research is to examine the underlying structure of the network characteristics in relation to innovation performance. Previous research examined the relation between the individual network characteristics and innovation performance. This research developed the measurement instrument that is needed to be able to examine how innovation performance and multiple network characteristics are related. Further research can be conducted to examine this structure using the developed measurement instrument. This issue is addressed in Chapter 4 of this thesis in which the interaction between network characteristics and innovation performance is examined. It was outside the scope of this chapter to measure the relationship between network characteristics and innovation performance. However, this limitation is addressed in Chapter 5. As a final suggestion, future research might also examine how the different network characteristics interact with each other in relation to innovation performance.

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Chapter 4

SME Network Characteristics and Product Innovativeness for high Innovation Performance: What really counts in the Medical Devices Sector

Based on:

Pullen, A.J.J., Fisscher, O.A.M., Groen, A.J., De Weerd-Nederhof, P.C. (2010). *SME product innovativeness and network characteristics for high innovation performance: What really counts in the medical devices sector.* In Conference Proceedings of the "17th Internal Product Development Management Conference ", 13 – 15 June 2010, Murcia, Spain

Abstract

Many companies desperately seek to improve their innovation performance, as both theory and practice indicated the importance of innovation and new product development (NPD) for company survival. This is especially relevant in the context of small and medium sized companies (SMEs). On the one hand these companies must innovate for company survival, but on the other hand they need to collaborate. This need for collaboration is a consequence of the fact that SMEs have to focus on core competences for efficiency matters. In addition, SMEs often don't have other products to compensate for lack of sales and profits if an innovation project doesn't succeed. This makes selecting the right degree of innovativeness of new products highly important. Even though numerous research has addressed the role of product innovativeness in the context of the internal NPD organization, the role of product innovativeness in the context of external NPD organization (collaboration context) has not been addressed adequately. Therefore, this research examines the relation of network characteristics and product innovativeness on innovation performance in SMEs. In this context we aim to offer consensus in the theoretical and empirical question of whether or not network characteristics and product innovativeness have a direct effect on innovation performance of SMEs.

The medical devices sector is the setting of this research. Survey responses of 60 SMEs from the Dutch medical devices sector were received which resulted in a response rate of 61,9% (which is 57% of the population). Multiple logistic regression results found no significant main effect of product innovativeness on innovation performance. This might be explained by the strict sector regulations that put their constraints on product characteristics. A positive interaction effect of multiple network characteristics on innovation performance was found. This confirms the significant importance and main effect of network configuration (i.e. the combination of network characteristics) on innovation performance for SMEs in the medical devices sector. It indicates that, for SMEs in a highly regulated sector like the medical devices sector, the interaction of network characteristics is of crucial importance for high innovation performance. It is the combination of network characteristics that counts.

1. Introduction

Given the vast amount of literature on innovation performance and the importance of innovation and new product development for company survival it is not surprising that many companies desperately seek to improve their innovation performance.

Especially small and medium sized companies (SMEs[1]) encounter difficulties in their NPD process due to a lack of financial resources and a lack of manpower (Kaufmann & Tödtling, 2002). For efficiency matters these companies need to focus on their core competences (Penrose, 1959). This focus on core competences inherently means that SMEs cannot do everything themselves and therefore they need to cooperate in new product development (Hanna & Walsh, 2002; Karlsson & Olsson, 1998; MacPherson, 1997; Rogers, 2004; Rothwell, 1991). By using interorganizational relationships the "burden" of innovation can be shared between several organizations (Ritter & Gemünden, 2003).

Nieto and Santamaría (2010) find that technological collaboration is a useful mechanism for firms of all sizes to improve innovation performance. It is, however, a critical factor for small firms. They find that collaboration contributes to improving the innovation performance of SMEs (Nieto & Santamaría, 2010). Nooteboom (1994) argues that 1) small firms have potentially more to gain from innovative partnerships than larger firms, and 2) that small and large firms are probably good at different innovativeness types of innovation in accordance with their relative strengths and weaknesses (Nooteboom, 1994). Product innovativeness (i.e. the level of newness of the product to the market and the firm (Booz, et al., 1982; Langerak & Hultink, 2006)) is an important classifier of new products reflecting a choice, either explicit or implicit, of product strategies (X. M. Song & Montoya-Weiss, 1998). It is assumed to be an important moderating or control variable in relationships between organizational characteristics and innovation performance, because the level of resources and the mix of organizational characteristics varies between different levels of product innovativeness (Wheelwright & Clark, 1992). This argument has been proved to be correct for internal organizational characteristics in relation to innovation performance (Danneels & Kleinschmidt, 2001; Kleinschmidt & Cooper, 1991; Langerak & Hultink, 2006; Szymanski, et al., 2007). However, the role of product innovativeness in the relation between network characteristics and innovation performance is not thoroughly examined.

The research question we are trying to answer in this research is to what extent network characteristics, product innovativeness, and innovation performance are related in the context of SMEs. The objective is to examine the underlying structure of network characteristics, innovation performance and product innovativeness to

[1] According to European standards, SMEs are defined as companies that have 250 or fewer fulltime employees ((Commission of the European Communities, 2003b))

be able to improve the innovation performance of SMEs and to offer consensus in the theoretical and empirical question of whether or not product innovativeness and network characteristics have direct effects on innovation performance. By doing so we build on the findings of Danneels and Kleinschmidt (2001) by specifying mediator and moderator variables and developing the theoretical rationale for their inclusion (Danneels & Kleinschmidt, 2001) and we address the suggestion for further research of Szymanski et al (2007) to study the possibility that innovativeness effects on performance may be mediated by selected firm, marketplace, or consumer factors (Szymanski, et al., 2007).
As suggested by Langerak and Hultink (2006) we conducted a single-industry study to rule out possible confounding effects due to unmeasured industry level factors (Langerak & Hultink, 2006). The industry we selected to conduct the research in is the medical devices industry, because collaboration with external partners for new product development becomes increasingly important due to the complexity of the products and the fragmentation of the market. In their study on success factors for medical devices SMEs in the UK Hourd and Williams (2008) found that all their case companies had established collaborations throughout the value chain in order to provide the skills, competencies, and sometimes investment in (among others) the area of new product development (Hourd & Williams, 2008). Furthermore, due to the strict regulations the level of product innovativeness is a relevant issue in new product development (Atun, et al., 2002; Kaplan, et al., 2004). The average development time for medical devices ranges from 1-2 years for incremental devices and 5-7 years for radical devices, dependent on the product type, complexity, and degree of risk to the patient that dictates their regulatory defined conformance and approval route (Hourd & Williams, 2008).

We take the perspective of the SME to analyze its network, and thereby adopt the ego-centered network perspective in our research which consists of a focal actor, termed ego, a set of alters who have ties to ego, and measurements of the ties among these alters (Wasserman & Faust, 1994).

To answer our main research question “to what extent are network characteristics, product innovativeness, and innovation performance related?” we construct a number of theory-based hypotheses in section 1 of this paper. In section 2 the theoretical framework and hypotheses are build. In the methodology section (section 3) we elaborate on the research context of the medical devices sector, the data gathering process and sample, the operationalization of variables and the

research method of multiple logistic regression. Section 4 presents the research results which are discussed in section 5. Section 6 discusses the research limitations and suggestions for future research. Finally, section 7 presents the concluding remarks.

2. Building Hypotheses on Network Characteristics, Product Innovativeness and Innovation Performance

The theoretical framework as described in this section covers literature on the relation between network characteristics and innovation performance (§2.1) and on the relation between product innovativeness and innovation performance (§2.2). In addition, based on literature three research hypotheses are constructed in this section.

2.1. Network Characteristics in relation to Innovation Performance

One of the first lines of theory development which stressed the role of interaction patterns between actors to explain the sustainability of a social system as a reaction against the too atomistic classical economic theories was developed in the social systems perspective by Talcott Parsons(Parsons, 1937, 1964). The assumption of the importance of relationships among interacting units is further developed in structural network theory (Wasserman & Faust, 1994). In strategic management Child followed up in this acknowledging the presence of strategic choice (Child, 1972) which implies that organizations are not always passive recipients of environmental influence but also have the power to reshape the environment. The focus of the network dimension of the social systems perspective is on relationships among social entities, and on the patterns and implications of these relationships In the social systems perspective the interaction between actors in an external environment is what adds value (Aldrich & Pfeffer, 1976; Wasserman & Faust, 1994).

Jacobs and Man (1996) find that each company has to strike a balance between the development of its own core competencies and activities it contracts out to other firms. A firm should pursue a clear strategy of differentiation, in order to be attractive as a partner for other firms (Jacobs & Man, 1996). It is widely acknowledged that organizations are embedded in networks of cooperative and competitive relations with other organizations (Ritter & Gemünden, 2003). The more firms engage in a variety of different inter-organizational collaborations (i.e. the more they interact with external partners), the more likely they are to create

new or improved products that are commercially successful (Faems, et al., 2005). successful commercialization of technology often requires collaboration among horizontal competitors that have different capabilities (Teece, 1989). More recently there is a shift from vertical integration (which decreases) to more informal arrangements that keep industrial networks together (Gadde & Håkansson, 1994). Especially in the field of new product development networking activity becomes more and more popular as cooperation with other organizations increases the innovation performance of organizations (Chang, 2003; Groen, Wakkee, & DeWeerd-Nederhof, 2008a; Håkansson, 1987; Hanna & Walsh, 2002; Pittaway, et al., 2004; Ritter & Gemünden, 2003, 2004; Rothwell, 1991; Salman & Saives, 2005). The innovation benefits of networking Pittaway et al (2004) indentify include: 1) risk sharing, 2) obtaining access to new markets and technologies, 3) speeding products to market, 4) pooling complementary skills, 5) safeguarding property rights when complete or contingent contracts are not possible, and 6) acting as a key vehicle for obtaining access to external knowledge (Pittaway, et al., 2004).

A literature study on the network characteristics that are related to innovation performance and are relevant to SMEs indicated that the network characteristics "resource complementarity", "fairness trust", "network position strength", "reliability distrust", and "(lack of) goal alignment" should be included in network – innovation performance research (see chapter 3). Prior research has frequently considered the effect of these network characteristics on innovation performance. For example, Bourgeois III (1980) concludes that a coalition of strategy makers cannot focus on alternative means without a clearly conceived set of *goals* in mind. Dess (1987) builds on the research of Bourgeois III and finds that consensus on competitive methods has an important relationship to performance (Bourgeois III, 1980; Dess, 1987). Value, in terms of innovation performance, can be created through cooperation and knowledge sharing (Inkpen & Tsang, 2005). When the objectives and strategies of an alliance are clearly stated, a foundation of common understanding and the means to achieve the collaborative purpose is established among the partners.

Further, in relationships between companies the physical and organizational *resources* of the company are exchanged and combined with those of its counterparts in order to achieve the set goals (Haythornthwaite, 1996; Tichy, et al., 1979). Lambe et al (2002) distinguish between resources that are developed and resources that are used in external collaboration: idiosyncratic and complementary resources (Lambe, et al., 2002). Firms are encouraged to innovate by searching out

new resources, or new ways of using existing resources, as the basis for future organizational rents (Galunic & Rodan, 1998; Håkansson, 1989; Oerlemans, et al., 1998).

Another important firm network characteristic is "*trust*". Trust is necessary for people to work together on common projects, even if only to the extent that all parties believe they will be compensated in full and on time (Leana & Van Buren III, 1999). Trust is defined as the belief that the results of somebody's intended action will be appropriate from our point of view (Nahapiet & Ghoshal, 1998) and is often the base for external cooperation. Faems et al (2008) distinguish between competence trust, which is defined as encompassing positive expectations about a partner's ability to perform according to an agreement, and goodwill trust, which is defined as the partner's intention to perform according to an agreement. They find that competence trust is a crucial condition for subsequent transactions and goodwill trust is found to be a condition that determines how contracts are applied (Faems, Janssens, Madhok, & Van Looy, 2008) Trust is an important factor in determining commitment, over and above any strict cost benefit accounting, particularly among small and medium sized producers (Suarez-Villa, 1998).Some element of trust will be required for any transaction in which simultaneous exchange is unavailable to the parties (Ring & Van de Ven, 1992) as in new product development. Based on empirical examination and validity tests of the concept of "trust" (see Chapter 3), we distinguish between "fairness trust" and "reliability distrust". (Fairness) trust considers the expectation that an actor will act and negotiate fairly. (Reliability) distrust considers the expectation that an actor can be relied upon to fulfill obligations.

The structure of the network is based on the combination of contacts an actor has in relation to contacts that other actors have (Groen, et al., 2008a) and the strength of a company's network position determines to a great extent its access to knowledge and other resources that are necessary for successful product development. Even though the extensive body of literature concerning network characteristics repeatedly indicates the importance of the structure of the network in terms of the presence of structural holes (Burt, 1992b), the density of the network (Burt, 1992b; Gilsing & Nooteboom, 2005) and the size of the network (Borgatti, et al., 1998) in relation to innovation performance it lacks a solid measure to measure the structure of the ego network. Therefore, based on literature, a measure for "*network position strength*" was developed. "Network position strength" includes the items "density", and "structural holes" (see chapter 3). Density is the number of actual links in the network as a ratio of the number of

possible links in the network (Borgatti, et al., 1998; Burt, 1992a; Haythornthwaite, 1996; Inkpen & Tsang, 2005; Kerssens-VanDrongelen & Groen, 2004; Liao & Welsch, 2005; Nahapiet & Ghoshal, 1998; Rowley, 1997; Tichy, et al., 1979). As density increases, communication across the network becomes more efficient. Furthermore as interorganizational linkages become more dense, behaviors become more similar across the network, and the likelihood that shared behavioral expectations will be established increases (Rowley, 1997). Irrespective of one's position, high density inhibits the existence and utilization of diversity, and hence of novelty value, while at low levels it does not support absorption sufficiently (Gilsing, et al., 2008). When a company occupies a structural holes position in the network, the company is able to broker connections between other companies in his network (Burt, 1992a; Haythornthwaite, 1996) and by occupying this network position, a company is the missing link between other companies in the network. Based on the above literature our first hypothesis is :

H1: The network characteristics "goal alignment", "resource complementarity", "fairness trust", "reliability distrust" and "network position strength" of the SME all have a direct effect on innovation performance

The focus on one or more network characteristics in solitude in relation to innovation performance leads to a form of reductionism (Van de Ven & Drazin, 1985), as 1) real-life organizations and networks consist of multiple characteristics in combination, and 2) the interaction between the variables is ignored which might lead to different research results. This form of reductionism can be overcome by addressing the characteristics of organizations in combination (Miller & Friesen, 1982). As Van de Ven and Drazin (1985) state: "Only by simultaneously addressing the multiple characteristics of organizations can relationships between performance and these organizational characteristics be fully understood" (Van de Ven & Drazin, 1985). The network characteristics in combination, or in other words the network configuration, must be taken into account when analyzing technological networks. This result is important for managerial day-to-day decision making too (Gemünden, Ritter, & Heydebreck, 1996) and research has not yet clearly demonstrated which configurations most affect innovation in particular contexts (Pittaway, et al., 2004). The configuration approach provides more detail, incorporates interdependencies, and acknowledges the ideas of equifinality and dynamics (Harms, Kraus, & Schwarz, 2009). Our second hypothesis is based on the research of Drazin and Van de Ven and states:

H2: Network configuration (the interaction between network characteristics) is directly related to innovation performance

2.2. Product Innovativeness in relation to Innovation Performance

Product innovativeness is defined as the extent to which a product is new to the target market and to the developing firm (Langerak & Hultink, 2006). Booz, Allen and Hamilton (1982) categorize new products along two dimension (see Figure 1): newness to the developing firm and newness to the market. In their typology they distinguish between six types of new products: new-to-the-world products, new product lines, additions to existing product lines, repositionings, improvements/ revisions to existing products, and cost reductions (Booz, et al., 1982).

Figure 1: Product innovativeness typology (Booz, et al., 1982)

Newness to Company	Low	**Newness to Market**	High
High	New Product Lines		New-to-World Products
	Improvements/ Revisions to existing products	Additions to existing product lines	
Low	Cost Reductions	Repositionings	

The relation between product innovativeness and innovation performance has een studied extensively in prior research, but most often in the context of the internal NPD organization. An important contribution in this field was made by Kleinschmidt and Cooper (1991) and Wheelwright and Clark 1992). Kleinschmidt and Cooper (1991) find that low and highly innovative new products tend to be more successful than moderately innovative new products (Kleinschmidt & Cooper, 1991). Wheelwright and Clark (1992) also distinguish in product innovativeness as they state that the level of resources and the mix of organizational characteristics (the pattern) is different for radical and incremental innovation (Wheelwright & Clark, 1992). Both Kleinschmidt and Cooper (1991) and Wheelwright and Clark (1992) imply a direct relation between product innovativeness and innovation performance.

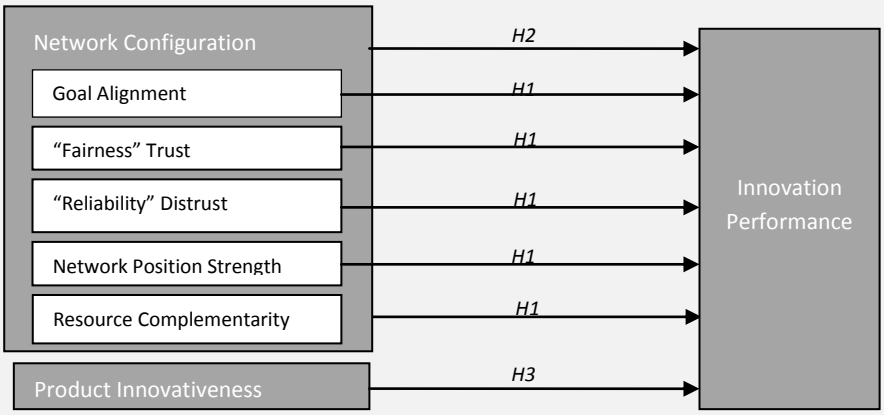
The direct relation between product innovativeness and innovation performance in the internal context has been confirmed by several scholars. More recently, Danneels and Kleinschmidt (2001) conducted an extensive literature review on the role of product innovativeness on firm performance. In empirically testing the proposed dimensions of product innovativeness from the firm's perspective and their relation with new product outcomes they use the typology of Booz, Allen and Hamilton (1982). Product innovativeness is found to have the role of independent variable and is found to have a direct effect on innovation performance (Danneels & Kleinschmidt, 2001). This direct relation has also been found in the research of Szymanski et al (2007). They find a direct relationship between product innovativeness and performance but since this effect explains only 5% of the variance across correlations it suggests that there are other factors that exert a significant main effect on new product performance (Szymanski, et al., 2007).

In the context of the external NPD organization, the direct relation between product innovativeness and innovation performance has not yet been studied as thoroughly. However, since organizational boundaries are blurring and network characteristics are part of the organizational characteristics in general, the same direct relation between product innovativeness and innovation performance in the context of external NPD organization is expected to be found. Therefore, the third hypothesis is:

H3: Product innovativeness is directly related to Innovation performance in the context of external NPD organization

The variables and their hypothesized relations are visualized in the research model on the next page.

Figure 2: Research Model



3. Towards a Research Approach

This methodology section first explains more in-depth why the medical devices sector was selected as research context (§3.1). Second, it describes the sampling and datagathering process (§3.2). §3.3 describes the operationalization of variables we conducted to test the validity of the self-administered questionnaire. The research method of multiple logistic regression is described in §3.4.

3.1. The Medical Devices Sector as Research Context

The context of the research is the Dutch medical devices sector[2]. This sector was selected, because collaboration with external partners for new product development becomes increasingly important due to the complexity of the products and the fragmentation of the market. 80% of the companies in this sector are SMEs and based on theory and in line with earlier research we assume that they need to cooperate with external partners to share resources for the development of new products (Biemans, 1989; Millson & Wilemon, 2000;

[2] According to medical device directive 93/42/EEC , a medical device is:"…any instrument, apparatus, appliance, material, or other article, whether used alone or in combination, including the software necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of a) Diagnosis, prevention, monitoring, treatment or alleviation of a disease, b)Diagnosis, monitoring, treatment or alleviation of or compensation for an injury or handicap, c)Investigation or modification of the anatomy or of a physiological process, or, d)Control of conception. And which does not achieve its principal intended action in or on the human body by a) Pharmacological, b)Immunological or c) Metabolic means, but which may be assisted in its function by such means".

Prabhakar, 2006). In addition the sector is characterized by very strict regulations (Kaplan, et al., 2004). Both the quality and safety of products are very important and guaranteed by very strict regulations that vary in their strictness based on the innovativeness of the newly developed product. These regulations are the cause of the time and cost consuming product development process (Atun, et al., 2002). Unfortunately many product concepts are not being approved by these clinical trials and in doing so do not meet the regulations which means that the product may not be produced and commercialized (Shaw, 1998) (FDA, 2004). Mainly due to these regulations which cause a very time- and cost consuming new product development process (Kaplan, et al., 2004; Nieto & Santamaría, 2010) SMEs in the medical devices sector face the problem of a lack of financial resources and a lack of qualified personnel in their NPD process which makes it necessary for them to cooperate (Kaufmann & Tödtling, 2002; Rogers, 2004). In addition, the intense competition, high rate of growth, continuing technological innovation, and customer sophistication suggest a significantly above average level of new product development activity (Rochford & Rudelius, 1997).

