The influence of innovation activities and organization structure on the technological and commercial performance of large established companies in the medical device industry

Kirsten Janssen | Master Health Sciences | University of Twente

The influence of innovation activities and organization structure on the technological and commercial performance of large established companies in the medical device industry

Author:
Kirsten Janssen
Master Health Sciences
(student number: 0157805)
University of Twente

Supervision:
Dr.ir. K. Visscher
Department of Operations, Organization and Human Resources (OOHR),
University of Twente, School of Management & Governance

Prof Dr M.J. IJzerman
Department of Health Technology & Services Research (HTSR)
University of Twente, School of Management & Governance

Prof.dr. B. van Looy
Department of Managerial Economics, Strategy and Innovation (MSI)
Catholic University Leuven

KATHOLIEKE UNIVERSITEIT LEUVEN

UNIVERSITY OF TWENTE.

Preface

Before you lies my master thesis, which is the final report to complete my master Health Sciences at the University of Twente. Creating and writing the thesis was a challenge and an opportunity for me to learn about innovation management. As it was sometimes a struggle, the encouragements of the people surrounding me, gave me the energy and will to complete this thesis.

I would like to thank my supervisors, Klaasjan Visscher, Maarten IJzerman and Bart van Looy, for their support and endurance. Their guidance provided me with insights in the terminology, the methodology and analyses and also provided suggestions of how to interpret the results. Hopefully this research encourages further research in the field of innovation management.

By completing this final assignment I am closing a chapter of my life. The chapter starts at the age of 18 and beginning with the study Health Sciences of which I knew little. Moving out of my parents' home and making new friends was scary but exciting at the same time.

During my years of study I undertook several side projects. I went abroad to South Africa for my minor, organized the introduction period of the University and became president of a dance group.

By studying I learned to analyze research and think critical. The side activities I learned a lot about myself, developed leadership-skills and challenged myself to go out of my comfort zone of the study. All these experiences together thought me valuable lessons about life itself.

I am thankful for my friends and housemates who were there to drink cups of tea with, practicing sports with and go out dancing with once in a while. I enjoyed being around them and hope that closing my student life will not be the end of these relations.

During the past few years my family went through some hurdles but I always knew that they would be there for me when I needed it. I could always call, they never stopped believing in me and tried to motivate me to persevere in difficult times. Thank you all.

I am grateful for the help of my boyfriend, Guido, who helped me to get a better understanding of the theory, offered his excel-skills to help me analyze the data, was always there to motivate me and cook delicious meals from time to time.

Kirsten Janssen
April 2012

Summary

Introduction

The market of medical devices is increasingly challenging to operate in. Increasing competition and decreasing healthcare budgets for providers of health care, lead to more pressure on the cost-effectiveness of medical device companies. Also, stricter regulations are making it harder to bring new products to the market and to obtain reasonable prices once proven valuable. In these times it is of more importance that high-risk developments actually result in reimbursement and the technological- and financial performance of medical device companies are key to survival. To improve their technological- and financial performance, companies employ strategies to stay innovative and competitive. The choice in strategy is often reflected in the organization structure and innovation activities of the company. Research on these topics is rarely conducted on medical device companies.

Research goal

The goal of this research is to provide insights in how the organization structure and innovation activities of a company in the field of medical devices affect their technological and commercial performance. These insights will help medical device companies to determine which strategies are most effective given the financial and dynamic challenges that they are faced with.

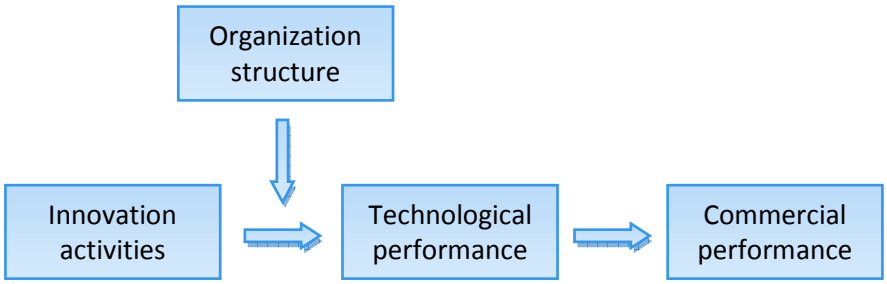
Theory

The commercial performance of a company provides insights in how well the company is performing on the financial aspect. Past research provides evidence that an increasing technological performance has a positive influence on the market value of a company.