3.2. Data Gathering and Sample

Through a telephone pre-survey among 751 Dutch medical devices companies, companies that actively participate in the development of new medical devices and that have less than or equal to 250 Full Time Equivalents were identified as suitable companies to participate in the research. In this telephone pre-survey also key respondents were identified, the purpose of the research was explained and the potential respondents were asked to participate in the research. A total of 105 suitable companies were identified. A total of 97 potential respondents indicated that they were willing to cooperate with the research. They received a personalized letter explaining the purpose of the study, along with a questionnaire by e-mail. The questionnaire could be filled-in electronically and returned by e-mail. Non-respondents received reminder telephone calls and a second questionnaire. Respondents were new product development managers, R&D Managers, CTO's and CEO's. These efforts yielded 60 usable responses, giving a response rate of 61,9% percent which is 57,1% percent of the population of Dutch small-and medium sized medical devices companies with an NPD department (see Tables 1 and 2).

Table 1: Response rate of the sample

		Frequency	Percent	Cumulative Percent
Valid	filled-in questionnaire	13	13,4	13,4
	filled-in questionnaire + interview	47	48,5	**61,9**
	withdrawn participation	37	38,1	100,0
	Total	97	100,0	

Table 2: Response rate of the population

		Frequency	Percent	Cumulative Percent
Valid	filled-in questionnaire	13	12,4	12,4
	filled-in questionnaire + interview	47	44,8	**57,1**
	withdrawn participation	37	35,2	92,4
	not interested in participation	8	7,6	100,0
	Total	105	100,0	

3.3. Operationalization of Innovation Performance, Network Characteristics and Product Innovativeness

This section describes the operationalization of the variables "innovation performance", "product innovativeness", "goal alignment", "trust", "distrust", and "resource complementarity" and "network position strength". In addition, the validity of the questionnaire and the measurements is demonstrated through factor analysis.

Innovation Performance

The measure of Atuahene-Gima, Slater and Olsen (2007) to measure innovation performance was used. Innovation performance was measured through 5 items on a 7-point Likert scale. After factor analysis (see Table 3) the factor scores of innovation performance were divided in three categories: low (score <= (mean-stdev)), medium ((mean-stdev) < score < (mean +stdev)) and high (score =>

(mean+stdev)). This was done, because using the factor scores lead to non-significance of the goodness of fit of the model.

Table 3: Component matrix (for the dependent variable)

	Component
	Innovation Performance
Q8.1_MarketShare_Objective	,797
Q8.2_Sales_Objective	,876
Q8.3_ReturnAssets_Objective	,897
Q8.4_ReturnInvestment_Objective	,894
Q8.5_Profitability_Objective	,906
Eigenvalue	3,828
% Variance explained	76,56
Cronbach's α	0,923
# items	5

Extraction Method: Principal Component Analysis.

Network Characteristics

From literature we extracted 5 network characteristics (a total of 17 items) that are suggested to have a relation to the companies' innovation performance (see chapter 3 and Appendix 2 of this thesis). These network characteristics have been operationalized based on theory. The validity and reliability of the constructs that include the five network characteristics has been tested through factor analysis (see Table 4). Factor analysis on the network characteristics indicated that the items in the questionnaire together build five constructs that together explain 76,38% of the variance (see chapter 3). Items with loadings greater than 0,40 on a factor are considered significant. As can be seen in Table 3 there are three items (Q20.1, Q20.2 and Q20.3) that load on more than one factor. There is some disagreement in literature about what to do when items load on multiple factors. Kline (2000) suggests to drop the items that load on multiple factors, because they are difficult to interpret (Kline, 2000). However Hair et al. (1995) argues that the meaning of an item must be taken into account when assigning labels to a factor (Hair, et al., 1995). In line with Hair et al. (1995) Pett et al. (2003) suggest placing the item with the factor it is most closely related to conceptually instead of dropping the item. They argue that reliability tests of the factors will show the

internal consistency of a factor and will also indicate whether or not reliability of a factor will increase by dropping an item (Pett, et al., 2003). As Hair et al. (1995) and Pett et al. (2003) we do not drop the items with multiple (significant) factor loadings, rather we assign the item to the factor it is most closely related to and use reliability test for internal consistency. All five constructs had high reliabilities, and high Eigenvalues.

Table 4: Rotated component matrix (for the independent variables)

	Component				
	1	2	3	4	5
	Resource Complementarity	"Fairness" Trust	"Reliability" Distrust	Network Position Strenth	Lack of Goal Alignment
Q19.1_CreatedUniqueCapabilities	,807				
Q19.2_TogetherDevelopedKnowledge	,784				
Q19.3_TogetherInvestedInBuildingBusiness	,810				
Q19.4_TogetherInvestedInRelationship	,798				
Q19.5_IfEndedKnowledgeWasted	,735				
Q19.6_IfPartnerSwitchInvestmentsWasted	,836				
Q20.1_ContributeDifferentResources	,683				,505
Q20.2_ComplementaryStrengths	,590	,439			
Q20.3_SeparateAbilitiesCombined	,695	,418			
Goal_Differences					,861
Q25.1_TreatYouFairly		,897			
Q25.2_ConfidentialityOfInformation		,933			
Q25.4_Inv_ProfitAtYourExpense			,797		
Q25.5_Inv_CannotCompletelyRelyOnPromises			,857		
Q25.6_Inv_HesitantVagueSpecifications			,771		
Inv_Density				,934	
Ties_Brokered_normalized				,942	
Eigenvalue	6,39	2,16	1,95	1,47	1,01
% Variance explained	37,61	12,71	11,49	8,63	5,93
Cronbach's α	0,922	0,928	0,749	0,906	X
# items	9	2	3	2	1

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

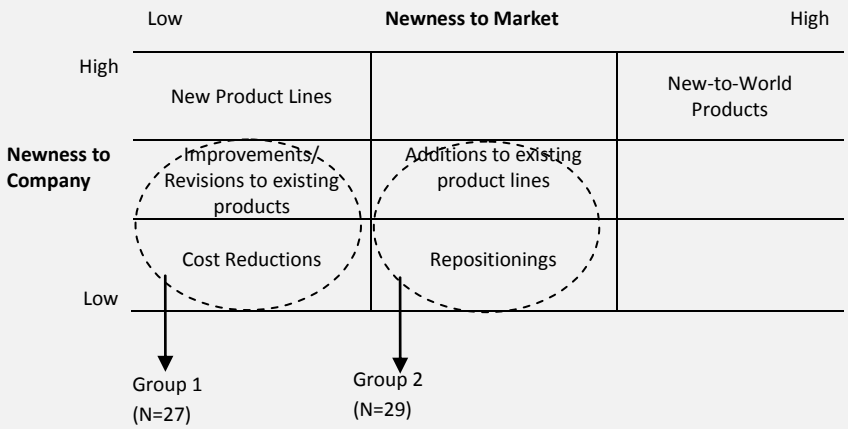
a. Rotation converged in 5 iterations.

Product Innovativeness

To measure product innovativeness we use the Booz, Allen and Hamilton (1982) typology. Respondents are asked to mark the product innovativeness category that best describes their newly developed product (see Appendix 2, question 7). In our sample from medical devices SMEs only 3 companies marked their products as "new to the world" or "new product lines". All the other companies scored in the lower four quadrants of the Booz, Allen and Hamilton typology. To ensure that the number of cases per product innovativeness type is sufficient for data analyses, the 3 cases in "new to the world" and "new product lines" are deleted from the sample.

The companies in the sample (when "new to the world" and "new product lines" are eliminated) are categorized in two groups (see figure 3). Group 1 includes the companies who indicated that their new developed product could be labeled as "improvement/ revision to existing products" or as "cost reductions". The products in this group have a low newness to the market in terms of Booz, Allen, and Hamilton (1982). Group 2 includes the companies who indicated that their newly developed product could be labeled as "addition to existing product lines" or as "repositioning". The products in this group have moderate newness to market. Group 2 is more market oriented that group 1. These 2 groups of product innovativeness are used for data analysis.

Figure 3: Product innovativeness types in the sample



3.4. Multiple Logistic Regression as Research Method

An interaction approach based on Drazin and Van de Ven (1985) was used to test the hypotheses. The focus of this interaction approach is on explaining variations in organizational performance from the interaction of organizational structure and context (Drazin & Van de Ven, 1985). The most common approach to the interaction test of fit consists of a series of two-way analyses of variance or regressions (Drazin & Van de Ven, 1985).

Multiple logistic regression was conducted to examine the effect of "product innovativeness" and the effect of the network characteristics "resource complementarity", "lack of goal alignment", "fairness trust", "reliability distrust", and "network position strength" on the categorical variable innovation performance. Not only the main effects of these variables were examined, also the interaction effect of the network characteristics in combination on the innovation performance was examined. To prevent multicollinearity we used the factor scores of the different network characteristics as independent variables in the multiple logistic regression.

4. Results

After the main effects were entered in model 0 of the multiple logistic regression. All 2-way, 3-way, 4-way, and 5-way interaction terms were entered in the successive models. Table 5 shows the amount of unexplained variability in the data in the original model and the final model (the result of the analysis). This difference ($\chi 2$= 45,447) is significant (p<0,000) which indicates that the final model explains a significant amount of the original variability. In short, our model is better than no model or the original model.

Table 5: Model fitting information

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	96,751			
Final	51,304	45,447	10	,000

The final model is not only significantly better than the original model, the final model is also a good fit of the data as shown in Table 6. The statistics are not significant which indicates that the predicted values are not significantly different from the observed values.

Table 6: Goodness of fit

	Chi-Square	df	Sig.
Pearson	86,834	100	,823
Deviance	51,304	100	1,000

The specific effects of the predictors can be found in Table 7 which shows the individual parameter estimates. The first part of the model in Table 7 compares the category “low innovation performance” to the category “medium innovation performance”.
In Table 7 “B” represents the change in the logit of the outcome variable associated with a one-unit change in the predictor variable. The logit is the natural logarithm of the odds of Y occurring. More crucial to the interpretation of logistic regression is the value of the odds ratio “Exp(B)”. “Exp(B)” is the indicator of the change in odds resulting from a unit change in the predictor. It is similar to the b coefficient, but it doesn’t require the logarithmic transformation. Therefore, we use the “Exp(b)” to interpret the results from Table 7.

The first part of Table 7 shows the effects of network characteristics and product innovativeness on the increase from low to medium innovation performance. We included all two-way, three-way, four-way an five-way interaction effects in the model. However only interaction effects that led to significance of the regression model, are included in the final regression model. As Table 7 shows, there is no significant direct effect between product innovativeness and innovation performance. In addition also no direct significant effect was found between individual network characteristics and innovation performance, since the effects of individual network characteristics were eliminated from the model (by the statistics package) as they led to insignificance of the model. However the interaction between multiple network characteristics has a strong direct significant effect on increasing innovation performance.

The interaction between "reliability" distrust and network position strength significantly (p<0,048) predicted whether medium or low innovation performance was achieved, b = 1,875, Wald $\chi 2(1)=3,900$, p<0,048. Which means that as the interaction term Distrust* NetworkPositionStrength changes by one unit, the change in the odds (see column "Exp(B)" in Table 7) of achieving medium innovation performance compared to achieving low innovation performance is 6,523. In other words, the odds, when distrust and network position strength increase, of achieving medium innovation performance compared to low innovation performance is 1/6,523 = 0,15 times more than when the values of distrust and network position strength do not increase.

The interaction between resource complementarity and network position strength significantly predicts whether medium or low innovation performance is achieved, b = -3,782 Wald $\chi 2(1)=9,090$, p<0,003. This means that when both these network characteristics change by one unit, the change in the odds (see column "Exp(B)" in Table 7) of achieving medium innovation performance compared to achieving low innovation performance is 0,023. In other words the odds, when resource complementarity and network position strength both increase, of achieving medium innovation performance compared to low innovation performance is 1/0,023 = 43,48 times more than when the values of resource complementarity and network position strength don't increase.

The second part of Table 7 shows the effects of network characteristics and product innovativeness on the increase from low to high innovation performance. As Table 7 shows, again we found no direct significant effect of neither product innovativeness nor individual network characteristics on innovation performance. However, multiple interaction effects were found to have a direct effect on achieving high innovation performance.

Table 7: Parameter estimates

FACInnovationPerformance3cat[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
medium	Intercept	2,127	,723	8,657	1	,003			
	[Innovativeness2cat=1]	-,253	,997	,065	1	,799	,776	,110	5,473
	[Innovativeness2cat=2]	0[b]	.	.	0	.	.	.	.
	FACNetworkPositionStrength * FACLackOfGoalAlignment	-,297	,810	,134	1	,714	,743	,152	3,639
	FACDistrust * FACNetworkPositionStrength	1,875	,950	3,900	1	,048	6,523	1,014	41,955
	FACResourceComplementarity * FACNetworkPositionStrength	-3,782	1,254	9,090	1	,003	,023	,002	,266
	FACTrust * FACNetworkPositionStrength	-1,672	1,060	2,487	1	,115	,188	,024	1,501
high	Intercept	-4,396	2,980	2,176	1	,140			
	[Innovativeness2cat=1]	5,146	2,953	3,038	1	,081	171,783	,527	56016,173
	[Innovativeness2cat=2]	0[b]	.	.	0	.	.	.	.
	FACNetworkPositionStrength * FACLackOfGoalAlignment	-3,458	1,429	5,858	1	,016	,031	,002	,518
	FACDistrust * FACNetworkPositionStrength	1,635	1,082	2,280	1	,131	5,128	,614	42,788
	FACResourceComplementarity * FACNetworkPositionStrength	-3,126	1,516	4,249	1	,039	,044	,002	,858
	FACTrust * FACNetworkPositionStrength	-4,135	1,808	5,234	1	,022	,016	,000	,553

a. The reference category is: low.

b. This parameter is set to zero because it is redundant.

The interaction between “lack of goal alignment” and “network position strength” significantly predicts whether high or low innovation performance is achieved, b = -3,458, $\chi 2(1) = 5,858$, p< 0,016. Which means that when these network characteristics change by one unit, the odds of achieving high innovation performance compared to achieving low innovation performance is 0,031 (see column “Exp(B)” in Table 7). So the odds, when the interaction term “lack of goal alignment”*”network position strength” increases, of achieving high innovation

performance compared to low innovation performance is 1/0,031 = 32,26 times more than when the interaction term doesn't increase.
Furthermore, the interaction between "resource complementarity" and "network position strength" significantly predicts whether high or low innovation performance is achieved (b = -3,126, $\chi 2(1) = 4,249$, $p < 0,039$) as it also significantly predicted whether medium or low innovation performance is achieved. The odds, when the interaction term "resource complementarity"*"network position strength" increases, of achieving high innovation performance compared to low innovation performance is 1/0,044 = 22,72 times more than when the interaction term doesn't increase
Finally, the interaction between "trust" and "network position strength" significantly predicts whether high or low innovation performance is achieved, b = -4,135 Wald $\chi 2(1)= 1,808$, $p<0,022$. When the interaction term changes by one unit, the change of the odds (see column "Exp(B)" in Table 7) of achieving high innovation performance compared to achieving low innovation performance is 0,631. This indicates that the odds of achieving high innovation performance instead of low innovation performance increases by 1/0,016 = 62,50 times when the values of the interaction term "trust"*"network position strength" increase by one unit.

Figure 4 and 5 summarize the results and show the significant direct effect that were found.

Figure 4: Support of hypotheses when shifting from low to medium innovation performance

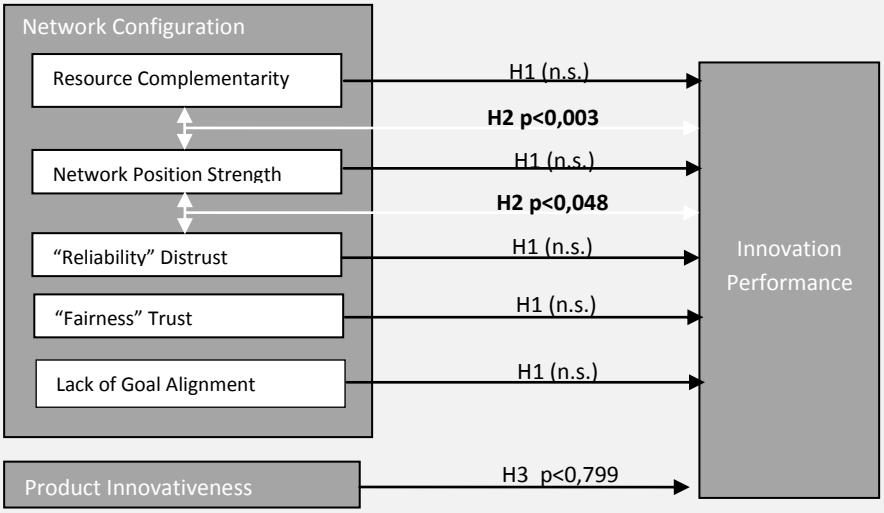
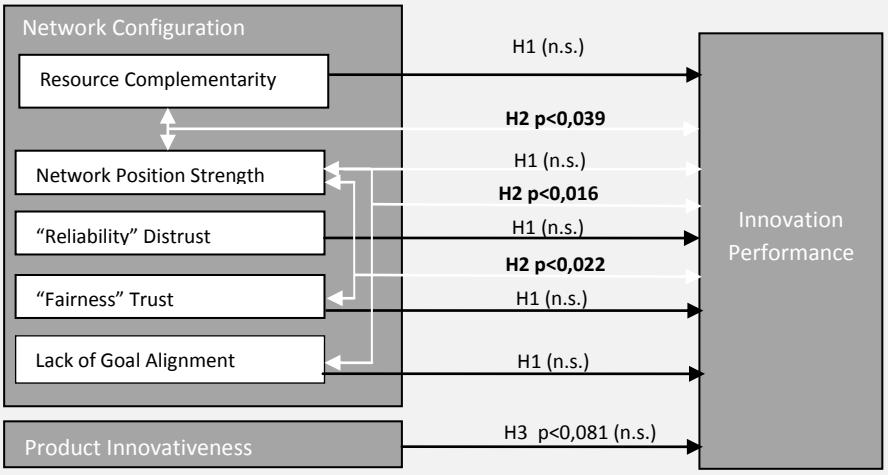


Figure 5: Support of hypotheses when shifting from low to high innovation performance



As can be seen from the models there is no direct effect of product innovativeness on innovation performance when shifting either from low to medium or from low to high innovation performance. this means that hypothesis 3 is rejected.
Hypotheses 1 and 2 considered the relation between network characteristics and innovation performance. Hypothesis 1 stated that the network characteristics "resource complementarity", "fairness trust", "network position strength", "reliability distrust" and "lack of goal alignment" all have a direct effect on innovation performance. This hypothesis is not supported, as no direct significant effects were found. Inclusion of these direct effect tests in the model, even led to insignificance of the regression model.
The most important results we found are related to hypothesis 2. Hypothesis 2 stated that the interaction between the network characteristics (the network configuration) has a direct effect on innovation performance. A number of significant 2-way interaction effects between network characteristics on innovation performance were found to be significantly effective for increasing innovation performance. This supports hypothesis 2 and indicates that the interaction between network characteristics is directly related to innovation performance.

5. Discussion

We began by observing that there is vast amount of research exploring the factors that influence or might influence the innovation performance among which product innovativeness (Booz, et al., 1982; Danneels & Kleinschmidt, 2001; Kleinschmidt & Cooper, 1991; Langerak & Hultink, 2006; Rothwell, 1991; Salomo, Talke, & Strecker, 2008; Szymanski, et al., 2007) internal company characteristics (Cooper, et al., 2004a, 2004b, 2004c; Ernst, 2002; Griffin, 1997; Parry, Song, DeWeerd-Nederhof, & Visscher, 2009) and network characteristics (Ahuja, 2000; Becker & Dietz, 2004; Branzei & Thornhill, 2006; Capaldo, 2007; Chang, 2003; Deeds & Hill, 1996; Faems, et al., 2005; Hillebrand & Biemans, 2004; Powell, et al., 1996; Ritter & Gemünden, 2003; Teece, 1989). In the context of SMEs especially network characteristics and product innovativeness are of importance in relation to innovation performance as SMEs are bounded by a lack of financial resources, manpower and substitutes for lack of sales (Hanna & Walsh, 2002; Kaufmann & Tödtling, 2002) in the new product development process. We examined the relation of network characteristic and product innovativeness on innovation performance.
One of the most telling result of our study concerns the fact that the network characteristics in interaction, the network configuration, have a direct effect on

innovation performance. The significant interaction effect of the network configuration on innovation performance fully supports hypothesis 2 and indicates the importance of viewing a company's external network characteristics in combination. Our findings show that, for SMEs in a highly regulated sector like the medical devices sector, the interaction of network characteristics is of crucial importance for high innovation performance. These findings support the argument of Van de Ven and Drazin (1985) that combinations of organizational (in this case network) characteristics need to be considered in order to fully understand its relation to performance. This aligns with configuration theory that posits that for each set of network characteristics, there exists an ideal set of organizational characteristics that yields superior performance (Van de Ven & Drazin, 1985).

In addition, contrary to expectations, we found no direct relationship between product innovativeness and innovation performance. A large body of research examined the relation between product innovativeness and innovation performance in the context of the internal NPD organization and find a direct relationship. We expected that also in the context of the external NPD organization this relationship would hold. However, our results prove otherwise. In the context of the external NPD organization we found no direct relationship between product innovativeness and innovation performance, which provides new insights and adds to a better understanding of the relation of network characteristics and product innovativeness on innovation performance. Our findings are in line with the findings of Brown et al. (2008) who also find no statistically significant correlation between perceived success of the product and product innovativeness (A. Brown, et al., 2008). One possible explanation for this lack of support is that our sample consisted of small and medium sized companies that were all active in the highly regulated medical devices sector (Atun, et al., 2002; Kaplan, et al., 2004). Since all companies in this sector must meet these strict product regulations we expect that companies rather focus on "safe" low and moderately innovative products rather than on "risky" highly innovative products. Another explanation might be that as Kleinschmidt and Cooper (1991), Wheelwright and Clark (1992), Langerak and Hultink (2006) and Gemünden et al (2007) confirmed in their research product innovativeness serves as a control variable.