How companies enact the innovations activities is partly reflected in whether companies apply for patents that are explorative or exploitative. Explorative activities are seen as new developments of ideas that are situated in a technological domain in which the company has not patented technology during the past five years. Exploitative activities are seen as further development in technological domains where the company has patented technology in the previous five years. Research indicates that companies are often performing at their best ability when they have a balance between exploration and exploitation, also called ambidexterity.

The organization structure of companies is often seen in structures such as matrix, vertical or horizontal. Those structures define the relationships between different units of company. The units of a company can also be divided by the subsidiaries a company has. The company can organize its innovation activities between several subsidiaries or concentrate it at one location. Subsidiaries are often seen as more flexible and better able to pursue exploration as they do not always rely on the basic experiences, values and capabilities. Logical reasoning suggests that the degree of differentiation of explorative activities influences the relationship of innovations activities has on technological performance.

This study investigates what influence the different *innovation activities* have on *technological performance*. Besides that, it will measure the effect of the *organization structure* as a moderating variable between the relation of innovation activities and technological performance. In consideration of those relationships the research indicates which different technological performances are leading to different outcomes in commercial *performance*.



(theoretical framework)

Methodology
27 Large medical device companies are selected of which the suggested relations are examined. The innovation activities are measured through the balance of exploration and exploitation (ambidexterity), in the patent applications by the company. Organization structure is measured by the degree of concentration of explorative patents in subsidiaries of the company. The technological performance is measured by the number of patent applications by each company and the commercial performance by sales with a lag of one and two years.

The patent data on the innovation activities, organization structure and technological performance is extracted from the dataset EPO. Data on the commercial performance, measured through the annual sales, was obtained from financial year reports. To be able to do the statistical analyses and make a benchmark of the best practices, a longitudinal database is created over the years 2002-2008.

Results
The results of the statistical analysis suggest that the large medical device companies who want to increase their performance on sales, in short term and number of patent applications should not invest in exploration. It suggests that it is better to invest in improving existing technologies and apply for new exploitative patents.

Contrasting to these previous results is that the best performing company, Johnson & Johnson, does do some exploration. This seems to suggest that it is necessary to have some degree of exploration to be able to stay competitive. Further results on organization structure indicate that if companies do invest in explorative activities it is better to differentiate.

Discussion

It could be that sales is not a good dependent variable as it often takes much longer than one or two years before a patent is transformed to a product and the item is allowed on the market. A value of like the Tobin's Q, which includes stock values, would be more sufficient. However this was not possible for this research as only the data of the segment of medical devices is used. Also the negative impact of exploration on the technological performance could imply that this group of the largest medical device companies has already passed the top of the inverted u-shape. Meaning that the more medium and small sized companies should explore more and the larger should invest more in exploitation.

Conclusion

Within the scope of this research the explorative innovation activities have negative effect on the number of patent applications of the medical device companies. It does not provide support for the moderating effect on the relation of the exploration share and number of patent applications; instead it indicates a negative main effect to the number of patent applications. A significant positive influence is found on the relation between the number of patent applications and the sales. The study also suggests a different theoretical framework for companies who produce medical devices.

Further research into why these results are different than expected is necessary. For example by taking a larger group of medical device companies with also small and medium sized companies and/or taking the performances of sales with a much bigger lag.