6. Limitations and Further Research

Our study has some limitations that suggest a number of directions for future research. We showed that the interaction between network characteristics (the network configuration) has a direct effect on innovation performance. As we

focused on examining the relation of network characteristics and product innovativeness on innovation performance it was out of the scope of this research to examine the interaction between network characteristics within the configuration. Further research might focus on this interaction within network configurations. However, and additional interesting question for further research is "Which specific pattern of network characteristics leads to high innovation performance?". We agree with Pittaway et al (2004) when they state that research has not yet clearly demonstrated which configurations most affect innovation in particular contexts and that the most significant are for future research is in the area of network dynamics and network configurations (Pittaway, et al., 2004). Even though the interaction approach provides accurate and useful details about individual structure and process variables (Van de Ven & Drazin, 1985) it also has certain limitations in studying the relationship between structure and context. 1) The interaction approach obtains mixed results. Correlational studies have shown that the relationships between structure and context are stronger for higher performing organizations than for lower performing organizations, but often the differences are small and not significant as was the case for our first hypothesis. 2) Multiplicative interaction terms in regression analysis limit the form of the interaction only to acceleration and deceleration effects, 3) the focus on how single contextual factors affect single structural characteristics and how these pairs of context and structure factors interact to explain performance leads to reductionism (Van de Ven & Drazin, 1985). Further research could be advanced by employing methodological approaches that allow addressing simultaneously the many contingencies, structural alternatives, and performance criteria that must be considered holistically to understand organization design (Van de Ven & Drazin, 1985) which may result in a clear demonstration of which configuration most affects innovation performance in a particular context. This is the main focus of the next chapter.

In addition, since our sample consisted mostly of companies that developed low and moderately new products, we were only able to detect the effects of these levels of product innovativeness and network characteristics in these companies. Future research may consider gathering additional data in order to have a more evenly spread of products with low, moderate and high innovativeness to examine the effect of product innovativeness and network characteristics on innovation performance. To examine the role of product innovativeness as a control variable for SMEs in a highly regulated sector more data on products with high product

innovativeness is needed. Additional data could be gathered in the drug sector or in the sector that focuses on the hybrid drug-device combinations.

A final suggestion for future research is a cross-industry study for generalizability of the research findings. As the context of our research was the highly regulated medical devices sector, we expect to find the same findings in other highly regulated sectors. A cross-industry study in multiple highly regulated sectors might shed additional light on the role of product innovativeness in relation to innovation performance when new product characteristics are bounded by regulations. Other highly regulated sectors which might be included in such a study are the biotechnology (Senker, 1991) and commercial space sector (Carayannis & Samanta Roy, 2000).

7. Concluding Remarks

We argued that both product innovativeness and SME network characteristics have a direct effect on the innovation performance of SMEs. Using the context of SMEs in the Dutch medical devices sector, we show that the interaction between multiple network characteristics of the SME (the network configuration) has a direct effect on innovation performance. In addition we find no evidence for a direct effect of low and moderate product innovativeness on innovation performance in this research context.

The research findings indicate that external collaboration is not merely an act of filling the resource gaps in the organization as a reaction on environmental dynamics, rather the network configuration is a strategic instrument of the SME, that has a direct effect on innovation performance which can lead to substantive competitive advantage in the area of new product development

Managers of SMEs in the medical devices sector that aim to achieve high innovation performance, should focus on the organization of the network (i.e. network configuration) that is specifically used for new product development, instead of focusing on the level of product innovativeness of new products. In conclusion, what really counts for achieving high innovation performance for SMEs in the medical devices sector is the way in which network characteristics are combined into a network configuration.

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Chapter 5

Organizing NPD Networks for high Innovation Performance: The case of Dutch Medical Devices SMEs

Based on:

Pullen, A.J.J., Fisscher, O.A.M., Groen, A.J., De Weerd-Nederhof, P.C. (2010). *Organizing NPD networks for high innovation performance: The case of Dutch medical devices SMEs* .In Conference Proceedings of the "High Tech Small Firm Conference (HTSF) 2010", 27-28 May, Enschede, The Netherlands

Abstract

Cooperation with other organizations increases the innovation performance of organizations. Especially for SMEs, as they are bounded by a lack of financial resources, manpower and substitutes for lack of sales. This research examines which combination of network characteristics (i.e. the network configuration) is related to high innovation performance and we thereby address the issue raised by Pittaway et al. (2004) who state that research has not yet clearly demonstrated which configurations most affect innovation in particular contexts.

In the medical devices sector, collaboration with external partners for new product development becomes increasingly important due to the complexity of the products and the fragmentation of the market. About 80% of companies in this sector are SMEs. In addition the sector is characterized by very strict regulations. These regulations are an important cause of the time and cost consuming product development process. These characteristics make the medical devices sector a suitable context for this research.

Both quantitative survey data (N=60, response rate 61,9%) and qualitative interview data (N=50) were gathered in triangulation. Using the triangulation approach enabled us to not only conduct quantitative data analysis, but also to gain additional insights in the organization of networks.

Since we aim to demonstrate which network configuration (i.e. combination of network characteristics) leads to high innovation performance, we needed a research approach in which multiple network characteristics can be simultaneously addressed. One way to do this is by using the systems approach as we did. In the systems approach an empirical-based ideal profile (i.e. network configuration) is constructed. For each company, the (Euclidean) distance between its network configuration and the ideal profile is calculated. Correlation statistics between Innovation Performance and the Euclidean Distance showed that the more a companies' network configuration differed from the successful network configuration, the lower the Innovation Performance of that company.

The results indicate that the network configuration that is related to high innovation performance combines high levels of resource complementarity, "fairness" trust and "reliability" distrust, and low levels of goal alignment and a low network position strength. This is contrary to what we expected from literature. Instead of the social way of networking, both our quantitative and qualitative findings show that a "businesslike" approach which is focused and consistent is related to high innovation performance.

1. Introduction

For successful New Product Development (NPD) SMEs[1] see themselves confronted with the need to collaborate (Karlsson & Olsson, 1998; Rogers, 2004). This need is caused by the fact that on the one hand, SMEs need to innovate to compete (Hanna & Walsh, 2002; O'Regan, et al., 2006) but on the other hand they also need to focus on their core competences for efficiency matters. This focus on core competences (Penrose, 1959) inherently means that SMEs cannot do everything themselves. The question that remains unanswered is "how to organize, from the perspective of the SME, the interaction pattern between the SME and its external partners in the network, in order to achieve high innovation performance?"

What we know from previous research is that collaboration positively influences the innovation performance. For example Branzei and Thronhill (2006) conclude that diverse networks increase the positive payoffs of internal innovation capabilities (Branzei & Thornhill, 2006). Furthermore, Teece (1989) states that the successful commercialization of technology often requires collaboration among horizontal competitors that have different capabilities (Teece, 1989). Especially in the field of new product development networking activity becomes more and more popular as cooperation with other organizations increases the innovation performance of organizations (Chang, 2003; Hanna & Walsh, 2002; Ritter & Gemünden, 2003, 2004; Rothwell, 1991; Salman & Saives, 2005). From alliance literature we know, that numerous external alliances fail in practice (Duysters, et al., 1999; Faems, et al., 2005; Sadowski & Duysters, 2008; Spekman, et al., 1996), mainly due to negative prospects and negative perceptions (Sadowski & Duysters, 2008), differences in cognition, conflicting interests, differences in timing of contributions (Mahnke & Overby, 2008), opportunistic hazards, and managerial complexity and uncertainty (Park & Ungson, 2001). Since alliances are a type of collaboration, we assume that the high alliance failure rate also has its effect on the failure rates of collaboration. However, up to this moment, research has not yet clearly demonstrated which combination of network variables (i.e. the network configuration) most affect innovation in particular contexts (Pittaway, et al., 2004). Therefore, the objective of this research is to examine which combination of network characteristics (the network configuration) leads to high innovation performance.

[1] According to European standards, SMEs are defined as companies that have 250 or fewer fulltime employees ((Commission of the European Communities, 2003b))

This research aligns with, and builds further on, configuration theory as it addresses multiple network characteristics simultaneously (i.e. network configurations) in relation to innovation performance instead of focusing on individual network characteristics as past research did. A configuration is a multidimensional constellation of the strategic and organizational characteristics of a business (Meyer, Tsui, & Hinings, 1993b). Mintzberg (1979) posited that in order to be maximally effective, organizations must have design configurations that are internally consistent and fit multiple contextual dimensions (Mintzberg, 1979). Configuration theory posits that for each set of network characteristics, there exists an ideal set of organizational characteristics that yields superior performance (Van de Ven & Drazin, 1985). The conceptualization of fit that is most consistent with the logical arguments of configuration theories is the systems approach to fit (Doty, et al., 1993) which we use in this research. The systems approach defines fit in terms of consistency across multiple dimensions of organizational design and context (Drazin & Van de Ven, 1985). Fit is high to the extent that an organization is similar to an ideal profile along multiple dimensions (Van de Ven & Drazin, 1985). Interpreting the organizational forms as ideal profiles rather than as categories of organizations means that each real organization in a sample need not be classified into one of the nominal groups identified in the theory. Instead, the degree of deviation between each real organization and the ideal profile is measured (Doty, et al., 1993). Ideal profiles are defined as combinations of network characteristics that fit together (i.e. are internally consistent) and are related to high performance. By enabling multiple variables to be assessed simultaneously, this approach also enables researchers to more closely represent the complex constructs and multiple contingencies faced by managers in the "real world" (Gresov, 1989).
Focusing on multiple network configurations and applying the systems approach leads to new insights in the external organization of new product development (NPD). In addition, the research contributes to practice by offering SMEs a benchmark in organizing their NPD network. This not only improves the innovation performance of the SME, but it also improves the innovativeness of the medical devices sector as a whole.

In examining fit-performance relationships, the configuration theory literature advocates the use of single industry studies to control for industry effects and isolate more effectively the relationships of interest (Vorhies & Morgan, 2003). The sector we selected for this research is the Dutch medical devices sector. This sector was selected for data gathering because collaboration with external partners for

new product development means becomes increasingly important due to the complexity of the products and the fragmentation of the market (Atun, et al., 2002; MacPherson, 2002; Prabhakar, 2006). In addition the sector is characterized by very strict regulations. These regulations are the cause of the time and cost consuming product development process (Atun, et al., 2002; Kaplan, et al., 2004; MacPherson, 2002).

To answer our research question "how to organize the interaction between the SME and its external partners, in order to achieve high innovation performance?" we constructed hypotheses based on theory in section 2 of this paper. Section 3 describes the methodology which includes the research context (§3.1) and sample (§3.2), the research method of the social systems approach (§3.3) and the operationalization of variables (§3.4). The results of the quantitative data analysis (§4.1) which are complemented by a qualitative data analysis (§4.2) are described in section 4. In addition, section 5 discusses the research results. Section 6 presents the research limitations and suggestions for further research. Finally, the concluding remarks can be found in section 7.

2. Towards a Theoretical Framework and Hypothesis on Network Characteristics in relation to Innovation Performance

An in-depth literature review on network characteristics that are related to innovation performance and new product development was conducted (see Chapter 3). The literature research was inspired by in the social systems perspective (Parsons, 1964) and used the multidimensional framework of Groen et al. (2005). In this framework it is assumed, that each of the four dimensions of the social system produces its own type of capital: social capital, strategic capital, economic capital and cultural capital. Sufficient capital is needed on each of the four dimensions to create sustainable enterprises (Groen, 2005).

Next to theoretically selecting and operationalizing network characteristics, we empirically tested the validity of the constructs through factor analysis. The network characteristics that were found to be related to innovation performance are "Resource Complementarity" (relates to *economic capital)*, "Trust" and "Distrust" (relates to *cultural capital)*, "Network Position Strength" (relates to *social capital)*, and "Goal Alignment" (relates to *strategic capital)*. This section defines these network characteristics and their relation to innovation performance. Based on literature the research hypothesis is formulated.

2.1. Innovation Performance

In this research the definition of innovation proposed by Afuah (1998) is used, which states that in the field of high technology innovation is invention + commercialization (Afuah, 1998). Garcia and Calantone (2002) align with this definition as they state that innovation is ‘‘an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention’’ (Garcia & Calantone, 2002).

The performance that is achieved as a result of new product development is the innovation performance (Salomo, et al., 2007). For this research a measure of innovation performance which is not bound to a certain time span and which is also applicable at the project level is needed. Such a measure is developed by Atuahene-Gima, Slater, and Olsen (2005; 2007) who present a measure for product innovation performance which focuses on whether the product development objectives were achieved. (Atuahene-Gima, et al., 2005). Therefore we use the innovation performance measure of Atuahene-Gima et al. (2005)

2.2. Resource Complementarity

In relationships between companies the physical and organizational resources of the company are exchanged and combined with those of its counterparts in order to achieve the set goals (Haythornthwaite, 1996; Tichy, et al., 1979). Firms are encouraged to innovate by searching out new resources, or new ways of using existing resources, as the basis for future organizational rents (Galunic & Rodan, 1998; Håkansson, 1989; Oerlemans, et al., 1998). Such resources will fuel the firm’s innovative activities by providing the external information necessary to generate new ideas. Equally, the innovative work of the firm will benefit from access to new knowledge necessary to resolve design and manufacturing problems (Tsai, 2001). Simply having resources is not enough to produce innovative output. It is also the way these resources are utilized in the innovation process, which determines whether innovative outputs are produced in an effective and efficient way (Oerlemans, et al., 2001). In fact, the innovation effects of resource exchange in NPD collaborations can be located at two levels. First, the adaptation of external resources leads to an extension of firms’ technological capabilities of developing new products. Second, the implementation of additional capacities from outside raises the probability of realizing innovations (Becker & Dietz, 2004).

The resources of the companies are affected, both in terms of how they are used and how they develop (Gadde, et al., 2003).

Lambe et al (2002) distinguish between resources that are developed and resources that are used in external collaboration: idiosyncratic and complementary resources. Idiosyncratic resources are developed during the life of the collaboration, are unique, and facilitate the combining of resources contributed by the partner firms. Complementary resources are defined as the degree to which firms in an alliance are able to eliminate deficiencies in each other's portfolio of resources by supplying distinct capabilities, knowledge, and other entities (Lambe, et al., 2002). Since both resource types should be present as they affect the success of the external collaboration (Lambe et al. 2002), we initially used the measure for complementary and idiosyncratic resources of Lambe et al. (2002) (see Chapter 3). However, when validating these measures we found that "resources" is not a two-dimensional construct, but a one-dimensional construct labeled "resource complementarity" which inhibits both idiosyncratic and complementary resource issues (see Chapter 3).

2.3. Trust

Trust is defined as the belief that the results of somebody's intended action will be appropriate from our point of view (Nahapiet & Ghoshal, 1998). Trust is necessary for people to work together on common projects, even if only to the extent that all parties believe they will be compensated in full and on time (Leana & Van Buren III, 1999). Faems et al (2008) distinguish between competence trust, which is defined as encompassing positive expectations about a partner's ability to perform according to an agreement, and goodwill trust, which is defined as the partner's intention to perform according to an agreement. They find that competence trust is a crucial condition for subsequent transactions and goodwill trust is found to be a condition that determines how contracts are applied (Faems, et al., 2008). Trust that builds up over time may in itself lead to unforeseen benefits, even when the expected gains are not fully realized over a given time period. Trust is an important factor in determining commitment, over and above any strict cost-benefit accounting, particularly among small and medium sized producers (Suarez-Villa, 1998). Some element of trust will be required for any transaction in which simultaneous exchange is unavailable to the parties (Ring & Van de Ven, 1992) as in new product development.

Rempel and Holmes (1986) were among the first researchers that focused on trust and that developed a measurement for trust. They distinguish between cognitive, behavioral and emotional trust (Rempel & Holmes, 1986). In studying the relation

of interpersonal and interorganizational trust on performance, Zaheer et al. (1998) build on the research of Rempel and Holmes (1986) and define trust as follows: "Trust is the expectation that an actor (1) can be relied on to fulfill obligations, (2) will behave in a predictable manner, and (3) will act and negotiate fairly when the possibility for opportunism is present (Zaheer, et al., 1998). They distinguish between reliability, predictability and fairness as dimensions of trust. More recentely Gulati and Sytch (2008) investigated the formation of trust between firms, as we do. They specifically focus on relational trust, which is the expectation that another organization can be relied on to fulfill its obligations, to behave in a predictable manner, and to act and negotiate fairly, even when the possibility of opportunism is present (Gulati, 1995; Zaheer, et al., 1998). To measure interorganizational trust, they adapted the trust measures of Zaheer et al. (1998) (who, in turn, based their measures on the research of Rempel and Holmes (1986)). In our measurement instrument we initially adopted the trust measures of Gulati and Sytch (2008) (see Chapter 3), since their measurement specifically focuses on interorganizational trust rather than on interpersonal trust. In addition, their measurement is the most recent measurement of trust, which is based on, and which is tested and improved over time by acknowledged scholars in the field of research on trust.

Validating the measurement with our dataset resulted in the finding that trust is not one-dimensional as suggested in theory, but is two-dimensional (see Chapter 3). It consists of "fairness trust" on the one hand (i.e. the expectation that a partner will negotiate fairly), and "reliability distrust" on the other hand (i.e. the expectation that a partner can be relied on to fulfill its obligations).

2.4. Network Position Strength

Even though the extensive body of literature concerning network characteristics repeatedly indicates the importance of the structure of the network in terms of the presence of structural holes (Burt, 1992b), the density of the network (Burt, 1992b; Gilsing & Nooteboom, 2005) and the size of the network (Borgatti, et al., 1998) in relation to innovation performance it lacks a solid measure to measure the structure of the ego network. Therefore, based on literature, a measure for "network position strength" was developed (see Chapter 3). "Network position strength" includes the items "density", "size", and "structural holes".

Density is the number of actual links in the network as a ratio of the number of possible links in the network (Borgatti, et al., 1998; Burt, 1992a; Haythornthwaite, 1996; Inkpen & Tsang, 2005; Kerssens-VanDrongelen & Groen, 2004; Liao &

Welsch, 2005; Nahapiet & Ghoshal, 1998; Rowley, 1997; Tichy, et al., 1979). As density increases, communication across the network becomes more efficient. Furthermore as interorganizational linkages become more dense, behaviors become more similar across the network, and the likelihood that shared behavioral expectations will be established increases (Rowley, 1997). Irrespective of one's position, high density inhibits the existence and utilization of diversity, and hence of novelty value, while at low levels it does not support absorption sufficiently (Gilsing, et al., 2008).

When ego occupies a structural holes position in the network, ego is able to broker connections between alters in his network (Burt, 1992a; Haythornthwaite, 1996). In an ego network, ego is connected to every other actor (by definition). If these others are not connected directly to one another, ego may be a "broker" if ego falls on the paths between the others (Hanneman & Riddle, 2005). Firms occupying the favored network position of bridging structural holes are likely to perform better because of the their superior access to information (Burt, 1992b; Zaheer & Bell, 2005). Actors in a network rich in structural holes will be able to access novel information from remote parts of the network, and exploit that information to their advantage (Burt, 1992b, 2001, 2004). Consequently, networks rich of structural holes are more likely to yield new information, which can lead then to the discovery of entrepreneurial opportunities (Arenius & De Clerq, 2005).

The size of the network is determined by the number of alters that an ego is directly related to (Borgatti, et al., 1998; Kerssens-VanDrongelen & Groen, 2004; Koka & Prescott, 2002; Tichy, et al., 1979).

2.5. Goal Alignment

Value, in terms of innovation performance, can be created through cooperation and knowledge sharing (Inkpen & Tsang, 2005). When the objectives and strategies of an alliance are clearly stated, a foundation of common understanding and the means to achieve the collaborative purpose is established among the partners. Subordinating cooperation to strategic goals can provide longer-term horizons for the alliances, compared with circumstantial cooperative outsourcing, even when an alliance is structured to deal with specific projects of a pre-determined duration (Suarez-Villa, 1998).

Goal alignment is the degree to which every pair of individuals has clearly defined expectations about each other's behavior in the relation (Tichy, et al., 1979), or the degree to which network members share a common understanding and approach to the achievement of network tasks and outcomes (Inkpen & Tsang, 2005). When

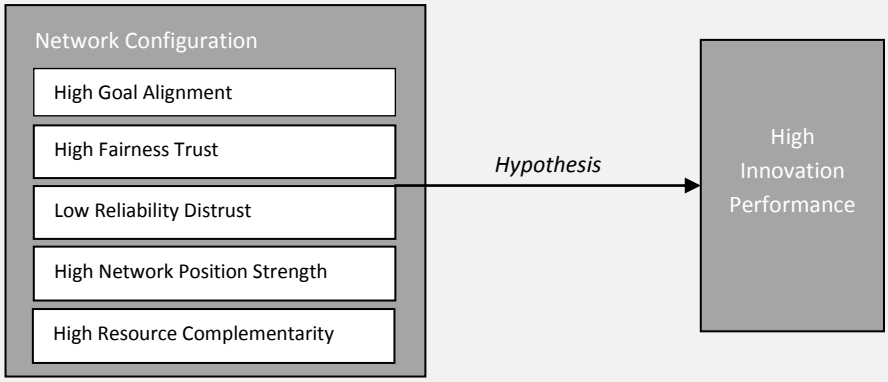
partners have contradicting or inconsistent goals, inter-partner conflicts may arise. This is not conducive to the flow of knowledge between the partners and the alliance. For goal alignment Bourgeois III (1980) uses the term goal consensus. In his research on goal consensus Bourgeois III (1980) concludes that a coalition of strategy makers cannot focus on alternative means without a clearly conceived set of goals in mind. Therefore goals agreement is paramount/ predominant. Dess (1987) builds on the research and questionnaire of Bourgeois (1980). He finds that consensus on competitive methods has an important relationship to performance. We adopt the measure of Dess (1987) to measure goal alignment.

The literature on network characteristics as described above, states that all these network variables when considered separately are related to innovation performance. The focus on one or more network characteristics in solitude in relation to innovation performance leads to a form of reductionism (Van de Ven & Drazin, 1985), as 1) real-life organizations and networks consist of multiple characteristics in combination, and 2) the interaction between the variables is ignored which might lead to different research results. This form of reductionism can be overcome by addressing the characteristics of organizations in combination (Miller & Friesen, 1982). The network characteristics in combination, or in other words the network configuration, must be taken into account when analyzing technological networks. In their research on the underlying structure of network characteristics and innovation performance, Pullen et al. (2010) find that the network characteristics in solitude do not have a direct main effect on innovation performance. However the interaction effect of the network characteristics has a direct significant effect on innovation performance (Pullen, Groen, De Weerd-Nederhof, & Fisscher, 2010). However research has not yet clearly demonstrated which configurations most affect innovation in particular contexts (Pittaway, et al., 2004). In the context of SMEs in the medical devices sector we hypothesize that:

H1: The network configuration of SMEs that is related to high innovation performance in the medical devices sector combines high levels of resource complementarity and "fairness" trust, a strong network position, a high level of goal alignment, and a low level of "reliability" distrust.

The variables that are included in the hypothesis and their hypothesized relations are visualized in the research model below.

Figure 1: Research Model



3. Methodology

This methodology section first explains more in-depth why the medical devices sector was selected as research context (§3.1). Second, it describes the sampling and datagathering process (§3.2). The research method of the systems approach is described in §3.3. §3.4 describes the operationalization of variables we conducted to test the validity of the self-administered questionnaire.

3.1. Research Context

As research context for this research a sector in which both collaboration and new product development are of high importance is needed. A sector that meets these requirements is the (Dutch) medical devices sector[2]. In this sector, collaboration with external partners for new product development becomes increasingly important due to the complexity of the products and the fragmentation of the market. The sector is characterized by very strict regulations (Kaplan, et al., 2004). Mainly due to these regulations, which are an important cause of the very time-

[2] According to medical device directive 93/42/EEC , a medical device is:"*…any instrument, apparatus, appliance, material, or other article, whether used alone or in combination, including the software necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of a) Diagnosis, prevention, monitoring, treatment or alleviation of a disease, b)Diagnosis, monitoring, treatment or alleviation of or compensation for an injury or handicap, c)Investigation or modification of the anatomy or of a physiological process, or, d)Control of conception. And which does not achieve its principal intended action in or on the human body by a) Pharmacological, b)Immunological or c) Metabolic means, but which may be assisted in its function by such means".*

and cost consuming new product development process (Kaplan, et al., 2004; Nieto & Santamaría, 2010), SMEs in the medical devices sector face the problem of a lack of financial resources and a lack of qualified personnel in their NPD process. This makes it necessary for them to cooperate (Kaufmann & Tödtling, 2002; Rogers, 2004). In addition, the intense competition, high rate of growth, continuing technological innovation, and customer sophistication suggest a significantly above average level of new product development activity (Rochford & Rudelius, 1997). Finally, 80% of the companies in this sector are SMEs. These characteristics make the medical devices sector a suitable context for this research.

3.2. Data Gathering and Sample

The data gathering has taken place during the autumn and winter of 2009. Through a telephone pre-survey in the complete population of 751 Dutch medical devices companies, companies that actively participate in the development of new medical devices and that have less than or equal to 250 Full Time Equivalents were identified as suitable companies to participate in the research. In this telephone pre-survey also key respondents were identified, the purpose of the research was explained and the potential respondents were asked to participate in the research. A total population of 105 suitable companies were identified. 97 of these companies indicated that they were willing to cooperate with the research. They received a personalized letter explaining the purpose of the study, along with a questionnaire by e-mail. The questionnaire could be filled-in electronically and returned by e-mail. Non-respondents received reminder telephone calls and a second questionnaire. Respondents were new product development managers, R&D Managers, CTO's and CEO's. These efforts yielded N=60 usable responses, giving a response rate of 61,9% percent (see Table 1).

In triangulation with quantitative survey data, also qualitative data was gathered through semi-structured interviews in 50 of these same companies. Gathering both quantitative and qualitative data enriches the data to a large extent

Table 1: Response rate of the sample

		Frequency	Percent	**Cumulative Percent**
Valid	filled-in questionnaire	13	13,4	13,4
	filled-in questionnaire + interview	47	48,5	**61,9**
	withdrawn participation	37	38,1	100,0
	Total	97	100,0	

3.3. Research Method

To examine which combination of network characteristics leads to high innovation performance we used the triangulation approach in which both quantitative and qualitative data is used. By doing so, we are able to enrich and verify our quantitative results with qualitative insights. This leads to a more in-depth understanding of the phenomenon under study than when either quantitative or qualitative data is used.

The quantitative research approach we use is the systems approach of Drazin and Van de Ven (1985). This approach enables us to consider multiple network characteristics simultaneously even when samples are relatively small. Other approaches to simultaneously measure multiple organization characteristics like for instance regression analysis or cluster analysis can include numerous organizational characteristics, but the results are only reliable in large samples. The systems approach presents reliable results even when samples are relatively small.

The systems approach examines the impact of the combined network characteristics on innovation performance by calculating the distance from an ideal profile (Govindarajan, 1988). This ideal profile is in the context of this research the combination of network characteristics that is related to high innovation performance (i.e. the successful network configuration). The successful network configuration of design variables can be generated either theoretically or empirically. In line with Drazin and Van de Ven (1985), we chose to use the empirical-based successful network configuration. Consistent with configuration theory procedures, we identified the 15% highest performing businesses in terms of innovation performance.

Based on the quantitative results, semi-structured interviews were conducted in 78% of the case companies to verify and complement the quantitative data results. The first question we asked respondents considered the position of the company in the supply chain, because we expect this to have its affect on goal alignment and network position strength. Second, we were interested in where the NPD project was initiated, because this might explain differences in for instance the concepts of goal alignment and network position strength. Third, we were interested in the attitude of the company towards its NPD partners, since this might explain differences in for instance “trust” and “distrust”. The interview questionnaire can be found in Appendix 3 of this thesis.

3.4. Operationalization of Variables

This section describes the operationalization and validity of the dependent variable "innovation performance" and the independent variables "network characteristics" (i.e., "(lack of) goal alignment", "fairness trust", "reliability distrust", "resource complementarity" and "network position strength".

Innovation Performance

The measure of Atuahene-Gima, Slater and Olsen (2005) to measure innovation performance was used. Innovation performance was measured through 5 items on a 7-point Likert scale (see Appendix 2, question 8). The 15% of companies with the highest mean scores for innovation performance together formed the "successful configuration sample (top 15%)" (N=7). The other 85% of companies together formed the "calibration sample (bottom 85%)".

Network Characteristics

From literature we extracted and operationalized 5 network characteristics (a total of 17 items) that are suggested to have a relation to the companies' innovation performance (see Chapter 3 and Appendix 2). Since not all measures were directly extracted from literature, nor previously tested in combination, an exploratory factor analysis was conducted. Factor analysis on the network characteristics that the 17 items in the questionnaire together build five constructs (see Table 2) that together explain 76,38% of the variance (see Chapter 3, for a more in-depth description of the factor analysis). Items with loadings greater than 0,40 on a factor are considered significant. As can be seen in Table 3 there are three items (Q20., 20.1 and Q20.3) that load on more than one factor. There is some disagreement in literature about what to do when items load on multiple factors. Kline (2000) suggests to drop the items that load on multiple factors, because they are difficult to interpret (Kline, 2000). However Hair et al. (1995) argues that the meaning of an item must be taken into account when assigning labels to a factor (Hair, et al., 1995). In line with Hair et al. (1995) Pett et al. (2003) suggest placing the item with the factor it is most closely related to conceptually instead of dropping the item. They argue that reliability tests of the factors will show the internal consistency of a factor and will also indicate whether or not reliability of a factor will increase by dropping an item (Pett, et al., 2003). As Hair et al. (1995) and Pett et al. (2003) we do not drop the items with multiple (significant) factor loadings, rather we assign the item to the factor it is most closely related to and use reliability test for internal consistency. All constructs had high reliabilities, and high Eigenvalues.

In line with Drazin and Van de Ven (1985) the mean scores of the network characteristics for each case company have been calculated and used in the analyses. When a company achieved a mean score on a network characteristic which is high than the mean network characteristics score of the full sample, the company score was considered "high". Vice versa, a mean score below the sample mean was considered "low".

Table 2: Rotated component matrix (for the independent variables)

	Component				
	1	2	3	4	5
	Resource Complementarity	"Fairness" Trust	"Reliability" Distrust	Network Position Strenth	Lack of Goal Alignment
Q19.1_CreatedUniqueCapabilities	,807				
Q19.2_TogetherDevelopedKnowledge	,784				
Q19.3_TogetherInvestedInBuildingBusiness	,810				
Q19.4_TogetherInvestedInRelationship	,798				
Q19.5_IfEndedKnowledgeWasted	,735				
Q19.6_IfPartnerSwitchInvestmentsWasted	,836				
Q20.1_ContributeDifferentResources	,683				,505
Q20.2_ComplementaryStrengths	,590	,439			
Q20.3_SeparateAbilitiesCombined	,695	,418			
Goal_Differences					,861
Q25.1_TreatYouFairly		,897			
Q25.2_ConfidentialityOfInformation		,933			
Q25.4_Inv_ProfitAtYourExpense			,797		
Q25.5_Inv_CannotCompletelyRelyOnPromises			,857		
Q25.6_Inv_HesitantVagueSpecifications			,771		
Inv_Density				,934	
Ties_Brokered_normalized				,942	
Eigenvalue	6,39	2,16	1,95	1,47	1,01
% Variance explained	37,61	12,71	11,49	8,63	5,93
Cronbach's α	0,922	0,928	0,749	0,906	X
# items	9	2	3	2	1

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

After factor analysis some differences occur in the grouping of the measurement variables (see chapter 3). First, when measured in combination with other network characteristics, the measures for idiosyncratic and complementary resources (Lambe, et al., 2002) are not two separate measures as suggested in literature. Rather, they together form one construct: resource complementarity. Second, the two network variables "density" and "structural holes position" were found to be forming one network characteristics "Network Position Strength". Prior research considered these items as individual constructs, but we showed that in fact they belong to a higher level construct. Third, trust is not a one-dimensional construct as suggested in earlier research (Gulati & Sytch, 2008; Zaheer, et al., 1998), but is a two-dimensional construct. The first dimension labeled "fairness trust" focuses on the expectation that an actor will act and negotiate fairly, which aligns with the "fairness" dimension of Zaheer et al. (1998). This second dimension labeled "reliability distrust" focuses on the expectation that an actor can be relied on to fulfill obligations, which aligns with the "reliability" dimension of Zaheer et al. (1998). This means, that in practice companies can have both trust and distrust towards their collaboration partners.

4. Results

This section describes the research results of both the quantitative data analysis (social systems approach) which tests our hypothesis (§3.1), and the qualitative data analysis (§3.2) which is used to complement and clarify the quantitative data results.

4.1. Quantitative Data Analysis

The empirical-based successful network configuration consists of the best performing 15% of companies (top 15%) in terms of Innovation Performance. The other 85% of companies in the sample is the calibration sample. Table 3 below shows the mean scores of the five network characteristics for both the successful network configuration sample and the calibration sample. The mean scores of the top 15% best performing companies is considered as the empirical-based successful network configuration (i.e. the ideal profile).

Table 3: Descriptive statistics for the Ideal Profile (top 15%) and the Calibration Sample (bottom 15%)

	Sample	N	Mean	Std. Deviation
Goal_Differences	Calibration Sample (bottom 85%)	52	8,46	4,41
	High Performers (top 15%)	7	13,74	3,98
	Total	59	9,09	4,66
Resource_Complementarity	Calibration Sample (bottom 85%)	52	4,85	1,38
	High Performers (top 15%)	7	5,38	1,07
	Total	59	4,91	1,35
Fairness_Trust	Calibration Sample (bottom 85%)	52	5,37	1,67
	High Performers (top 15%)	7	6,07	,73
	Total	59	5,45	1,60
Reliability_Distrust	Calibration Sample (bottom 85%)	52	4,21	1,61
	High Performers (top 15%)	7	5,29	1,47
	Total	59	4,60	1,54
Network_Position_Strength	Calibration Sample (bottom 85%)	51	,63	,38
	High Performers (top 15%)	7	,50	,50
	Total	58	,61	,39

We have to show that the ideal profile (i.e. successful network configuration) is related to high innovation performance. This means, that we have to show that the more the network configuration of a company differs from the ideal profile, the lower its innovation performance will be. This is done by 1) calculating the Euclidean distance for each case company and by 2) correlating this distance measure with innovation performance. The Euclidean distance is the difference between the successful network configuration and the network configuration of an individual case company. The Euclidean distance was calculated as follows: Euclidean Distance = $\sqrt{\Sigma(X_{is} - X_{js})^2}$, where X_{is} is the score of the successful network configuration on the s^{th} network characteristic and where X_{js} is the score of the j^{th} case company on s^{th} network characteristic (Van de Ven & Drazin, 1985).

Table 4 shows the correlation between the Euclidean Distance and the Innovation Performance. The Euclidean Distance correlates -0,444 ($p<0,01$) with Innovation Performance. The results indicate that when the network configuration (i.e. the combination of network characteristics) of a company differs more from the successful network configuration (i.e. the Euclidean distance increases), the

Innovation Performance will decrease. In other words, the more the combination of network characteristics is similar to the successful network configuration of the top 15% best performing companies, the higher the Innovation Performance of the company will be. In addition these results show significant support for the systems approach in the context of networks in new product development.

Table 4: Correlations

		Innovation_Performance	EuclideanDistance_means
Innovation_Performance	Pearson Correlation	1,000	-,444**
	Sig. (2-tailed)		,001
	N	55,000	55
EuclideanDistance_means	Pearson Correlation	-,444**	1,000
	Sig. (2-tailed)	,001	
	N	55	59,000

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

Table 5 shows the mean scores of the top 15% performing companies on the network characteristics. In line with Drazin and Van de Ven (1985) scores above the mean of the full sample are considered "high" and scores below this mean are considered "low". As the last column in table 5 shows can the successful network configuration be described as one having high levels of "resource complementarity", "fairness trust", "reliability distrust" and "lack of goal alignment", and low "network position strength".

Table 5: Successful Network Configuration (top 15%)

	N	Minimum	Maximum	Mean	Std. Deviation	**Level**
Goal_Differences	7	8,49	19,80	13,74	3,98	**High**
Resource_Complementarity	7	4,42	7,00	5,38	1,07	**High**
Fairness_Trust	7	5,00	7,00	6,07	,73	**High**
Reliability_Distrust	7	3,00	7,00	5,29	1,47	**High**
Network_Position_Strength	7	,00	1,00	,50	,50	**Low**
Valid N (listwise)	7					

The network configuration of the calibration sample (the bottom 85%) is the inverse of the successful network configuration (see table 6). This network configuration, that is related to a lower level of Innovation Performance, has low levels of "resource complementarity", "fairness trust", "reliability distrust" and "lack of goal alignment", and high "network position strength".
If the mean represents the data well, then most of the scores will cluster close to the mean and the resulting standard deviation is small relative to the mean. Considering the range of scores of both the ideal profile and calibration sample, the standard deviations are small to modest in size, indicating a good representation of the data.

Table 6: Network configuration of the Calibration Sample (bottom 85%)

	N	Minimum	Maximum	Mean	Std. Deviation	**Level**
Goal_Differences	52	,00	21,92	8,46	4,41	**Low**
Resource_Complementarity	52	,00	6,58	4,85	1,38	**Low**
Fairness_Trust	52	,00	7,00	5,37	1,67	**Low**
Reliability_Distrust	52	,00	7,00	4,21	1,61	**Low**
Network_Position_Strength	51	,00	1,00	,63	,38	**High**
Valid N (listwise)	51					

The contents of the successful network configuration (table 5) show that the top 15% best performing companies have a clear focus and are functional when it comes to collaboration with other companies. They collaborate only when the partner firm is able to offer the resources that the company initially lacks. Even though they trust their partner to negotiate fairly (i.e. fairness trust), the company also has a certain level of distrust towards the partner firm when it comes to fulfilling obligations. Partners are not only trusted based on 'face-to-face" fairness trust. The network position strength is low due to the low density of the network. These companies are very focused, functional and consistent in collaborating for new product development. The successful companies have a "businesslike", more objective, approach towards collaboration.
In contrast, the lower performing companies do not trust their partners to negotiate fairly (i.e. fairness trust), but they do trust that their partners will fulfill obligations (i.e. low reliability distrust). In addition, partners in the network know each other. It seems that these companies are less focused on objective selection

criteria like the complementarity of resources in selecting collaboration partners. These lower performing companies are far more shifty and devious than the straight and focused high performing companies. It seems, these companies have a more “soft and friendly”, maybe even idealistic, approach towards collaboration.
These findings partially support our hypothesis in which we stated that the successful network configuration combines high levels of resource complementarity and “fairness” trust, a strong network position, a high level of goal alignment and a low level of “reliability” distrust. What is interesting is, that we find that a high level of distrust, a low level of network position strength and a low level of goal alignment are included in the successful network configuration.

4.2. Qualitative Data Analysis

To complement and clarify these quantitative results and, we conducted semi-structured interviews with companies in both the top 15% sample and the bottom 85% sample. The questionnaire that was used for the semi-structured interviews can be found in Appendix 3 of this thesis.
The first question we asked respondents considered the position of the company in the supply chain. Companies in the medical devices sector that deliver to the end-market have to negotiate with (among others) hospitals and insurance companies, which is time and cost consuming. Companies that do not deliver to the end market also have to deal with this partner, but indirectly and to a far lesser extent. We expect that this might affect the network configuration in terms of, for instance, goal alignment: aligning with the goals of the insurance company is a necessity for approval and commercialization of the product.
In general, the top 15% best performing companies do not deliver their products to the end- market (see table 7). In case of the medical devices industry this end-market most of the time consists of hospitals and other health care institutions. Rather they deliver their products to distributors. Instead of the company having to deal with the difficult commercialization of medical devices to the end-market, the distributor deals with these difficulties like negotiations with health care insurance companies. For the company this a more efficient sales strategy than direct sales to health care institutions.

Table 7: Position of companies from both samples in the supply chain with regard to end market delivery

			DeliveryToEndMarket			
			Yes	No	Mixed	Total
Sample	Calibration sample (Bottom 15%)	Count	12	19	7	38
		% within Sample	31,6%	50,0%	18,4%	100,0%
	Successful network configuration (Top 15%)	Count	1	5	0	6
		% within Sample	16,7%	83,3%	,0%	100,0%
	Total	Count	13	24	7	44
		% within Sample	29,5%	54,5%	15,9%	100,0%

Second, we were interested in where the NPD project was initiated, because this might explain differences in the concepts of goal alignment and network position strength of the network configuration.

Table 8 shows that for the majority of companies in the calibration sample (59,5%) the NPD project is initiated by the company itself. In contrast, in only 33,3% of the top 15% best performing companies the project is initiated internally. In the majority of the top 15% best performing companies the company is approached by an external company who is not able or not willing to execute the NPD process itself. By not internally initiating the NPD project, but by executing the NPD project "on demand", the top 15% best performing companies guarantee their external revenues from the NPD project.

Table 8: Initiation sources of the NPD project

			SourceNPDProject				
			Client Order (external)	Development Order (external)	Physician (external)	Company (internal)	Total
Sample	Calibration sample (Bottom 85%)	Count	10	1	4	22	37
		% within Sample	27,0%	2,7%	10,8%	59,5%	100,0%
	Successful netwok configuration (Top 15%)	Count	3	1	0	2	6
		% within Sample	50,0%	16,7%	,0%	33,3%	100,0%
	Total	Count	13	2	4	24	43
		% within Sample	30,2%	4,7%	9,3%	55,8%	100,0%

Third, we were interested in the attitude of the company towards its NPD partners, since this might explain differences in for instance “trust” and “distrust”. Trust (i.e. fairness) might be considered a prerequisite in companies that share NPD ideas and jointly design new products, whereas distrust (i.e. reliability) might be considered more important when the collaboration looks like a supplier-buyer relationship.
As table 9 shows, the attitude that these companies have towards their partners in the NPD project is far more business-like than the attitude that the lower performing companies have. The top 15% best performers use a focused strategy in contacting their partners with specific resource requests. It is rather a customer-supplier relationship than a collaborative relationship. The lower performing companies are far more collaborative towards their NPD partners. Not only are partners consulted, they also share ideas in NPD and are developing the new product together. Often IP is shared.

Table 9: Attitude towards partners

			AttitudeTowardsPartners		
			Business-like	Collaborative	Total
Sample	Calibration sample (Bottom 85%)	Count	17	22	39
		% within Sample	43,6%	56,4%	100,0%
	Successful network configuration (Top 15%)	Count	3	2	5
		% within Sample	60,0%	40,0%	100,0%
	Total	Count	20	24	44
		% within Sample	45,5%	54,5%	100,0%

These qualitative results help to explain the fact that the successful network configuration includes a low level of trust, a high level of distrust and low network position strength. As explained above, the successful companies use a focused strategy and pose specific resource requests to their partners. Whether the company trusts its partner in terms of fairness trust is not a prerequisite, which explains the low level of (fairness) trust in the network configuration. The fact that the partner has resources the company needs is far more important, which explains why a company collaborates with a partner even though (reliability) distrust is high. Contracts have to insure that agreements are met. In addition, posing a specific resource request to a partner instead of collaborating to build the necessary resources together, makes it unnecessary for partners to know one another in the

network. This explains the rather modest network size and low density in the network which lead to low network position strength.