Samenvatting

Introductie
Het is een steeds grotere uitdaging om in de markt van medische apparatuur te werken. De toenemende concurrentie en afnemende budgetten in de gezondheidszorg, leiden tot meer druk op de kosteneffectiviteit van medische apparatuur. Daarnaast zorgt de steeds strenger wordende regelgeving ervoor dat het steeds moeilijker wordt om nieuwe producten op de markt brengen en daarvoor een redelijke prijs te krijgen. In deze tijden is het van belang dat risicovolle ontwikkelingen werkelijk leiden tot financiële terugbetaling/vergoeding. Hierbij zijn de technologische en financiële prestaties van medische apparatuur de sleutel tot overleven.

Om de technologische en financiële prestaties van bedrijven te verbeteren en concurrerend te blijven is het van belang hoe een bedrijf zijn innovatie strategieën toepast. De keuze van de strategie is vaak terug te zien in de organisatie structuren en innovatie activiteiten van het bedrijf. Onderzoek over deze onderwerpen wordt zelden gedaan bij bedrijven die medische apparatuur produceren en verkopen.

Onderzoeksdoel
Het doel van dit onderzoek is het definiëren van de relatie tussen innovatie activiteiten, organisatie structuur, en de technisch en commerciële prestaties in de sector medische apparatuur. Deze inzichten zullen helpen bij medische apparatuur bedrijven helpen om te bepalen welke strategieën het meest effectief zijn gezien de financiële en dynamische uitdagingen waarmee zij geconfronteerd worden.

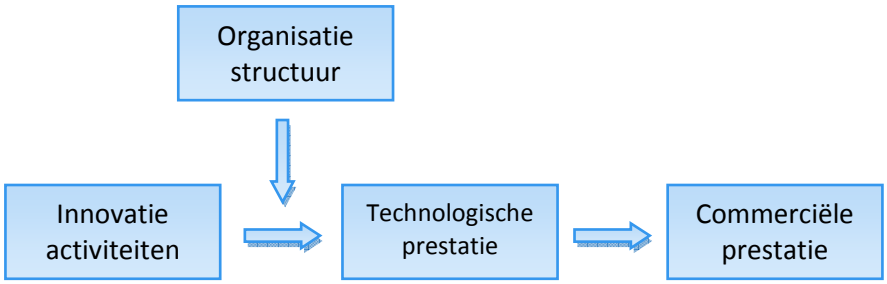
Theorie
De commerciële prestaties van de bedrijven geeft weer hoe goed bedrijven presteren op het financiële aspect. Eerder onderzoek toont aan dat toenemende technologische prestaties een positieve invloed is op de marktwaarde van bedrijven hebben.

De innovatie activiteiten van een bedrijf zijn deels terug te vinden in de patenten, deze kunnen zowel exploratief of exploitatief zijn. Exploratieve activiteiten worden gezien als ontwikkelingen van nieuwe ideeën die zich bevinden in een technologisch domein waarin het bedrijf niet heeft gepatenteerd in de afgelopen vijf jaar. Exploratieve activiteiten worden beschouwd als een verdere ontwikkeling van de technologische domeinen waar het bedrijf beschikt over gepatenteerde technologie in de voorgaande vijf jaar. Onderzoek toont aan dat bedrijven vaak op hun best presteren wanneer er een mate van balans is tussen exploratie en exploitatie, ook wel genaamd ambidexterity.

De organisatie structuur van de bedrijven worden vaak benoemd in vormen zoals matrix, verticale of horizontale eenheden. Deze structuren bepalen de relaties tussen verschillende eenheden van een bedrijf. Eenheden van een bedrijf kunnen ook worden gezien als de dochterondernemingen van een organisatie. Een bedrijf kan haar innovatie activiteiten tussen de verschillende dochterondernemingen verdelen of concentreren op een locatie.

Dochterondernemingen worden vaak gezien als flexibeler en beter in staat om te exploreren omdat zij niet altijd een beroep doen op de ervaring en kennis van het moederbedrijf. Het is de verwachting dat de mate van concentratie van de exploratieve activiteiten van invloed is op de relatie tussen the exploratie van een bedrijf en het aantal aangevraagde patenten.