5. Discussion

We began by observing that cooperation with other organizations increases the innovation performance of organizations (Chang, 2003; Hanna & Walsh, 2002; Ritter & Gemünden, 2003, 2004; Rothwell, 1991; Salman & Saives, 2005). Especially for SMEs, as they are bounded by a lack of financial resources, manpower and substitutes for lack of sales (Hanna & Walsh, 2002; Kaufmann & Tödtling, 2002). We examined which combination of network characteristics (the network configuration) is related to high innovation performance and we thereby address the issue raised by Pittaway et al. (2004) who state that research has not yet clearly demonstrated which configurations most affect innovation in particular contexts.

We used the systems approach (Drazin & Van de Ven, 1985) to examine which network configuration is related to high innovation performance. Using the systems approach we were able to address multiple network characteristics simultaneously which led to new insights in the successful external organization of new product development.

Partially contrary to what we predicted we found that the successful network configuration includes high levels of resource complementarity, “fairness” trust and “reliability” distrust, and low level of goal alignment (i.e. high goal difference (lack of goal alignment)) and low network position strength. We hypothesized high levels of resource complementarity, “fairness” trust, goal alignment and network position strength, and a low level of “reliability” distrust. The high performing companies have a businesslike mentality and are very focused and consistent in how they collaborate in NPD. The relation with their partners is almost like a customer-supplier relationship as the company contacts their partners with specific resource requests for which the partner is paid. Instead of trusting the partner firm blindfolded, the company has a certain level of distrust towards the partner firm. The network of the company consists of a limited number of partners and, in addition, these partners are not directly connected to each other (low density). In contrast, the lower performing companies are searching for partners with whom they can collaborate and build resources. Trust is considered crucial for these companies. Their approach to collaboration in new product development is more soft and subjective in comparison to the approach of the high performing companies. These results are in line with the findings of Lindman (2002) who finds

that NPD can be highly successful regardless of the degree of cooperation (Lindman, 2002). Even though past research argues that a social way of networking is related to high innovation performance, both our quantitative and qualitative findings indicate that a businesslike way of networking is related to high innovation performance.

An explanation for the fact that the businesslike, objective network configuration of the high performers is related to high innovation performance can be explained by the fact that these high performers face less risk in the NPD process. The NPD projects are most of the time initiated outside the company: the high performers develop new products on request which secures their NPD revenues. In addition by not trusting their partners blindfolded and by maintaining a businesslike relationship towards partners the risk of being deceived is minimized. As Duysters et al. (1999) concluded, effective technology partnering selection should involve an evaluation of the potential partner on the basis of that partner's competitive and technological position and access to business networks but also on its track record of successful partnerships and the transferability of desired resources (licenses, patents etc.) (Duysters, et al., 1999).

An explanation for the fact that the successful network configuration (in this context) is a businesslike configuration seems to be caused by the fact that companies in our dataset mainly focus on low (incremental) and moderately innovative new products. We assume that this is caused by the strict sector regulations. The average development time for medical devices ranges from 1-2 years for incremental devices and 5-7 years for radical devices, dependent on the product type, complexity, and degree of risk to the patient that dictates their regulatory defined conformance and approval route (Hourd & Williams, 2008). Since the developed products are not highly innovative the SME can focus more on efficiency and routines instead of focusing on the early research and development stages. There is less need for the company to involve the partner in the development project. Rather, the company is able to pose a specific resource request. Also, because the company and the partner do not develop brand new products of which the market and competitors are unaware of, trust is not a prerequisite for collaboration. Resource complementarity and goal alignment are more important, which is in line with research of Oerlemans et al. (2001), Becker and Dietz (2004), Inkpen and Tsang (2005) and Suarez-Villa (1998).

6. Limitations and Further Research

Our study has some limitations that suggest a number of directions for further research. A limitation of this study is the limited sample size. For the purpose of

generalizability, additional data could be gathered. A suggestion is to include additional European countries in the sample, because medical devices companies in these countries have to comply to the same regulations as Dutch medical devices companies. Another argument to include more countries in the research is the fact the Dutch population of medical devices companies is limited to 105 (see §3.2.). For larger sample sizes, additional countries are needed.

Furthermore, in this research radically new development projects were not included. We expect that companies that focus on highly innovative development projects in this sector face even more difficulties in achieving high innovation performance due to more stricter sector specific regulations. For further research it might be interesting to focus also on this type of new product development projects, and examine whether or not a businesslike approach is in this context also related to high innovation performance.

Another suggestion for further research is to conduct a cross-industry study in multiple highly regulated sectors for generalizability of the research findings. Nowadays health related sectors like the medical devices sector are of interest to many initially non-health sectors. More and more sectors are embracing health related issues and start operating on the border of their main industry and the health industry. For instance, companies in the food sector tend to include biotechnology concepts in their new products. This means that companies increasingly have to deal with regulations and that sectors are becoming more and more regulated. Therefore we expect our research findings to be applicable in a wide array of sectors. Further research might focus on the relation between organization of the network and innovation performance in other highly regulated sectors.

Furthermore, in studying the organization of NPD ego-networks in relation to innovation performance, we focused on the social capital approach. However, another approach for studying network-innovation performance issues is the absorptive capacity approach. The ability to recognize the value of new information, assimilate it, and apply it to commercial ends. Is what is called a firm's "absorptive capacity." The ability to exploit external knowledge is a critical component of innovative capabilities. Absorptive capacity refers not only to the acquisition or assimilation of information by an organization but also to the organization's ability to exploit it. Absorptive capacity does not simply depend on the organization's direct interface with the external environment. It also depends

on transfers of knowledge across and within subunits (Cohen & Levinthal, 1990). Studying the relationship between NPD ego-networks and innovation performance from an absorptive capacity approach and combining these results with our findings from the social capital approach might present an even more complete understanding of successful network organization in terms of innovation performance.

We considered the network configuration and innovation performance at one point in time. However new product development is a dynamic process that changes over time. Longitudinal research is expected to shed more light on this issue. It would be interesting to study how companies change their network configurations over time to also achieve high future innovation performance.

A final suggestion for further research is to examine the interaction between the network characteristics in relation to the innovation performance. Earlier research showed that the interaction between network characteristics (the network configuration) is directly related to innovation performance (see chapter 4). In this research we demonstrated which configuration of network characteristics is related to high innovation performance for SMEs in the medical devices and thereby addressed the issue of Pittaway et al (2004). It was out of the scope of this research to also examine how the different network characteristics are related to each other and how they interact. Further research might address this issue.

7. Concluding Remarks

We argued that the successful network configuration of SMEs in the medical devices sector consists of high levels of resource complementarity, trust, network position strength, and goal alignment. Using the context of SMEs in the Dutch medical devices sector, we show that the a network configuration that includes high levels of resource complementarity and goal alignment, but low levels of trust and network position strength is related to high innovation performance.

In line with both our quantitative and qualitative research findings, we argue that a “soft and friendly” approach towards external NPD collaboration in which trust is an important prerequisite is not related to high innovation performance. Rather a more “businesslike” approach which is focused and consistent is related to high innovation performance.

Managers of SMEs in the medical devices sector that aim to achieve high innovation performance, should use objective criteria to select partners. Partner selection should not be mainly determined by trusting a partner. Developing new products "on demand" is a more effective way to achieve high innovation performance than by initiating NPD projects internally. Even though the latter is often associated with high firm innovativeness in a highly regulated sector like the medical devices sector it is not related to high innovation performance.

In conclusion, SMEs in the medical devices sector should aim for a businesslike organized network configuration that includes high levels of resource complementarity and goal alignment with development partners, a low network position strength and in which partners are not trusted blindfolded in order to achieve high innovation performance.

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Discussion

1. Introduction

The research described in this dissertation focused on how the interaction between firms could be organized for high innovation performance. The research context was the medical devices sector. The chapters 1 - 5 that are included in this dissertation have the structure of research papers. Chapters 1 and 2 are based on published papers, chapters 3, 4 and 5 are based on conference proceedings. Each of the papers describes and discusses research results and presents conclusions and suggestions for further research. In this final chapter of the dissertation, the research findings and conclusions of the 5 papers are combined. This discussion chapters brings together all 5 papers and in addition presents the theoretical and practical contributions of the research. The final section of this discussion chapter considers the research limitations and directions for future research.

2. Research Findings and Conclusions

Pilot Study

Main results:

- SMEs are less able to differentiate in terms of innovation performance through product concept issues than through efficiency of the NPD process;
- Focusing on the external NPD organization is a more successful strategy to gain competitive advantage in terms of innovation performance.

The first phase in the research was executing a pilot study. This pilot study was conducted to examine the possibility of SMEs in the medical devices sector to gain competitive advantage in terms of innovation performance through their internal NPD organization. This internal NPD organization consists of the product on the one hand and the NPD process on the other hand. The pilot study (**chapters 1 and 2**) verified the assumption that, SMEs in the medical devices sector are hardly able to gain competitive advantage through product concept issues like safety, quality and cost effectiveness, because these issues are highly bound to regulations. The pilot study showed that SMEs are less able to differentiate in terms of innovation performance through product concept issues than through efficiency of the NPD process. However, as stated before, due to limited financial and manpower resources, SMEs in general need to be efficient to be able to survive in the first place. This is in line with the findings of Brown et al (2008) who find that none of

the NPD process strategies such as Stage-Gate NPD, concurrent engineering, or the quality strategies such as TQM or Six Sigma are correlated with new product success in a statistically significant manner (A. Brown, et al., 2008).
Therefore the first finding, based on the pilot study, is that SMEs in a highly regulated sector like the medical devices sector are hardly able to distinguish themselves from competitors through their internal NPD organization. Focusing on the external NPD organization is a more successful strategy to gain competitive advantage through innovation performance.

Successful New Product Development through External Collaboration

Main results:

- Development of a measurement to simultaneously measure network-innovation performance issues;
- "Trust" was found to be two-dimensional rather than one-dimensional as suggested in literature;
- "Density" and "Structural holes position" are empirically and conceptually connected in one network characteristics, the so called "Network position strength";
- No direct significant effect of individual network characteristics on innovation performance;
- The combination of network characteristics taken together (i.e. the network configuration) does have a direct significant effect on innovation performance;
- SMEs in the medical devices sector that achieve high innovation performance combine high levels of resource complementarity, goal differences (i.e. lack of goal alignment), fairness trust and reliability distrust, with a below average level of network position strength;
- Open Innovation with a closed business model is the key to success for small- and medium sized companies in a highly regulated sector.

To examine the NPD network and the way the SME interacts with other firms in new product development a literature study on network characteristics that are most relevant in the context of NPD was conducted and a measurement instrument was developed (**chapter 3**). Based on this literature study "goal alignment", "resource complementarity", "trust" and the structural network characteristics "density" and "structural holes position" were found to be the most

relevant NPD related network characteristics of the SME. These characteristics were all operationalized and validated through factor analysis and reliability tests.
Based on this analysis new insights in the empirical applicability of a number of network characteristics were gained. First, the concept of "Trust" was found to be two-dimensional rather than one-dimensional as suggested in literature. The first dimension, labeled "fairness trust", focuses on the expectation that a partner will negotiate fairly. The second dimension, labeled "Reliability Distrust", focuses on the expectation that a partner can be relied on to fulfill its obligations. In addition, we found that "density" and "structural holes position" are empirically and conceptually connected in one network characteristics, the so called "network position strength". Up till this moment, literature lacked such a structural network measure. The final measurement instrument therefore includes the network characteristics "resource complementarity", "goal alignment", "fairness trust", "reliability distrust", and "network position strength".
In addition to selecting, operationalizing and validating network characteristics and constructing a measurement instrument, the relation between network characteristics and innovation performance was examined. To improve new product development and increase innovation performance it is not sufficient to realize that the network is of crucial importance. One needs to know exactly which network characteristic has the most significant effect on innovation performance. By using multiple logistic regression (**chapter 4**) the underlying structure of the network characteristics and innovation performance was explained. In contrast to earlier research, we found that there was no direct significant effect of individual network characteristics on innovation performance. However, more interesting is that the combination of network characteristics taken together (i.e. the network configuration) does have a direct significant effect on innovation performance. This means that the interaction between the network characteristics taken as a set is what impacts innovation performance. The network characteristics in solitude are found to have no significant impact on innovation performance.
The data that was gathered with the developed measurement instrument gives a clear insight in how SMEs organize and interact in their network with the goal of new product development. The specific interpretation of the combination of network characteristics that is related to high innovation performance sheds light on the way SMEs can achieve high innovation performance through the organization of their network **(chapter 5)**. SMEs in the medical devices sector that achieve high innovation performance combine high levels of resource complementarity, goal differences (i.e. lack of goal alignment), fairness trust and

reliability distrust, with a below average level of network position strength. In addition these successful companies hardly initiate an NPD project internally. The NPD project is initiated elsewhere and the company is asked to offer an innovative solution to a clients problem. This “innovation on request” strategy guarantees that the company receives financial (or other) resources once the project is finished. Furthermore, in the new product development process these successful companies treat their partners as if they were suppliers. They have a very business-like approach towards their partners. On the contrary, the less successful companies are really trying to collaborate with their partners in NPD. These less successful companies are more idealistic towards NPD and innovation. Their collaborative, trust-based mindset is the opposite of the business-like mentality of the successful companies. Based on the interviews, the impression is that successful companies consider new product development as a means for achieving competitive advantage, whereas less successful companies consider new product development as a goal in itself. The main research finding is, that open innovation with a closed business model is the key to success for small- and medium sized companies in a highly regulated sector.

3. Theoretical Implications and Contributions

The results of the pilot study contribute to innovation and new product development literature, in that it shows that internal NPD organization does not matter under all circumstances. It contributes to our understanding of the innovation process in small-and medium sized companies in highly regulated sectors. This implies that previous research findings should be interpreted in the context of the research design. Our findings question the generalizability of previous research in which the importance of the internal NPD organization in relation to innovation performance is stressed. We showed, that the research context does matter when it comes to the influence of the internal NPD organization on innovation performance.

Measuring NPD related network characteristics

The findings contribute to network and innovation literature in several ways, specifically with respect to understanding which precise network characteristics should be taken into account in the context of new product development (NPD). The literature review and resulting selection of network characteristics takes into account not only the large amount of network characteristics, but more important,

it takes into account the heterogeneity of the contents of network characteristics that are similarly labeled. By looking at the lowest level of operationalization, the item level, and by grouping similar items, the heterogeneity problem was overcome. The resulting list of network characteristics gives a complete overview of network characteristics that need to be taken into account in network-innovation research. The measurement instrument that was developed is based on these network characteristics. We contribute to theory by introducing to network and innovation literature a measurement instrument for testing relationships involving the simultaneous assessment of multiple interrelated variables (i.e. network characteristics and innovation performance).

Not only the measurement instrument in itself contributes to theory, also the newly developed network characteristic "network position strength" does so. The structural network variables "density" and "structural holes position" were found to be connected in this higher level construct. Previous research has thoroughly examined these three variables in relation to innovation performance, but found conflicting results (for instance the Burt versus Coleman debate). The two variables should not be separated since they together form one network characteristic: "network position strength". This contributes to the interpretation of earlier research findings and contributes to our understanding of the firm's position in its network.

In addition, we found that the measure of trust as developed primarly by Rempel and Holmes (1986) and later adapted and improved by Zaheer et al. (19980 and Gulati and Sytch (2008) is two-dimensional instead of one-dimensional as suggested by literature. The first factor (dimension) is labeled "Fairness Trust" and covers, what Zaheer et al. (1998) describe as the relational aspect of trust. It can be described as the expectation that a partner will negotiate fairly. The second factor is labeled "Reliability Distrust". and is strongly related to the reliability aspect of trust that Zaheer et al. (1998) introduce. It can be described as the expectation that a partner can be relied on to fulfill its obligations. As described earlier, Zaheer et al. (1998) distinguish in their definition of trust between 3 aspects of trust "fairness", "reliability", and "predictability". However in both their research and in the research of Gulati and Sytch (2008) the measurement of trust is found to be one-dimensional. Our research shows that trust is not only theoretically multidimensional, but also empirically. This means that, in practice, companies can have both "fairness" trust and "reliability" distrust towards their collaboration partners.

Applicability of configuration theory

Next to network and innovation literature, this thesis adds to configuration theory. A configuration is a multidimensional constellation of the strategic and organizational characteristics of a business (Meyer, Tsui, & Hinings, 1993). Configuration theory posits that for each set of network characteristics, there exists an ideal set of organizational characteristics that yields superior performance (Van de Ven & Drazin, 1985). Mintzberg (1979) posited that in order to be maximally effective, organizations must have design configurations that are internally consistent and fit multiple contextual dimensions (Mintzberg, 1979). We empirically tested what Van de Ven and Drazin (1985) argued. Namely that "only by simultaneously addressing the multiple characteristics of organizations can relationships between performance and these organizational characteristics be fully understood" (Van de Ven & Drazin, 1985). We examined the effect of individual network characteristics and found no significant effect. However when examining the effect of the interaction between network characteristics on innovation performance, there was a strong, direct, significant effect. This study contributes in that it, based on empirical examinations, demonstrates the utility and significance of configuration theory in organization research.

When fit among multiple variables is considered simultaneously and the impact on criterion variables is assessed, fit should be conceptualized and assessed as "profile deviation" (Doty, Glick, & Huber, 1993; Vorhies & Morgan, 2003). A profile deviation approach views fit between organization and network characteristics in terms of the degree to which the network characteristics of a business differ from those of a specified profile identified as ideal for achieving high innovation performance (Vorhies & Morgan, 2003). Fit is high to the extent that an organization is similar to an ideal profile along multiple dimensions (Van de Ven & Drazin, 1985). An ideal profile is a theoretical construct that can be used to represent a holistic configuration of organizational factors (Doty, et al., 1993).

Open innovation in theory and practice

We contribute to theory by demonstrating which configuration most affects innovation performance in particular contexts by using Van de Ven and Drazin's systems approach (1985). It was hypothesized that companies that combine high levels of resource complementarity, fairness trust, goal alignment and network position strength with a low level of reliability distrust in their network configuration achieve high innovation performance. This hypothesis was only partially supported as it was found that high levels of resource complementarity,

goal differences (i.e. lack of goal alignment), fairness trust, reliability distrust, combined with a low level of network position strength were related to high innovation performance. In contrast to past research that argues that a social way of networking is related to high innovation performance, we contribute by demonstrating, both quantitatively as well as qualitatively, that a businesslike way of networking and a rather closed approach towards Open Innovation is related to high innovation performance.

In theory, the concept of Open Innovation is defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively " (Chesbrough, 2006). SMEs are practicing extensively open innovation activities, and are increasingly doing so (Van de Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009). However *in practice*, as shown in this research, the most successful companies in terms of innovation performance use a rather closed approach in which high levels of resource complementarity, goal differences (i.e. lack of goal alignment), fairness trust, reliability distrust and a low level of network position strength are combined. This is in line with the research of Lichtenthaler (2008) who finds that in his sample of medium sized and large firms, most firms pursue a relatively closed innovation strategy. Accordingly, a high degree of openness in the innovation process may only be observed in a minority of firms (Lichtenthaler, 2008).

The rather hesitant attitude towards using an open business model might be explained by the fact that, in practice, companies face a number of barriers in employing Open Innovation. The main barrier to Open Innovation in SMEs is related to the organizational and cultural issues which arise when SMEs start to interact and collaborate with external partners (Van de Vrande, et al., 2009). Another barrier considers the risk of losing R&D as a core competence. According to Prahalad and Hamel, Core competencies remain to be nurtured within the company to be competitive. Outsourcing R&D makes a core competence non-core (Carpay, Hang, & Yu, 2007). The problem is that companies will lose their capability to develop new technologies if they over(!)-rely on suppliers to innovate or make improvements. Another risk is that they lose their key technologies to third parties through know-how leakages and brain drain (Carpay, et al., 2007). The difficulty of protection and management of intellectual property becomes another drawback of open innovation (Carpay, et al., 2007). The less successful companies in our dataset (in terms of innovation performance) have a more open approach to Open Innovation. This openness might be caused by the fact that these companies do not treat or consider R&D as their core competence. Since R&D is not a core

competence, it is expected that they do not excel and outperform competitors through R&D, which explains low innovation performance (they may perform economically well).

To successfully shift from closed to open innovation, companies must meet four management requirements, i.e. inter-organizational networks, organizational structures, evaluation processes and knowledge management systems, along which change could be managed and stimulated (Chiaroni, Chiesa, & Frattini, 2010). Firms that are relatively closed also appear to realize that sufficient openness is necessary to keep up with their competitors (Lichtenthaler, 2008). Therefore, firms implementing open innovation require the establishment of extensive networks of inter-organizational relationships with a number of external actors (Chiaroni, et al., 2010). Also, companies need to use new evaluation criteria to focus more on external sources of innovation (Chiaroni, et al., 2010). These are both characteristics that are found in the successful group of companies in our dataset.

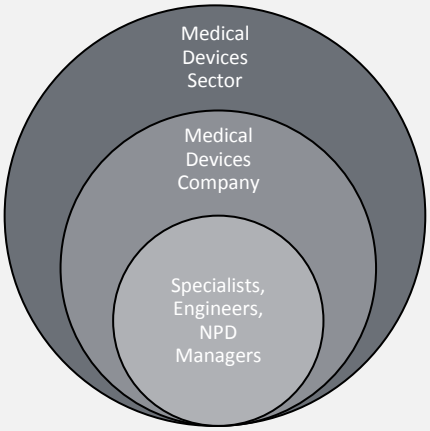
Openness is more relevant for big firms, but is more important and beneficial for small firms (Barge-Gil, 2010). Larger firms with a diversified product portfolio and with an emphasis on pursuing radical innovations have adopted more open approaches to innovation than the remaining firms (Lichtenthaler, 2008). Instead of large firms pursuing radical innovations, our dataset consist of SMEs that focus mainly on incremental innovations. Based on Lichtenthaler (2008) it seems to be, that an open approach is in this context less appropriate and beneficial. An open approach, especially in technology exploitation, may be particularly important and beneficial for firms that aim to develop radical innovations. For a successful commercialization of radical innovations, a more open approach in commercializing technological knowledge appears to be essential (Lichtenthaler, 2008).

SMEs acknowledge the necessity of open innovation, since they often lack resources to develop and commercialize new products in-house. As a result, they are more often inclined or forced to collaborate with other organizations (Van de Vrande, et al., 2009). Firms that are relatively closed also appear to realize that sufficient openness is necessary to keep up with their competitors (Lichtenthaler, 2008). Open Innovation will be a necessity rather than an option to keep up with the firm's competitors (Lichtenthaler, 2008). However, in practice, companies have a rather hesitant attitude towards using an open business model, because of the risk of core competences becoming non-core. In addition, as shown in this research, openness is not always beneficial. For SMEs that focus on incremental innovation projects a relatively closed approach to Open Innovation is most beneficial in terms of innovation performance.

4. Practical Implications and Contributions

This dissertation has implications for the three layers in the ecosystem that surround and include the company (see figure 1). The research not only has implications for SMEs in the medical devices sector, but also for specialists and NPD managers within the company and for the medical devices sector.

Figure 1: Ecosystem



Implications for individual specialists and NPD managers within the company

The research shows the importance of a well-defined strategy and focus for partner selection. It shows that partners need to be selected on grounds of resource complementarity, rather than on grounds of trust. Individuals within the company should be well aware of the value of the resources they possess, like for instance knowledge and expertise, in collaborating and exchanging resources with external partners. individuals within the company should not trust their collaboration partners blindfolded and exchange resources unthinkingly. A businesslike approach to collaboration should be pursued.

Implications for medical devices companies (SMEs)

First, it highlights the need for managers to focus on their network for high innovation performance instead of the internal NPD organization. It helps them to understand the multiple network characteristics that are important and the ways they must be combined for high innovation performance. Our findings highlight the need for managers to understand the multiple variables that are important characteristics of the way network characteristics are combined and the ways they

should be combined. This thesis provides clarity on which network characteristics to focus on when the goal is new product development. In addition it highlights the importance of considering the network characteristics in combination as they strongly interact with each other. Which implies that changing one network characteristic impacts the total network configuration. A businesslike approach towards collaboration, leads to high innovation performance. The more "soft and friendly" approach towards collaboration is found to be less successful for NPD.

Finally, the systems approach with profile deviation used in our study and the results we obtained may be useful to managers from a benchmarking perspective. The benchmark can be used to evaluate the way a company organizes its NPD network in comparison to the way high performing companies in the same industry organize their NPD network. This offers managers a guideline for improving innovation performance through their network configuration.

Implications for medical devices sector initiatives

These findings also have practical implications for the numerous innovation initiatives, platforms, and associations that are initiated by for instance governments or industry associations. Up till now, activities of these associations mainly focus on getting to know one another, sharing experiences, company visits, and the like. Adding activities that focus more on resource complementarity of members, rather than on these more softer concepts might provide additional and effective activities for members which help them improve innovation performance and increase the added value of innovation platforms.

Table 1 presents an overview of the research findings, theoretical contributions and practical contributions of each research phase.

Table 1: Overview of the Research Findings and Contributions

Chapter	Research Phase	Research Findings	Theoretical Contribution	Practical Contribution	Related Article
1	**Phase 1: Pilot Study** Relationship between internal organization and innovation performance	SMEs in a highly regulated sector like the medical devices sector cannot distinguish themselves from competitors through their internal NPD organization	Demonstrates that the internal NPD organization does influence innovation performance not under all circumstances: research context matters	Shows management to focus rather on the external network than on the internal NPD organization in the context of innovation performance	Pullen, A.J.J., Cabello-Medina C., De Weerd-Nederhof, P.C., Visscher, K. (2009); Development process effectiveness to achieve high innovation performance in the Spanish medical devices sector ***Accepted to be included in the 2nd EITIM BOOK, to published 2010 by Palgrave***
2					Pullen, A.J.J., De Weerd-Nederhof, P.C., Groen, A.J., Song, M., Fisscher, O.A.M. (2009); Successful Patterns of Internal SME characteristics leading to high overall innovation performance; ***Creativity and Innovation Management;*** **18(3); pp.209-223**
3	**Phase 2**: Identification of network variables in the context of new product development	"Goal alignment", "resource complementarity", "trust", "strength of ties" and "network position strength" are the most relevant NPD related network characteristics of the SME	Development of a measurement instrument Construction of a new and reliable measurement scale for structural network characteristics: "network position strength" Trust is found to be multi-dimensional instead of uni-dimensional.	Provides clarity on which network characteristics to focus on when the goal is new product development	Pullen, A.J.J., Fisscher, O.A.M., Groen, A.J., De Weerd-Nederhof, P.C. (2010); Measuring the Network – Innovation Performance: The Development of an Adequate Measurement Instrument ***In proceedings of the "R&D Management Conference 2010", 30 June-1 July 2010, Manchester, UK***
4	**Phase 3:** Relationship between innovation performance, product innovativeness and network configuration	The interaction between the network characteristics taken as a set is what impacts innovation performance. The network characteristics in solitude have no significant impact on innovation performance.	Demonstrates the utility and significance of configuration theory in organization research	Highlights the importance of considering the network characteristics in combination as they strongly interact with each other	Pullen, A.J.J., Groen, A.J., De Weerd-Nederhof P.C., ,Fisscher,' O.A.M. (2010); SME product innovativeness and network characteristics for high innovation performance: What really counts in the medical devices sector ***In proceedings of the "17th International Product Development Management Conference (IPDMC)", 13-15 June 2010, Murcia, Spain***
5	**Phase 4:** Organization of the network configuration in relation to the innovation performance	A network configuration that combines high levels of resource complementarity, goal differences, fairness trust, and reliability distrust with a below average level of network position strength is related to high innovation performance.	Demonstrates, both quantitatively as well as qualitatively, that a businesslike way of networking is related to high innovation performance in contrast to past research findings	Benchmark tool to evaluate the companies' own network configuration in relation to the way high performing companies organize their NPD network	Pullen, A.J.J., Groen, A.J., De Weerd-Nederhof P.C., Fisscher, O.A.M. (2010); Organizing NPD network for high innovation performance: The case of Dutch medical devices SMEs ***In proceedings of the "High Tech Small Firm Conference 2010 (HTSF)", 27-28 May 2010, Enschede, The Netherlands***

5. Research Limitations and Future Research

There are several limitations with respect to this study which offer directions for future research.

Research Approach

In order to study the organization of NPD (ego) networks in relation to innovation performance, in this research social systems theory (Parsons, 1964) was used. Inspired by this theory Groen a.o. developed the idea that interaction between actors is considered to add value in terms of strategic capital, social capital, cultural capital and economic capital can be used for analyzing business value creation processes (Groen, 2005).

A more specified approach for studying network – innovation performance issues is the absorptive capacity theory (Cohen & Levinthal, 1990) in which the benefit a firm can obtain from external knowledge is highly dependent on the firm's existing knowledge (Barge-Gil, 2010). It specifically focuses on the cultural capital aspect of social systems theory. Organizational units require external access and internal capacity to learn from their pears. Networks are an important part of a learning process in which organizational units discover new opportunities and obtain new knowledge through interacting with one another (Stock, Greis, & Fischer, 2001; Tsai, 2001; Zahra & George, 2002).

Using absorptive capacity theory enables one to study issues concerning knowledge management (as part of cultural capital in the social systems perspective) in the context of networks and innovation performance more in-depth. Using both absorptive capacity theory and social systems theory and combining these results would gain additional insights in the successful organization of NPD networks.

Sample bias

First, there is a limitation with respect to sample bias. The companies that participated in this research were selected based on their size and activity in new medical product development. One might expect that companies that give more priority to new product development and are receptive to collaboration networks are more interested in participating in this study than companies that find collaboration networks of minor importance. It would be interesting to examine how this latter group of companies organize their new product development networks. Is it possible that these companies are so efficiently organized and well-trained in new product development that they consider collaboration a normal

day-to-day business? Or is it possible that these companies are stubborn and suffer from the not-invented-here syndrome?

Sample Size

A methodological limitation is the limited sample size. This forced us to categorize the scores for innovation performance in the categories low, medium, and high even though we have the precise factor scores for innovation performance at hand. Using factor scores might present an even more subtle approach to explain differences in innovation performance. Given the current sample size, the conceptualization of fit that is most consistent with the logical arguments of configuration theories is the systems approach to fit (Doty, et al., 1993). This is the approach we used. Extending the dataset provides future research with the possibility to also examine the network configuration of the 15% lowest performing organizations.

An additional methodological limitation concerning sample size is the fact that the number of highly innovative NPD projects in the dataset was rather limited. The vast majority represented low or moderately high innovative NPD projects. This might be explained by the fact that the research focused on SMEs in highly regulated sectors. However, since theory underlines the importance of both incremental and radical innovation, gathering additional data on highly innovative NPD projects might provide additional insights.

Industry focus

In examining fit-performance relationships, the configuration theory literature advocates the use of single industry studies to control for industry effects and isolate more effectively the relationships of interest (Vorhies & Morgan, 2003). In this thesis we focused on one single industry: the medical devices industry. Even though we expect the research results to be also applicable in other highly regulated sector, cross-industry studies might shed additional light on the organization of networks in relation to innovation performance. Other highly regulated sectors which might be included are the biotechnology sector (Senker, 1991) and the commercial space sector (Carayannis & Samanta Roy, 2000).

Time Span

A final suggestion for future research considers the added value of longitudinal research. New product development and innovation are dynamic concepts that change over time. Due to the limited time frame of our study, we measured innovation performance and network characteristics at one point in time. It might

be interesting to see how the organization of the network and the innovation performance of a company changes over time due to, for instance, regulatory changes or technological advancements.

Internal-External Interaction

Due to increased collaboration between companies and actors that operate in both the internal and external company environment, company boundaries become blurred. The dividing line between internal and external NPD organizations is becoming increasingly difficult to indicate. It was outside the scope of this research to examine the interaction between internal and external NPD organization. Future research might focus on this issue as a clear insight in the interaction between internal and external NPD organization enables one to really consider companies as holistic entities

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Appendix 1

The Patterns in New Product Development Questionnaire

"Patterns in New Product Development"

In the questionnaire you will find instructions for each set of questions. We understand that in some cases you may find that the particular question does not entirely fit your case. Whenever such situations happen, please use your best judgment to answer the question and try not to skip it. We sincerely appreciate your efforts in completing all questions.

Please note that individual responses will be strictly confidential and only known to the research team. However, sometimes it is relevant to us to cite a company name. We will always ask written permission in these cases. Please indicate whether you want to stay anonymous in all cases, and/or whether we may contact you again for further collaboration

☐ Yes, I wish to remain anonymous in all cases

☐ Yes, I am happy to be contacted again

Thank you very much for your cooperation!

Your name:	
Your email address:	
Your telephone number:	
Your position within the organization:	
The name of your business unit (if applicable):	
Your mailing address:	

DESCRIPTION OF THE STRATEGIC BUSINESS UNIT

1. What is the name of your business unit?

2. What best describes your business unit (tick one)

- ☐ Independent company — Go to 4
- ☐ A division / business unit belonging to a parent company — Go to 3
- ☐ A single location / plant — Go to 3

3. What is the name of your parent company?

4. What is the year of establishment of your business unit?

5. What is the primary geographic region where you do business?

- ☐ Limited to a single location
- ☐ Spread out over a single geographic region
- ☐ Nationwide
- ☐ International

6. Please answer the next questions about the size of your business unit:

What are total annual sales?		Million EUR
What is the total number of employees in full time equivalent?		FTE

7. How would you describe the primary product mix (tick one)?

- ☐ High volume/high mix
- ☐ High volume/low mix
- ☐ Low volume/ High Mix
- ☐ Low volume/low mix

PRODUCTS AND PROCESSES

8. Identify the Core Products for which you will answer all questions in the questionnaire.

9. Please indicate the industry sector for this Core Product [SIC code(s)]:

10. What proportion of your customer orders for the Core Products identified are:

- % Industrial products (products to be used by other companies for their transformational processes).
- % Consumer products (products are intended to the final consumer market and no more transformations).

11. Please indicate the type of process that is used to manufacture your Core Products (Tick one answer):

- ☐ Engineer to order: Design, purchasing, manufacturing and assembly is done for a designated customer. (Go to 12)
- ☐ Manufacture to order: Design, raw materials, and components are in stock. (Go to 13)
- ☐ Assemble to order: Just subsystems and subassemblies are in stock and the final assembly occurs based on a designated customer order. (Go to 13)
- ☐ Produce to stock: Products are produced and are kept in stock near the customer or at the company. (Go to 13)

12. Please specify the influence of customer demand (Tick one answer).
When an order arrives we start our engineering activities based upon …

- ☐ … pre-defined product families.
- ☐ … pre-defined product sub-functions and solution principles.
- ☐ … pre-defined product modules.
- ☐ … pre-defined generally detailed finished goods.

ENVIRONMENT

13. Each of the following items consists of a pair of statements, which represent two extremes on characteristics of your industrial sector (as filled in for your Core Products) or on your business unit. Please circle the number on the scale that best approximates the actual conditions.

a.	**Safe**, little threat to the survival and well being of the organization.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	**Risky**, one false step can mean my organization's undoing.
b.	**Rich opportunities** in investment and marketing.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	**Few opportunities**, stressful, hostile, hard to keep afloat.
c.	A **dominant organization** that can control and manipulate the environment to its own advantage.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	A **dominating environment** in which our initiatives count for very little against environmental forces.
d.	Our organization **must rarely change** its practices to keep up with the market and competitors.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	Our organization **must frequently change** its practices.
e.	The rate at which products are getting obsolete in the industry is **low**.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	The rate at which products are getting obsolete in the industry is **high**.
f.	Actions of competitors are **easy to predict**.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	Actions of competitors are **unpredictable**.
g.	Demand for the product and consumer tastes are **easy to predict**.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	Demands for the product and consumer tastes are **unpredictable**.
h.	The production technology is subject to **little change**.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	The production technology is subject to **much change**..

i.	The nature of the competition is about **the same** for all products.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	The nature of the competition **varies a great deal** from one product to another.
j.	The required methods of production are about **the same** for all products.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	The required methods of production **vary a great deal** from one product to another.
k.	Customers' buying habits are about **the same** for all products.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	Customers' buying habits **vary a great deal** from one product to another.

BUSINESS STRATEGY

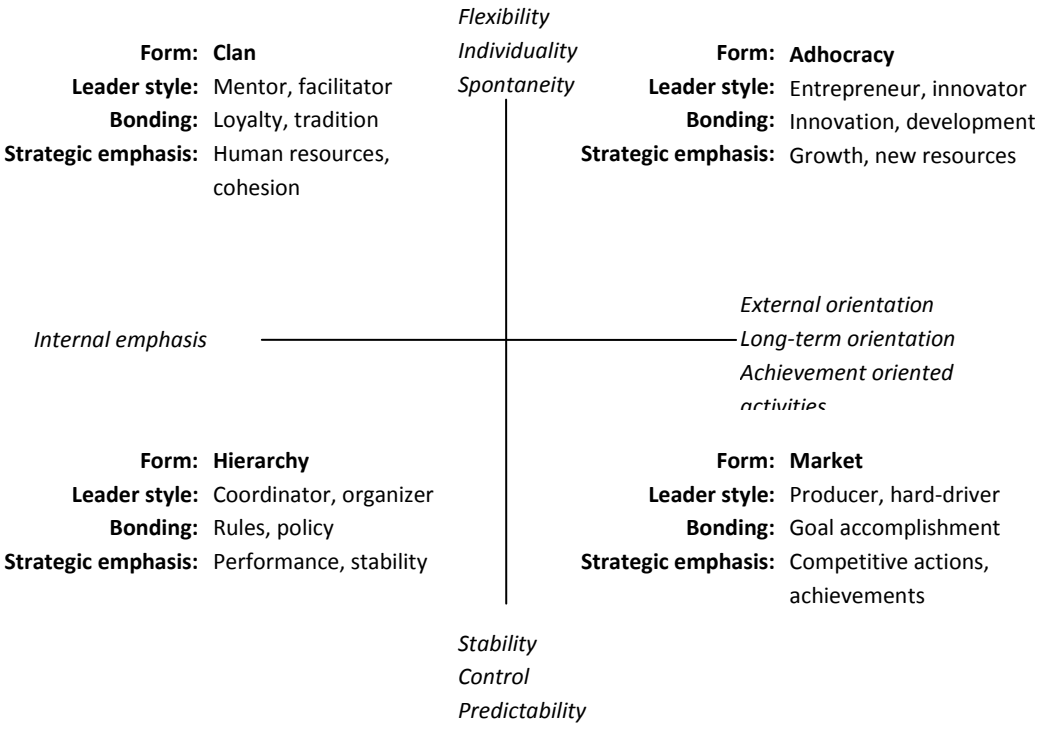
14. Which of the texts below most closely describes your business unit's approach your Core Product's marketplace?

- ☐ We continuously search for market opportunities and regularly experiment with potential responses to emerging environmental trends. Therefore, we often are the creators of change and uncertainty to which our competitors must respond.
- ☐ We attempt to maintain a stable, limited line of products or services, operating routinely and efficiently through the use of formalized structures and processes. At the same time, we monitor a carefully selected set of promising new product and market developments in different industries.
- ☐ We have narrow product-market domains. Our top-managers are experts in their business-limited area of operation but do not tend to search outside of their domains for new opportunities. We seldom need to make major adjustments in our technology, structure, or methods of operation. We devote primary attention to improving the efficiency of our operations.
- ☐ We frequently perceive change and uncertainty occurring in our organizational environments but are unable or unwilling to respond effectively. We lack a consistent strategy-structure relationship, and we

seldom make adjustments of any sort until we are forced to do so by environmental pressures.

BUSINESS UNIT'S CULTURE

15. Please have a look at the picture below visualizing various types of organizational culture. Which of these most closely describes your *business unit's*



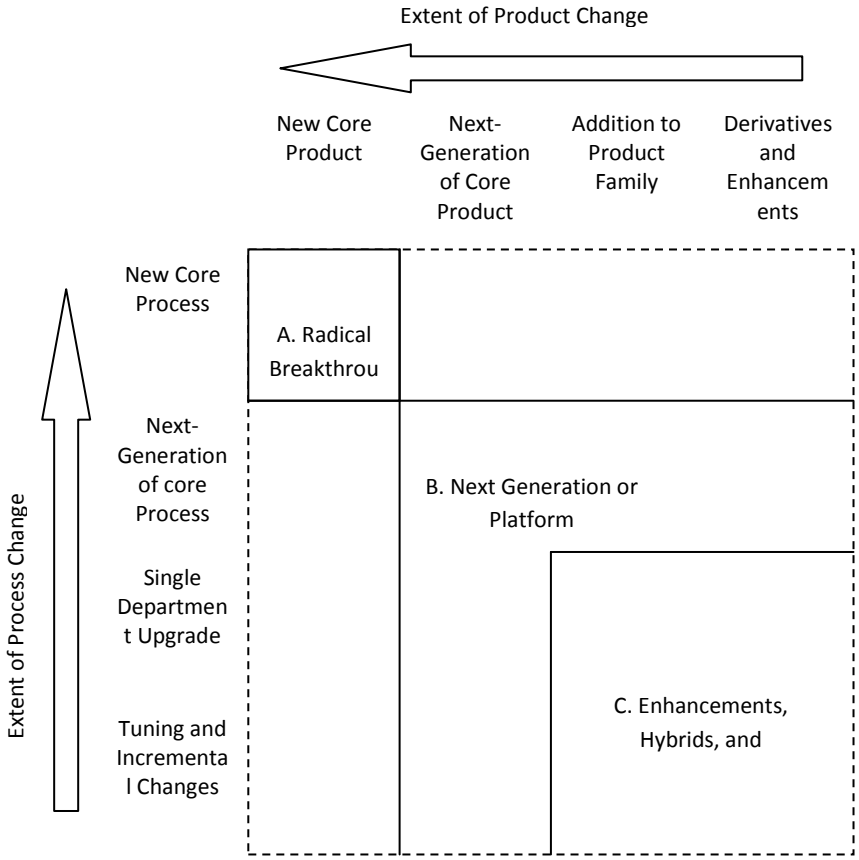
culture (choose one)?

- ☐ Clan
- ☐ Adhocracy
- ☐ Hierarchy
- ☐ Market

DESCRIPTION OF THE NEW PRODUCT DEVELOPMENT FUNCTION

With the *NPD Function*, the set of activities necessary to initiate, coordinate, and accomplish the product and related production process development activities of the business unit is meant. Please note therefore that the NPD function includes but is not necessarily restricted to the activities of the NPD department.

16. Please estimate the percentage of your organization's total new product development activities accounted for by the Core Products of each of the following three types.



%	A. Radical breakthroughs in core products and processes
%	B. Next generation of core product and / or process
%	C. Enhancements, hybrids, and derivatives of core product and or process
100 %	

17. Please distribute the percentages of your total annual sales (as filled in in question 6) originating from the following types of new products which have been introduced the last **three** years (the total sums up to 100%).