Deze studie onderzoekt welke invloed de verschillende innovatie activiteiten hebben op de technologische prestaties. Daarnaast zal het effect van de organisatiestructuur worden gemeten als moderator variabele tussen de relatie van innovatie activiteiten en technologische prestaties. Na beschouwing van die relaties kijkt het onderzoek naar de invloed van verschillende technologische prestaties welke kunnen leiden tot verschillende uitkomsten in de commerciële prestaties.



(Theoretisch kader)

Methodologie
Het bovenstaande model is onderzocht bij 27 grote bedrijven, gedurende de jaren 2002-2008, die medische apparatuur produceren en verkopen. De innovatie activiteiten worden gemeten door middel van door de verhouding van exploratie en exploitatie (ambidexterity), in de aangevraagde patenten van een bedrijf. Organisatiestructuur wordt gemeten door de mate van concentratie van exploratieve aangevraagde patenten van dochterondernemingen van een bedrijf. De technologische prestaties worden gemeten door het aantal aangevraagde patenten door elk bedrijf en de commerciële prestaties door de omzet met een vertraging van een en twee jaar.

De patent gegevens over de innovatie activiteiten, organisatiestructuur en technologische prestaties worden gewonnen uit de dataset EPO. Gegevens over de commerciële prestaties, gemeten door middel van de jaarlijkse omzet, zijn verkregen uit de financiële jaarverslagen. Met deze gegevens is een longitudinale database gemaakt van de jaren 2002-2008. Met deze database zijn de statische analyses gedaan en is er een basis benchmark gemaakt van de best presterende bedrijven.

Resultaten
Uit de resultaten van de statistische analyse blijkt dat de bedrijven die de verkoop en technologie willen verhogen op de korte termijn niet zou moeten investeren in exploratie. Het suggereert dat het beter is om te investeren in het verbeteren van bestaande technologieën en waarvoor exploitatieve patenten van toepassing zijn.

Tegenover de eerdere resultaten blijkt dat het best presterende bedrijf, Johnson & Johnson, wel aan exploratie doet. Dit kan suggereren dat het belangrijk is om toch zekere mate van exploratie te blijven doen om zo te kunnen blijven concurreren. Verdere resultaten geven aan dat als bedrijven wel gaan investeren in exploratie dat het dan beter is om deze bij verscheidende dochterondernemingen onder te brengen.

Conclusie

Binnen het bereik van dit onderzoek kunnen de volgende conclusies worden getrokken. De exploratieve innovatie activiteiten hebben een significante negatieve invloed op het aantal aangevraagde patenten. Ook geven de resultaten geen bewijs voor het modererende effect van de concentratie van exploratie op relatie tussen innovatie activiteiten en technologische prestaties. Het aantal aangevraagde patenten heeft een positieve invloed op de omzet van de bedrijven die medische apparatuur produceren en verkopen. De studie suggereert een ander theoretische kader voor bedrijven die medische apparatuur produceren.

Discussie

Het blijkt dat de omzet met een vertraging van één of twee jaar waarschijnlijk te weinig is. Het duurt veel langer voordat een patent wordt getransformeerd in een product en de benodigde rechten heeft om te worden verkocht. Een meetinstrument zoals de Tobin's Q, welke rekening houdt met de beurswaarden, zou beter toepasbaar zijn. Dit was echter niet mogelijk omdat er geen beurswaarden bekend zijn van alleen het bedrijfsegment waarin medische apparatuur wordt gemaakt.

De negatieve impact van de exploratieve activiteiten op het aantal aangevraagde patenten zou ook kunnen betekenen dat deze groep van de meest grote bedrijven op het gebied van medische apparatuur al voorbij de top van een omgekeerde u-vorm is. Dit zou betekenen dat wanneer men een dataset creëert met ook middel en kleine bedrijven deze u-vorm wel te vinden zou moeten zijn. Het is dus van belang om verder onderzoek te doen naar waarom deze resultaten een ander beeld geven dan was verwacht. Dit zou in een vervolg onderzoek gedaan kunnen worden door een grotere steekproef te nemen met ook middel en kleine bedrijven en/of door omzet prestaties te nemen van jaren later.

Contents

1. Introduction

Medical device companies, find themselves in a knowledge-intensive and dynamic industry. The industry is currently under pressure of tightening regulation and increased competition (Lobmayr, 2009). Next to a large number of small and medium sized enterprises, several multi-billion dollar companies are active in this sector, including Johnson & Johnson, Medtronic and Philips Medical Systems. Especially for these large companies, it is a huge challenge to exploit their current technologies, and – at the same time – foster exploration and entrepreneurship in order to investigate future technologies (Wyke, 2011). This requires, among other things, a good portfolio of research and development projects, an organizational structure to enable continuous innovation, good linkages with patients, doctors, suppliers and universities, and efficient R&D and clinical trial processes (Ahmed & Shepherd, 2010). Since the medical device companies are dealing with a rapidly changing environment, they are in a position where they need to make decisions under uncertain conditions. Stakeholders are increasingly implementing strategies, such as health technology assessment, to be able to make the best choices under these uncertain circumstances (IJzerman & Steuten, 2011).

In the industry of medical devices, research is conducted on the organization of innovation, technological- and commercial performance. This research involves identification of the best practices of key players in the medical device industry, both on the level of technological- and commercial performance. The goal of this research is to provide insights in how the organization structure and innovation activities of a medical device company affect their technological performance and commercial performance. This research will help medical device companies determine which strategies are most efficient given the commercial and dynamic challenges with which they are faced. This study provides an attribution to earlier research and could be beneficial for the competitiveness of the companies.

Every year the website “Medical Product Outsourcing (MPO)” provides a ranking of the main players of the industry based on their commercial performance. Based on this ranking and the availability of information a selection of main players 27 companies is made. With this selection a longitudinal database is created. This database contains technological activities and portfolios by firm and commercial performance data. With this data, relations between innovation activities, technological performance, organization structure and commercial performance are analyzed. This eventually leads to a simplified benchmark of the best technological- and commercial performing companies in the industry of medical devices.

2. Background

The companies producing health care products are facing tight regulations and financial pressure to be efficient and innovative. Health care products can be distinguished as the pharmaceuticals and medical devices. To get an understanding of the context in which the companies operate, some background information on the financial aspect and regulation of health care is provided in this chapter. Also the main differences between the pharmaceuticals and medical device companies are provided to explain why this research focuses on medical device companies.

2.1. Increasing pressure in the health care market

In the past decennia the health care industry has become a fast and dynamic system. Fast in the meaning that the developments of new or improved health care product follow rapidly after each other. Dynamic in the sense that the market is changing due to increased competition and which deals with a lot of regulations (Maarse & Bartholomée, 2007).

The health care system refers to a complex of facilities, companies, and trained personnel engaged in providing health care within a geographical area (Health Care Systems, 2011). The healthcare systems are different in every state and nation but the components of the stakeholders are similar. In all cases it is a complex system which can be divided into three main components; the people who are in need of health care, called the health care consumers; the people and companies who deliver the health care services, called the health care providers; and the organizations, public and private companies who provide the necessary financing, facilities etc., called the health care facilitators. The health care providers and facilitators consist of a broad range of institutions and organizations such as insurance companies, medical device companies and pharmaceutical companies, public agencies and universities.

The development of medical products is taking on an increasingly central role in the health care systems. The expectations are high for medical device and pharmaceutical innovation to improve the quality of people's lives, lower the costs of health care, and increase efficiency in health care systems; it is a challenging industry for all stakeholders. The stakeholders, such as governmental bodies, industrial companies, pharmaceuticals, medical device companies, hospitals, patients and universities, are faced with the challenge of achieving multiple goals, fulfilling the high expectations but also investing in developments which offer the best value for money (Borgonovi, Busse, & Kanavos, 2008).