%	Breakthrough new products
%	Next generation new products
%	Addition to Product Family and/or Derivatives/Enhancements
%	Non modified products
100 %	

18. Please indicate below for which part of the NPD function you are responsible (more than one answer is possible):

☐ Radical Innovation (Breakthrough New Products and/or Next Generation)

☐ Incremental Innovation (Addition to Product Family and/or Derivatives/enhancements)

19. Please answer the following questions about the size of your NPD function:

What is your total NPD budget in % of annual sales?	
How is this divided over the different types of NPD activities?	☐ Not divided ☐ Radical Innovation: ___ % ☐ Incremental Innovation:__ %
What is the total number in fulltime equivalent of employees in NPD?	
How is this divided over the different types of	☐ Not divided

NPD activities?	☐ Radical Innovation: ___ fte ☐ Incremental Innovation:__ fte

OPERATIONAL EFFECTIVENESS AND STRATEGIC FLEXIBILITY OF YOUR NPD FUNCTION

20. In this section please indicate your level of achievement on objectives concerning the *fit with market demands* achieved by your NPD function and the ability to *anticipate* on them.

		Not at all achieved						Very well achieved	Don't know
a.	Our new products meet customer requirements.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	Our new products are delivered on time.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	The cost of our new products is satisfactory.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
d.	The quality of our products is good.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
e.	The impact of our NPD program on our sales level is positive.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
f.	We get good returns from our NPD program relative to our spending on it.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
g.	Our current development projects include new product-market options.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
h.	We prefer NPD projects that generate options for future product development	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
i.	NPD is successful in opening new markets to our organization.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
j.	NPD is successful in leading our organization into new product areas.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

k.	Our NPD activities open new technologies to our organization.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
l.	We incorporate solutions to unarticulated customer needs in our new products.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

21. In this section please indicate your level of achievement on objectives concerning the *fit with firm competences* achieved by your NPD function and the ability to *build* these competencies.

		Not at all achieved						Very well achieved	Don't know
a.	The degree of manufacturing cost advantage that NPD provides is satisfactory.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	Few manufacturing problems occur during production start-up phases.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	Only few product design changes are needed to solve manufacturing performance.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
d.	Marketing and NPD often share information.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
e.	Conflicts between marketing and NPD are of a constructive kind.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
f.	Marketing and NPD are more like teammates than competitors.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
g.	Our competence to explore new technological developments from inside the BU is well developed	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
h.	We built upon manufacturing competences for the exploration of new technological developments	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
i.	We are very much inspired by marketing for the development of	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

	new ideas form inside the BU.								
j.	We can pass lessons learned on across organizational boundaries.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
k.	We can pass lessons learned on over time.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
l.	We are able to enhance our competences by tapping into external sources	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

In the following section please indicate your level of achievement on objectives concerning the *speed* of the processes carried out by your NPD function as well as your ability to *anticipate* on future time constraints.

You may first want to take a look at this figure that shows the concepts of Development Time, Concept To Customer time and Total Time which are used in this question.

Stage	**0**	**1**	**2**	**3**	**4**
Name	**Concept generation**	**Project evaluation**	**Development**	**Manufacturing development**	**Commercialization**
Starting activity	Surfacing of idea	Developing of specs	Spending on physical development	Documentation of process development	Production trials (End: manufacturing for sales)
			Development Time (DT)		
		Concept To Customer time (CTC)			
Total Time (TT)					

22. Please indicate your level of achievement on following objectives:

		Not at all achieved						Very well achieved	Don't know
a.	Our new products are launched on schedule.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

		1	2	3	4	5	6	7	
b.	Scheduled time is in line with total development time (TT).	☐	☐	☐	☐	☐	☐	☐	☐
c.	Our Development Time (DT) is satisfactory.	☐	☐	☐	☐	☐	☐	☐	☐
d.	Our Concept to Customer Time (CTC) is satisfactory.	☐	☐	☐	☐	☐	☐	☐	☐
e.	Our Total Time (TT) is satisfactory.	☐	☐	☐	☐	☐	☐	☐	☐
f.	The speed of the NPD decision making process is satisfactory.	☐	☐	☐	☐	☐	☐	☐	☐
g.	We can estimate future requirements on our total development time (TT).	☐	☐	☐	☐	☐	☐	☐	☐
h.	We are able to adjust our NPD process to future time requirements.	☐	☐	☐	☐	☐	☐	☐	☐
i.	We can estimate future requirements on the speed of our NPD decision making process.	☐	☐	☐	☐	☐	☐	☐	☐
j.	We are able to adjust our NPD decision making process to future requirements.	☐	☐	☐	☐	☐	☐	☐	☐
k.	We are able to forecast the future requirements on the commitment to translating our NPD decisions into actions.	☐	☐	☐	☐	☐	☐	☐	☐
l.	We are able to adjust the commitment to translating NPD decisions into actions to the requirements.	☐	☐	☐	☐	☐	☐	☐	☐

23. In this section please indicate your level of achievement on objectives concerning the *productivity* of your NPD function as well as your ability to *anticipate* on future productivity constraints.

	Not at all						Very well	Don't

		achieved						achieved	know
a.	We can develop the same products with a lower budget than assigned.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	Development costs of our products hardly exceed budgets.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	Beyond-budget products do not exceed budgets with a large amount.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
d.	Our development costs are relatively low.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
e.	Realized development hours do not often exceed budgeted hours.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
f.	We can estimate the future internal cost requirements for our development process.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
g.	We are able to adjust our development process to the future cost requirements.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
h.	Our ability to predict future development costs is well developed.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
i.	We are well capable to adjust development costs	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
j.	We are able to adjust the number of development hours to future requirements.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

24. In this section please indicate your level of achievement on objectives concerning the *flexibility* of the processes of your NPD function as well as the ability to *anticipate* on future needs for operational process flexibility.

		Not at all achieved						Very well achieved	Don't know
a.	The average time of product enhancement is satisfactory.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

b.	The average time of product redesign is satisfactory.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	Our ability to change the design fast, after being confronted with new specs, is well developed.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
d.	The average cost of redesign is satisfactory.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
e.	We can process a change of specs without a lot of extra financial resources.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
f.	Our ability to change specs late is satisfactory.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
g.	We are able to forecast the requirements on the time of redesign.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
h.	We are able to adjust the average time of product redesign to future requirements.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
i.	We are capable in forecasting the future requirements on the cost of product redesign.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
j.	We are capable to adjust the average cost of product redesign to future requirements.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
k.	We are able to predict changes in specifications.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
l.	We are able to anticipate on changes in specifications.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

NPD PROCESS AND ROLES

25. Please check the box that most closely describes your business unit's incremental development processes. Please tick one answer.

☐ No standard approach to new product development.

☐ While no formally-documented process is followed, we have a

clearly understood path of the tasks to be completed in product development.

☐ We have a formally-documented process where one function completes a set of tasks, then passes the results on to the next function which completes another set of tasks.

☐ We have a formally-documented process where a cross-functional team completes a set of tasks; management reviews the result and gives the go-ahead for the team to complete the next set of cross-functional tasks.

☐ We have a formally-documented process where a facilitating "process owner" helps cross-functional teams move through stages and management reviews.

☐ We have a formally-documented process where a cross-functional team uses a staged process with overlapping, fluid stages and "fuzzy" or conditional stage decisions.

26. Please check the box that most closely describes your business unit's radical development processes. Please tick one answer.

☐ No standard approach to new product development.

☐ While no formally-documented process is followed, we have a clearly understood path of the tasks to be completed in product development.

☐ We have a formally-documented process where one function completes a set of tasks, then passes the results on to the next function which completes another set of tasks.

☐ We have a formally-documented process where a cross-functional team completes a set of tasks; management reviews the result and gives the go-ahead for the team to complete the next set of cross-functional tasks.

☐ We have a formally-documented process where a facilitating "process owner" helps cross-functional teams move through stages and management reviews.

☐ We have a formally-documented process where a cross-functional team uses a staged process with overlapping, fluid stages and "fuzzy" or conditional stage decisions.

27. The development of a new product is often described as a series of interdependent and possibly overlapping stages. Below are descriptions of several development activities. Please cross the activity if your business units' new product development process includes this activity. (Tick one or more answers for each type of innovation)

Incremental		Radical
☐	Project Strategy Development: Delineate the target market, determine market need, attractiveness.	☐
☐	Idea / Concept Generation: Identify opportunities and initial generation of possible solutions.	☐
☐	Idea Screening: Sort and rank solutions, eliminate unsuitable and unattractive options.	☐
☐	Business Analysis: Evaluate the concept financially, write business case, prepare protocol/development contract.	☐
☐	Development: Convert concept into a working product.	☐
☐	Test and Validation: Product use, field, market and regulatory testing with customers.	☐
☐	Manufacturing Development: Developing and piloting the manufacturing processes.	☐
☐	Commercialization: Launching the new product or service into full scale production and sales.	☐

28. Please indicate for each of the roles described below whether these behaviors can be identified throughout your NPD function.

	Present in NPD? [yes/no]	Limited to one phase					Throughout the whole NPD process
Idea Generator							
- searching for breakthroughs by linking diverse ideas - testing feasibility of ideas	☐ Yes ☐ No	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
Champion							
- sells new ideas to others in the organization and	☐ Yes ☐ No	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐

gets resources - recognizes, proposes and pushes a new technical idea for formal management approval							
Project Leader - provides the team leadership and motivation - plans and coordinates the diverse sets of activities and people involved in moving a demonstrated idea into practice	☐ Yes ☐ No	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
Gatekeeper - collects and channels information about important changes in the internal and external environments - passes information on to others	☐ Yes ☐ No	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
Sponsor - provides encouragement, guidance, and acts as a sounding board for the project leader and others - guides and develops less experienced personnel in their roles	☐ Yes ☐ No	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐

NPD STRATEGY

29. How important is the role of the following competitive priorities in your business unit's NPD strategy? Please indicate for each of the indicators if their priority has changed over the last three years and also if you expect their importance to change over the next three years.

	Over the last three years the competitive priority has							Over the next three years the competitive priority will							
	become less important			stayed the same		become more important		become less important			stay the same		become more important		Don't know
Product price	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Product functionality	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Conformance quality	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Time-to-market for new products	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Product design/innovation	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Product customization	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Product range	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Company reputation	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Environmentally sound products	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
Others, namely: _____	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

30. In this section please indicate your level of agreement with each statement about NPD strategy.

		Strongly disagree						Strongly agree	Don't know
a.	The role of NPD in achieving business goals is clearly articulated.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	There is a formally stated NPD strategy.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	We have clearly defined goals for all our	1	2	3	4	5	6	7	☐

	individual new products.	☐	☐	☐	☐	☐	☐	☐	
d.	Systematic project portfolio management is in place.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
e.	The project portfolios are aligned with the business strategy.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

31. Each of the following items consists of a pair of statements, which represent the two extremes on goals mentioned in your NPD Strategy. Please circle the number on the scale that best approximates the actual content of your NPD strategy.

a.	We primary focus on **long-term growth**.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	We primary focus on **short-term profit**.
b.	We primary focus on projects with **risky** outcomes.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	We primary focus on projects with **predictable** outcomes.
c.	We are mainly focused on creating **breakthrough** new products.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	We are mainly focused on creating **incremental** new products.
d.	We mainly focus on **long-term performance** of our NPD function.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	We mainly focus on **short-term performance** of our NPD function.

32. In this section please indicate your level of agreement with each statement about NPD technology strategy

		Strongly disagree						Strongly agree	Don't know
a.	We clearly identify technological areas that focus our NPD efforts.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

b.	Future technological trends are important in our NPD planning.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	Our project portfolio is balanced across technologies.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

33. In this section please indicate your level of agreement with each statement about NPD product strategy

		Strongly disagree						Strongly agree	Don't know
a.	We clearly identify future products as a focus of our NPD efforts.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	Future products are explicitly included in our NPD planning.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	Our project portfolio is balanced across products.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

34. In this section please indicate your level of agreement with each statement about NPD market strategy

		Strongly disagree						Strongly agree	Don't know
a.	The focus of our NPD efforts clearly relates to target markets.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	Future markets are explicitly addressed in our NPD planning.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	Our project portfolio is balanced across markets.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

NPD STRUCTURE

35. How are people within the NPD function organized?

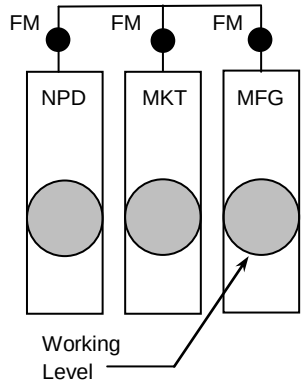
☐ Departments

☐ Project teams
☐ Matrix management
☐ Self-managed work teams
☐ Other

36. Please indicate which of the structures pictured and described in the next figure is the most common NPD structure within your business unit. Tick one option.
If the team structure for incremental innovation is different from the one for radical innovation please indicate the appropriate option (one per type)). If your NPD function is not divided, just fill in the appropriate structure for the whole NPD function.

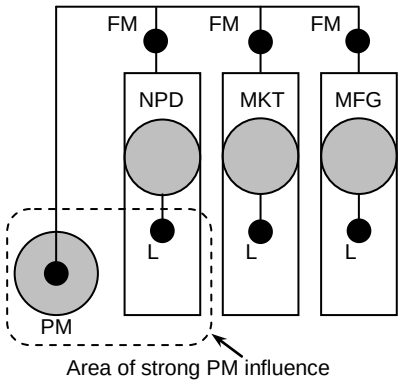
	One structure for whole NPD function:	Incremental Innovation	Radical innovation
Team structure A	☐	☐	☐
Team structure B	☐	☐	☐
Team structure C	☐	☐	☐
Team structure D	☐	☐	☐

Team Structure A



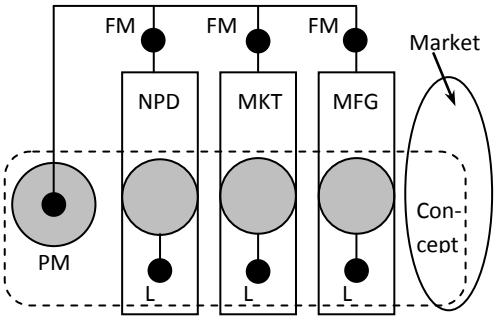
1. People are grouped principally by functional areas.
2. They work under the direction of a Functional Manager (FM).
3. Over time, primary responsibility for the project passes sequently from one function to the next.

Team Structure B



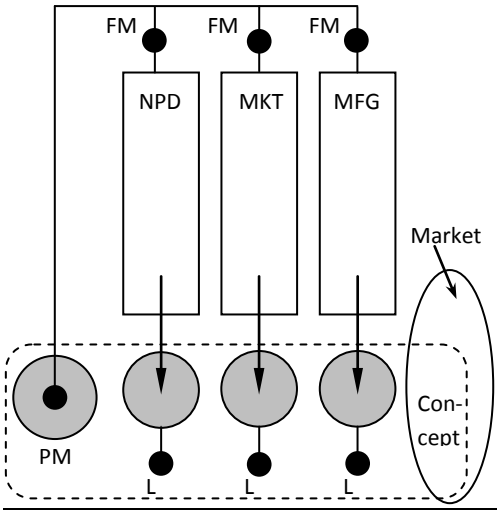
1. Like structure A, those assigned to the team reside physically in their functional areas
2. However, they designate a Liaison person (L) to "represent" it on a coordinating committee.
3. A Project Manager (PM) coordinates the different functions' activities. The Project Manager does not have power to reassign people or reallocate resources.

Team Structure C



1. Liaisons from the functions still reside in the team.
2. In contrast to structure B, the Project Manager (PM) has primary responsibility for the work of all those involved in the project.
3. However, team members are not

Team Structure D



1. Individuals from the different functional areas are formally assigned, dedicated, and co-located to the project team.
2. The Project Manager (PM) is given full control over the resources contributed by the different functional groups.

NPD CLIMATE

37. In this section please indicate your level of agreement with each statement regarding your overall innovative climate

		Strongly disagree						Strongly agree	Don't know
a.	People are emotionally involved in goals set.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	People have freedom to define their own work.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	There is a high level of trust between people.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

d.	There is time for people to develop unplanned new ideas.	1 2 3 4 5 6 7 ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐
e.	There is a relaxed atmosphere.	1 2 3 4 5 6 7 ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐
f.	There is a high level of conflict.	1 2 3 4 5 6 7 ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐
g.	There is a strong support for further development of new ideas.	1 2 3 4 5 6 7 ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐
h	People are involved in debates about differing viewpoints.	1 2 3 4 5 6 7 ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐
I	High risk taking behavior is tolerated.	1 2 3 4 5 6 7 ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐

38. If your radical innovation activities are organized separately from your incremental innovation, please indicate to what extent the climate in your more radical NPD differs from the overall innovative climate.

	In our radical NPD…	Strongly disagree						Strongly agree	Don't know
a.	The degree to which people are emotionally involved in goals is higher.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
b.	People have more freedom to define their own work.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
c.	There is a higher level of trust between people.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
d.	There is more time for people to develop unplanned new ideas.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
e.	There is a more relaxed atmosphere.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
f.	There is often a higher level of conflict.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
g.	There is a stronger support for further development of new ideas.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

h.	People are more involved in debates about differing viewpoints.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐
i.	Higher risk taking behavior is tolerated.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	☐

This is the end of the questionnaire. Thank you again for your cooperation!

Your answers will be treated with full confidentiality and the names of companies, business units, products or individuals will not be released!

Appendix 2

The Measurement Instrument for the Simultaneous Measurement of Network Characteristics and Innovation Performance

Question Theme	Reference	Item number in Table 6 "Rotated Component Matrix"
Question 1: Innovation Performance	based on Atuahene-Gima et al. (2005)	Q8.1 – Q8.5
Question 2: Resource Complementarity	based on Lambe et al. (2002)	Q19.1-Q19.6 & Q20.1-Q20.3
Question 3: Goal Alignment	based on Dess (1987)	Goal_Differences (= inverse of Goal Alignment)
Question 4: Goal Alignment	based on Dess (1987)	Goal_Differences (= inverse of Goal Alignment)
Question 5: Network Position Strength		Ties_Brokered_normalized & Inv_Density
Question 6: Trust,	based on Gulati and Sytch (2008)	Q25.1-Q25.2
Question 7: Distrust	based on Gulati and Sytch (2008)	Q25.4-Q25.6

The questionnaire is divided in four parts: Part A - General, Part B - Strategic network characteristics, Part C - Structural network characteristics and Part D - Relational network characteristics. Filling in the questionnaire will take approximately 40 minutes.

In the questionnaire you will find instructions for each set of questions. We understand that in some cases you may find that the particular question does not entirely fit your case. Whenever such situations happen, please use your best judgment to answer the question and try not to skip it. We sincerely appreciate your efforts in completing all questions.

PART A - GENERAL

Please indicate your contact details below.

Your name:

Your position within the organization:

Mailing address:

Your e-mail address:

Telephone nr.:

Company Description

1. What is the name of your company?

2. In which year was the company established?
If your company has multiple locations, please indicate the year in which the location you are working for was established.

3. How many Full Time Equivalents (FTEs) are present in the total company?

Please fill in the following question ONLY if your company has multiple locations

4. How many Full Time Equivalents (FTEs) are present in your location?

5. What is the nationality of your organization?

If you are part of a multinational, take the country in which your business unit is located as point of reference.

New Product (Medical Device) Development Project

6. Which new medical device development project in which your company was (preferably) project leader is most recently completed?
Please provide the project name and the name of the product that was developed.

N.B. If you are not able to answer the above question due to confidentiality, please check the box below

☐ Unable to answer this question due to confidentiality

7. Please indicate the innovativeness of the newly developed medical device by marking <u>one</u> of the categories below.

☐ New-to-world products (highly innovative)
☐ New product lines to the firm (moderately innovative)
☐ Additions to one of the firm's existing lines (moderately innovative)
☐ Improvements/ revisions to existing company products (low innovativeness)
☐ Cost reductions to existing costumers (low innovativeness)
☐ Repositionings of existing company products (low innovativeness)

8. Please rate the extent to which your firm has achieved the following product development objectives with the newly developed product you described in question 6.

	Low 1	2	3	4	5	6	High 7
8.1. Market share relative to the firm's stated objectives	☐	☐	☐	☐	☐	☐	☐
8.2. Sales relative to the firm's stated objectives	☐	☐	☐	☐	☐	☐	☐
8.3. Return on assets relative to the stated objectives	☐	☐	☐	☐	☐	☐	☐
8.4. Return on investment related to stated objectives	☐	☐	☐	☐	☐	☐	☐
8.5. Profitability relative to stated objectives	☐	☐	☐	☐	☐	☐	☐

9. In which year did this project start?

10. In which year was this project completed?

PART B - STRATEGIC NETWORK CHARACTERISTICS

Partner Diversity

Please indicate the external partners with whom you collaboratively executed this project on the supplementary sheet. This supplementary sheet helps you to remind the number you gave to the different external partners.

Please fill in the table below, based on the partners you filled in on the supplementary sheet that was provided.

	External Partner nr.									
	1	2	3	4	5	6	7	8	9	10
11. Please indicate the country of residence										
12. Please indicate the number of Full Time Equivalent (FTE) Answer categories: “1” = 1-50 FTE “2” = 51-150 FTE “3” = 151-250 FTE										
13. What was the role of the external partner in the project? Answer categories: “1” = idea generator “2”= champion/ entrepreneur “3” = project leader “4” = gatekeeper “5” = sponsor/coach										
14. Please provide the industry name in which the external partner is active										

15. **Please indicate the total number of external partners with whom you collaboratively executed the project that you previously described (in question 6)** ☐

16. **With which 3 external partners did you collaborate most during this project?**
please use the same nr. for the external partner as on the supplementary sheet

External partner A nr. ☐

External partner B nr. ☐

External partner C nr. ☐

Resource Exchange

17. **Which type of resource(s) that your company initially lacked does your company acquire (in the project of question 6) through the external network partner(s)?**
Please mark the resource(s) you acquire through your network in the list below. There is more than one answer possible.