2.1.1. Financial pressure and dynamic environment

As billions of dollars are invested in the development of medical technology, an increasing pressure on maximizing the revenues of these investments arises (Dorsey, et al., 2010). The challenge to achieve optimal allocation of available resources in order to maximize health gains is a trigger for the search for norms to regulate and manage the industry of medical devices and pharmaceuticals. Regulating and managing the industry deals with factors such as accessibility, quality, and safety of medical products, which are relevant for the clients and public funding from governmental agencies.
Measures such as laws, directives, CE marks and FDA approvals are introduced to regulate and manage the industry of medical devices and pharmaceuticals. The increasingly strict regulations seem to lead to less financial growth in the industry, when compared to others (IJzerman & Steuten, 2011).

This decreasing financial growth not only impacts upon manufacturers of medical devices and pharmaceuticals but the whole mechanism of the health care system. The financial tensions have become one of the key challenges of the health care system, as it is related to product utilization, innovation, product diffusion and product acceptability to patients (Borgonovi, Busse, & Kanavos, 2008).

Increasing pressure is put on reimbursement of invested money in medical technology. Investors, public and private agencies, and insurance companies want to know what the benefits are for them or for the population before they invest. The pressure rises through the increasing scarcity of private and governmental funding and centralized procurement of medical technologies in the European Union. Centralized procurement is used by purchasers of medical technologies as means to drive down costs (Steuten, 2012). This is making it even more important to be able to manage innovation activities of the medical device companies. The Organization for Economic Co-operation and Development (OECD) gives a broad definition, which will be operationalized later, of *innovation activities*:

> 'All scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations. Some innovation activities are themselves innovative; others are not novel activities but are necessary for the implementation of innovations. Innovation activities also include research that is not directly related to the development of a specific innovation (OECD, 2005).

Next to the financial challenges, the industry faces fast dynamic changes in what is demanded from health care technologies. The facilitators find themselves operating in times where economies of countries are decreasing, populations are ageing, and the demand for efficient and high quality health care is rising (Wyke, 2011). Consequently, the constant pressure on reimbursement, results in that the managers of companies strive towards optimization of the allocation of their resources. At the same time the managers are expected to implement structures and strategies to achieve the goals and to be able to compete on the market.

2.1.2. Tight regulations

One of the main characteristics of the market of medical device companies and pharmaceuticals is that it is limited by boundaries and/or rules imposed by governmental bodies. The products have to be proven safe and effective before they are even allowed to enter the market, which is due to risks of the use of the medical devices and pharmaceuticals by customers. There are two main regulatory bodies involved, i.e. the FDA and the EMA. In the United States of America (USA) the regulatory body, named the Food and Drug Administration (FDA), is in charge of controlling the products (Lobmayr, 2009). For Europe the devices and pharmaceuticals need to have a Conformité Européene mark (CE mark), before they are allowed on the market (European Commission, 2011). In addition, for medicines there is also the European Medicines Agency (EMA), a decentralized body of the European Union. EMA's main responsibility is the protection and promotion of public and animal health. The agency supervises, evaluates and gives scientific advice to the Member States about the use of medicines for human and animals (European Medicine Agency; 1995-2011). Within this organization a party called 'EMA Committee for Advanced Therapies – Notified Body Collaboration Group' facilitates the implementation of regulations relating to advanced therapy medicinal products when they are combined with medical devices (EMA/CAT and Medical Devices' Notified Body (EMA/CAT-NB) Collaboration Group, 1995-2011).

The development of the regulation of medicines dates from the late 1960s in a response to the thalidomide tragedy, while that of the medical devices only began in the mid 1990s. The difference in moment of initiation of control between regulation of medicines and devices reflects the different characteristics of the products and industry (Jefferys, 2001).