☐ Financial resources

☐ Physical resources (e.g. materials, buildings)

☐ Human resources (e.g. personnel)

☐ Technological resources (e.g. patents, copyrights)

☐ Reputation

☐ Organizational resources (e.g. culture)

18. **Which type of resource(s) does your company give to your external partner(s) in exchange of the resources you acquire *[as indicated in the previous question]*?**
Please mark the resource(s) you offer your network partners in the list below. There is more than one answer possible.

☐ Financial resources

☐ Physical resources (e.g. materials, buildings)

☐ Human resources (e.g. personnel)

☐ Technological resources (e.g. patents, copyrights)

☐ Reputation

☐ Organizational resources (e.g. culture)

19. Please answer the questions below to indicate to what extent resources are developed during the project through combining the resources that the different partners contributed.

		Not true at all 1	2	3	4	5	6	Very True 7
19.1.	All of us (our company & external partner(s)) have created capabilities that are unique to this alliance	☐	☐	☐	☐	☐	☐	☐
19.2.	Together we have developed a lot of knowledge that is tailored to our relationship	☐	☐	☐	☐	☐	☐	☐
19.3.	Together we have invested a great deal in building up our joint business	☐	☐	☐	☐	☐	☐	☐
19.4.	All of us have made a great deal of investments in this relationship	☐	☐	☐	☐	☐	☐	☐
19.5.	If this relationship were to end, we would be wasting a lot of knowledge that is tailored to our relationship	☐	☐	☐	☐	☐	☐	☐
19.6.	If either company were to switch to another partner, we would lose a lot of investments made in the present relationship	☐	☐	☐	☐	☐	☐	☐

20. Please answer the questions below to indicate the to what extent the resources of the different partners complemented each other in the development project

		Strongly disagree 1	2	3	4	5	6	Strongly agree 7
20.1.	We all contribute different resources to the relationship that help us achieve mutual goals	☐	☐	☐	☐	☐	☐	☐
20.2.	We have complementary strengths that are useful to our relationship	☐	☐	☐	☐	☐	☐	☐
20.3.	We each have separate abilities that, when combined together enable us to achieve goals beyond our individual reach	☐	☐	☐	☐	☐	☐	☐

Goal Alignment

21. With which objective (goal) does your company cooperate with external partners in the project you described in question 6?

There is more than one answer possible.

		Not at all important				Extremely important
		1	2	3	4	5
21.1.	Net profit over five years	☐	☐	☐	☐	☐
21.2.	Rate of sales growth	☐	☐	☐	☐	☐
21.3.	Recognition as an innovative firm	☐	☐	☐	☐	☐
21.4.	Retaining key personnel	☐	☐	☐	☐	☐
21.5.	Employee satisfaction/morale	☐	☐	☐	☐	☐
21.6.	Development of new products	☐	☐	☐	☐	☐
21.7.	Net profit over one year	☐	☐	☐	☐	☐
21.8.	Firm prestige/reputation	☐	☐	☐	☐	☐
21.9.	Market penetration	☐	☐	☐	☐	☐
21.10.	Management development/selection	☐	☐	☐	☐	☐
21.11.	Lowest cost relative to competitors	☐	☐	☐	☐	☐
21.12.	Employee compensation and benefits	☐	☐	☐	☐	☐
21.13.	Growth in assets and reserves	☐	☐	☐	☐	☐
21.14.	Dividends distributed	☐	☐	☐	☐	☐
21.15.	Community service/goodwill in community	☐	☐	☐	☐	☐

22. With which objective (goal) do your external partners (who you listed on the supplementary sheet) cooperate with you?

There is more than one answer possible

		Not at all important				Extremely important
		1	2	3	4	5
22.1.	Net profit over five years	☐	☐	☐	☐	☐
22.2.	Rate of sales growth	☐	☐	☐	☐	☐
22.3.	Recognition as an innovative firm	☐	☐	☐	☐	☐
22.4.	Retaining key personnel	☐	☐	☐	☐	☐
22.5.	Employee satisfaction/morale	☐	☐	☐	☐	☐
22.6.	Development of new products	☐	☐	☐	☐	☐
22.7.	Net profit over one year	☐	☐	☐	☐	☐
22.8.	Firm prestige/reputation	☐	☐	☐	☐	☐
22.9.	Market penetration	☐	☐	☐	☐	☐

22.10.	Management development/selection	☐	☐	☐	☐	☐
22.11.	Lowest cost relative to competitors	☐	☐	☐	☐	☐
22.12.	Employee compensation and benefits	☐	☐	☐	☐	☐
22.13.	Growth in assets and reserves	☐	☐	☐	☐	☐
22.14.	Dividends distributed	☐	☐	☐	☐	☐
22.15.	Community service/goodwill in community	☐	☐	☐	☐	☐

PART C - STRUCTURAL NETWORK CHARACTERISTICS

23. In the table below, please mark the partners that have DIRECT ties with each other in the project you described in question 6.
Please use the same partner numbers as you filled in on the supplementary sheet.

N.B. Together with this questionnaire you received a supplementary sheet. This supplementary sheet helps you to remind the number you gave to the different external partners

			External Partner									
		You	1	2	3	4	5	6	7	8	9	10
	You	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
External Partner	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	9	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	10	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

PART D - RELATIONAL NETWORK CHARACTERISTICS

Strength of Ties

24. How close do you and your external partners (who you listed on the supplementary sheet) cooperate?

Please fill in the table below. Please use the same partner numbers as you filled in on the supplementary sheet.

	External Partner nr.									
	1	2	3	4	5	6	7	8	9	10
24.1. How many joint-design agreements did you sign with the partner during the relationship's overall duration? Please indicate the number [1,2,3 ….∞].										
24.2. What is the overall time-span between the subscription of the first joint-design agreement and the launch of the last joint-designed new product in the collaboration with the partner? Please indicate the number of years [1,2,3 ….∞].										
24.3. What is the number of individual years in which you and the partner have actually collaborated on joint activities during the relationship's overall duration? Please indicate the number of years [1,2,3 ….∞].										

Trust

25. To what extent do you trust your external partners?

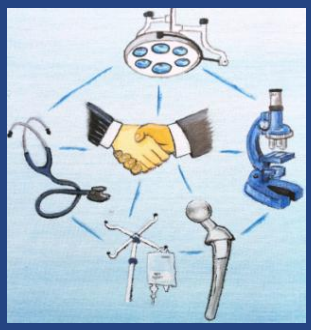
		Disagree strongly						Agree strongly
		1	*2*	*3*	*4*	*5*	*6*	*7*
25.1.	You trust these partner(s) to treat your fairly	☐	☐	☐	☐	☐	☐	☐
25.2.	You trust that confidential/proprietary information shared with these partners will be kept strictly confidential	☐	☐	☐	☐	☐	☐	☐
25.3.	The partner(s) have always been even handed in their negotiation with your company	☐	☐	☐	☐	☐	☐	☐
25.4.	These partners may use opportunities that arise to profit at your expense	☐	☐	☐	☐	☐	☐	☐
25.5.	Based on past experience, you cannot with complete confidence rely on this supplier to keep promises made to you	☐	☐	☐	☐	☐	☐	☐
25.6.	You are hesitant to transact with these partners when specifications are vague	☐	☐	☐	☐	☐	☐	☐

This is the end of the questionnaire

Thank you for taking the time to complete this questionnaire. If you have and queries please do not hesitate to contact me by telephoning +31534892024 or by e-mailing a.j.j.pullen@utwente.nl

Appendix 3

Additional Company Interview



ADDITIONAL COMPANY INTERVIEW

1. Could you please describe your company to me in short?
2. Could you describe the project you mentioned in Question 6 of the questionnaire in terms of functionalities of the device?
3. What is the position of your company in the supply chain of the product/device you refer to in Question 6 of the questionnaire?
4. Where was the project initiated? (internal or elsewhere?) Please explain.
5. Why did you decided to initiate the project/ Why did you decide to join in the project? (depends on answer previous question).
6. What was/were the biggest problem(s) you encountered in executing the project?
7. Now that the project is finished and knowing what you know now, what would you do differently in future projects?
8. Now that the project is finished and knowing what you know now, what would you do exactly the same in future projects?
9. To what extent is the product jointly developed (i.e. in close collaboration/ only delivery of resources in request etc.)?
10. How are the revenues of the project divided among partners?
11. To what extent did the project achieve the goals set?
12. What were the most important resources you received through the collaboration?
13. What were the most important resources you provided for your partners in the project?
14. How easily can partners be replaced?
15. To what extent do your partners in the project know each other (i.e. are they directly connected?)
16. To what extent do you trust your partners?

Summary in Dutch

Samenvatting in het Nederlands

Introductie

Dit onderzoek behandelt het thema hoe het midden- en klein bedrijf (MKB) nieuwe productontwikkeling organiseert.

Het MKB ziet zich aan de ene kant genoodzaakt om te innoveren en aan de andere kant ziet zij zich genoodzaakt tot samenwerking. Zowel financiële en personele, alsmede tijdsgebonden beperkingen zorgen ervoor dat MKB-bedrijven zich zo efficient mogelijk moeten organiseren en samenwerken om een zo hoog mogelijke prestatie te behalen. Met name op het gebied van innovatie en nieuwe productontwikkeling is dit van groot belang.

Onderzoekscontext: De Nederlandse sector van medische apparatuur

Een sector waar deze beweging duidelijk in te onderscheiden is, is de sector van medische apparatuur (medical devices). Deze industrie wordt gekenmerkt door strikte regelgeving, complexe producten, korte productlevenscycli, lange productontwikkeltijd, hoge ontwikkelingskosten en continue technologische vernieuwing. In deze veeleisende dynamische omgeving zien MKB-bedrijven zich genoodzaakt om samen te werken in de ontwikkeling van nieuwe medische apparatuur. De context waarin dit onderzoek is uitgevoerd is dan ook deze sector.

Onderzoeksachtergrond: via de interne organisatie naar de externe organisatie

De literatuur identificeert de interne en externe organisatie als twee factoren die de inovatieprestatie beïnvloeden. Daarbij wordt met name uitgebreid stilgestaan bij de interne organisatie. Echter, de praktijk laat zien dat de invloed van de externe organisatie toeneemt. Organisaties worden niet langer gezien als individuele entiteiten, maar steeds meer als actoren die in een gemeenschappelijk systeem opereren. Deze ontwikkeling is ook in dit proefschrift te onderscheiden. De nadruk komt steeds meer op de externe organisatie te liggen.

In hoofdstuk 1 en 2 wordt een pilot study naar de interne organisatie in relatie tot innovatieprestatie gepresenteerd. Deze interne organisatie bestaat enerzijds uit de effectiviteit van het product en anderzijds uit de efficiëntie van het productontwikkelingsproces. Uit de pilot study komt naar voren dat MKB-bedrijven in een streng gereguleerde sector zich moeilijk van elkaar kunnen onderscheiden middels producteffectiviteit. De strikte regelgeving is van toepassing op alle producten, wat betekent dat er slechts een beperkte mate van variatie aanwezig is in de kwaliteit, veiligheid, gebruiksvriendelijkheid, kosteneffectiviteit en werkzaamheid van producten. Wanneer MKB-bedrijven zich in termen van

innovatieprestatie willen onderscheiden via de interne organisatie, biedt de procesefficiëntie meer mogelijkheden dan de producteffectiviteit. Echter, door financiële, personele en tijdsgebonden beperkingen is het voor het MKB per definitie noodzaak om een efficiënt proces te hebben. Dit impliceert, dat MKB-bedrijven slechts weinig concurrentievoordeel kunnen behalen via de interne organisatie. Om concurrentievoordeel te behalen met een hoge innovatieprestatie is een focus op de externe organisatie wellicht een betere strategie voor MKB-bedrijven.

Naar aanleiding van de bevindingen van de pilot study wordt de focus in hoofdstuk 3, 4 en 5 verlegd naar de externe organisatie. De literatuur beschrijft duidelijk de positieve relatie tussen externe samenwerking in netwerken en innovatieprestatie. Echter, het academisch debat staat tot nu toe nog onvoldoende stil bij de vraag hoe bedrijven deze netwerken vorm zouden moeten geven. De vraag die in dit onderzoek centraal staat is dan ook:
"In welke mate kunnen verschillen in innovatieprestatie van MKB-bedrijven verklaard worden door verschillen in de organisatie van hun netwerk?"

Onderzoeksmethodologie: Aanpak en Resultaten

Om de bovenstaande vraag te beantwoorden is in hoofdstuk 3 een meetinstrument ontwikkeld voor het gelijktijdig meten van verschillende netwerkkarakteristieken en innovatieprestatie. Voor de ontwikkeling van dit meetinstrument is allereerst een literatuurstudie uitgevoerd naar de verschillende aspecten van netwerken die gerelateerd zijn aan nieuwe productontwikkeling (NPD). Uit deze literatuurstudie komt naar voren, dat "Resource Complementarity", "Goal Alignment", "Fairness Trust", "Reliability Distrust" en "Network Position Strength" de meest relevant en betekenisvolle netwerkkarakteristieken voor het MKB zijn in relatie tot NPD.
Vervolgens zijn deze netwerkkarakteristieken geoperationaliseerd en samengevoegd in het meetinstrument. Dit meetinstrument heeft de vorm van een self-administered questionnaire (zie Appendix 2). Het meetinstrument is door middel van factoranalyse en betrouwbaarheidstesten gevalideerd. Het uiteindelijke meetinstrument bevat de bovenstaande 5 netwerkkarakteristieken en innovatieprestatie.

Met behulp van het in hoofdstuk 3 ontwikkelde meetinstrument is data verzameld binnen 60 Nederlandse MKB-bedrijven die actief zijn in de ontwikkeling van nieuwe medische apparatuur (response rate 61,9%). In 50 van deze bedrijven zijn

aanvullende, semi-gestructureerde interviews (zie Appendix 3) afgenomen ter verduidelijking en toelichting op de ingevulde vragenlijst.

Als tweede stap in de beantwoording van de hoofdvraag van dit onderzoek is in hoofdstuk 4 gekeken naar de relatie tussen netwerkkarakteristieken en innovatieprestatie. In Hoofdstuk 4 staat vooral het belang van het bestuderen van configuraties van netwerkkarakteristieken centraal. Configuraties zijn intern consistente combinaties van organisatiekenmerken (in dit geval netwerkkarakteristieken). Oftewel in meer simpele bewoording: combinaties van verschillende netwerkkarakteristieken die één samenhangend geheel vormen. Zoals hoofdstuk 4 door middel van regressieanalyse laat zien, is het van belang om naar de combinaties van netwerkkarakteristieken te kijken in plaats van naar de individuele netwerkkarakteristieken. Dit omdat de analyse uitwijst dat deze combinaties een direct effect hebben op de innovatieprestatie. Het bestuderen van individuele netwerkkarakteristieken is ook vanuit het oogpunt van de praktijk minder relevant, aangezien organisaties niet uit één, maar uit combinaties van netwerkkarakteristieken bestaan.

De derde en laatste stap in het onderzoek wordt beschreven in hoofdstuk 5. In hoofdstuk 5 wordt onderzocht welke specificieke configuratie samenhangt met een hoge innovatieprestatie. Daartoe wordt onderscheid gemaakt tussen de 15% hoogst presterende bedrijven (top 15%) en de overige, lager presterende, 85% van bedrijven in de dataset (calibration sample).
Vervolgens wordt met behulp van de systems approach de netwerkconfiguratie van de top 15% bestudeerd. De combinatie van netwerkkarakteristieken die zij gebruiken is het zogenaamde ideaal profiel. Uit hoofdstuk 5 komt naar voren dat hoe verder de netwerkconfiguratie van een bedrijf van dit ideaal profiel afwijkt (dus hoe groter de afstand), hoe lager de innovatieprestatie is. De netwerkconfiguratie die is gerelateerd aan een hoge innovatieprestatie bevat een hoge mate van “Resource Complementarity”, “Goal Differences (lack of goal alignment)”, “Fairness Trust” en “Reliability Distrust”, gecombineerd met een lage “Network Position Strength”.

Theoretische Implicaties

De resultaten van de pilot study dragen bij aan de innovatiemanagement literatuur, aangezien de studie laat zien dat de interne NPD organisatie niet in iedere context van grote invloed is wanneer hoge innovatieprestatie wordt nagestreefd. Dit betekent dat de interpretatie van eerdere onderzoeksresultaten sterk afhangt van

de onderzoekscontext. Ook betekent dit, dat over de mate van generaliseerbaarheid van eerder onderzoek gediscussieerd kan worden.

Het meten van innovatiegerelateerde netwerkkarakteristieken

De resultaten dragen op verschillende manieren bij aan de netwerk- en innovatiemanagement literatuur. In het bijzonder met betrekking tot de vraag welke netwerkkarakteristieken in acht genomen moeten worden in de context van NPD. De literatuurstudie en de daaruit voortvloeiende selectie van netwerkkarakteristieken houdt niet alleen rekening met de grote hoeveelheid beschikbare netwerkkarakteristieken, maar ook met hun heterogene betekenis. Door te kijken naar het laagste niveau van operationalisatie, het item niveau, en door gelijke items te groeperen is het heterogeniteitsprobleem verholpen. Op basis van deze literatuurstudie is het eerder beschreven meetinstrument ontwikkeld. Niet alleen dit meetinstrument, maar ook het nieuw ontwikkelde construct "Network Position Strength" draagt bij aan de literatuur. Ook toont dit onderzoek aan dat "Trust" zowel theoretisch als empirisch niet een één-dimensionaal, maar een twee-dimensionaal construct is. De eerste dimensie is getypeerd als "Fairness Trust". Dit heeft betrekking op de verwachting dat een partner eerlijk zal onderhandelen. De tweede dimensie is getypeerd als "Reliability Distrust" en heeft betrekking op de verwachting dat een partner afspraken na zal komen. In de praktijk betekent dit dat bedrijven zowel "Fairness Trust" als "Reliability Distrust" jegens hun partners kunnen hebben.

De toepasbaarheid van configuratietheorie

Behalve aan netwerk- en innovatiemanagement literatuur draagt dit onderzoek ook bij aan configuratietheorie. Configuratietheorie stelt dat er voor iedere set van organisatiekenmerken een ideale set (combinatie) bestaat die leidt tot hoge prestatie. De relatie tussen individuele netwerkkarakteristieken en innovatieprestatie is in dit onderzoek niet significant bevonden. Echter, de combinatie van netwerkkarakteristieken, de netwerkconfiguratie, heeft wel een sterk, significant effect op de innovatieprestatie. Dit geeft het belang en de toepasbaarheid van configuratietheorie in organisatieonderzoek weer.

Open Innovatie in theorie en praktijk

Het onderzoek draagt bij aan de theorie door te laten zien welke netwerkconfiguratie is gerelateerd aan een hoge innovatieprestatie in een specifieke context. Zoals eerder beschreven is een hoge mate van "Resource

Complementarity", "Goal Differences (lack of goal alignment)", "Fairness Trust" en "Reliability Distrust", gecombineerd met een lage "Network Position Strength" gerelateerd aan een hoge innovatieprestatie. In tegenstelling tot eerder onderzoek laat dit onderzoek zowel kwantitatief als kwalitatief zien, dat een zakelijke manier van samenwerken en een gesloten benadering richting "Open Innovation" leiden tot hoge innovatieprestatie.

Theorie laat zien dat het MKB in toenemende mate het concept van "Open Innovation" toepast. Echter in de praktijk, zoals ook aangetoond in dit onderzoek, kiezen succesvolle (MKB) bedrijven een meer gesloten benadering richting "Open Innovation". Bedrijven zijn enigszins terughoudend om een open business model toe te passen, omdat dan het gevaar optreedt dat core competences non-core worden. Relatief gesloten organisaties, met name MKB-bedrijven, beseffen terdege dat een bepaalde mate van openheid nodig is in de vorm van samenwerking om de concurrentie in termen van innovatie bij te houden. Verregaande openheid leidt voor MKB-bedrijven in de sector van medische apparatuur echter niet altijd tot een hoge innovatieprestatie, zoals aangetoond in dit onderzoek.

Management Implicaties

Dit onderzoek heeft implicaties voor alle drie de niveaus van het eco-systeem waar de organisatie deel van uitmaakt. Het eerste niveau bevat de individuele specialisten in de organisatie. Een duidelijke strategie en focus met betrekking tot het selecteren van samenwerkingspartners is van groot belang. Individuen binnen de organisatie moeten de bronnen die zij bezitten in de vorm van kennis en kunde goed op waarde weten te schatten wanneer zij samenwerken en bronnen uitwisselen met externe partners.

Het tweede niveau van het eco-systeem is het bedrijfsniveau. Ten eerste laat dit onderzoek zien dat de organisatie van het externe netwerk meer mogelijkheden biedt voor het MKB dan de interne organisatie wanneer hoge innovatieprestatie wordt nagestreefd. Ook maakt dit onderzoek duidelijk dat de combinatie van verschillende netwerkkarakteristieken van belang is in tegenstelling tot een focus op slechts één karakteristiek. Ten derde toont dit onderzoek aan dat een zakelijke benadering van externe samenwerking tot een hogere innovatieprestatie leidt dan een meer open benadering. Tenslotte biedt dit onderzoek MKB-bedrijven in de sector van medische apparatuur een benchmark tool. Dit stelt bedrijven in staat om hun eigen innovatieprestatie en netwerkconfiguratie te meten en te vergelijken met de top 15% best presterende bedrijven.

Het derde niveau waar dit onderzoek betrekking op heeft is het niveau van medische brancheorganisaties en sector initiatieven. Tot op heden richten dergelijke initiatieven zich vaak op het leggen van contacten, uitwisselen van ervaring en bedrijfsbezoeken. Het toevoegen van activiteiten die zich meer richten op de mate waarin leden elkaars bronnen kunnen aanvullen zou leden aanvullende en effectieve mogelijkheden bieden voor het verhogen van de innovatieprestatie. Ook neemt hierdoor de toegevoegde waarde van dergelijke initiatieven toe.