Medical device regulation is not yet as tight and developed as that for medicines, and some experts argue that the regulations should remain less strict. Due to differences such as short product life cycle, lower costs and confounding factors (medical devices are often used as a part of a complex series of health care activities) and a greater role of process utilities. While acknowledging these differences, most experts recognize that the regulations for medical devices is poor in comparison to pharmaceuticals and that greater use of clinical trials and other forms of evaluation are essential if purchasers are to make informed decisions about high-cost device products at the time of launch. Experts and researchers see a continuously evolving shift towards tighter national and international regulation of medical devices (Cookson & Hutton, 2003).

2.2. Differences between pharmaceuticals and medical device companies

Historically, much of the related scientific research focuses on the strategies and structures of pharmaceuticals (Borgonovi, Busse, & Kanavos, 2008) and small and medium sized medical device companies (Lobmayr, 2009; Eucomed, 2011). To date, little research has been conducted on the finances, innovation and organizational structures of large medical device companies. Since both pharmaceuticals as medical device companies operate in the same market one could argue that data used for pharmaceutical studies could also be used for the medical device companies, but as elaborated on later on there are differences in regulation, product life cycle and reimbursement uncertainty.

Before elaborating the differences it is important to give the definitions, defined by the European Council and FDA, of the products of the companies.
Pharmaceuticals are medical products including:

(a) Any substance or combination of substances presented as having properties for treating or preventing disease in human beings
(b) Any substance or combination of substances which may be used in or administered to human beings either with a view to restoring, correcting or modifying physiological functions by exerting a pharmacological, immunological or metabolic action, or to making a medical diagnosis (Directive 2001/83/EC as amended by Directive 2004/27/EC, 2004)
Main point of the FDA is;
(c) It achieves it primary intended through a chemical reaction (FD&C Act SEC. 201. [21 U.S.C. 321], 2009)

Medical devices are by the Europeans Council defined as 'instruments, apparatus, appliances, software, materials or other articles, which are used alone or in combination, together with any accessories, including the software intended by its manufacturer to be used specifically for diagnostic and/or therapeutic purposes and 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 disease,
(b) diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,
(c) investigation, replacement or modification of the anatomy or of a physiological process,
(d) 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' (Directive 2007/47/EC, 2007).

Main points by the FDA are;

(e) recognized in the official National Formulary, or the United States Pharmacopeia, or any supplement to them,
(f) intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or
(g) intended to affect the structure or any function of the body of man or other animals (FD&C Act SEC. 201. [21 U.S.C. 321], 2009)

2.2.1. Differences

The regulation creates challenges for the companies, as it takes time and costs money to get a product through all the mandatory parts before the product can be introduced to the market. Beside those challenges, the medical device companies also face coping with economic evaluation and associated decision-making challenges that differ from pharmaceuticals (Sorenson, Tarricone, Siebert, & Drummond, 2011). Research of Drummond et al. (2009), Borgonovi et al. (2008) and Cookson & Hutton (2003) identify main points of difference.

First is that the sector of medical devices is characterized by a lot of small and medium sized companies, where especially the small companies are producing significant innovations. This could be due to other risk perception and regulations in connection to the clinical developments, which differ in extent, uncertainty and intensity of financial resources (Borgonovi et al., 2008; Eucomed, 2011). While the small companies produce the significant innovations, it is not they who are making revenues of over millions or even billions. There are several multi-billion companies are active in this sector, including companies as Johnson & Johnson, Medtronic and Philips Medical Systems (Delporte, Barbella, & Stommen, 2010).

Second is the significance of patents as incentives for innovation as they are influenced by the different nature of R&D. For pharmaceuticals it is nearly impossible to design and receive patents for a molecule that simulates all the efficacies and side effects of another drug. This is not the case for medical devices, for those it is often the case that the basic principle is patentable but the specific devices are not, which is difficult as the innovation often lies in the particular application (Borgonovi, Busse, & Kanavos, Financing Medical Devices in Europe, 2008).

Third is, those medical devices also require 'lead users' to be successful. When deliverers of health care do not see the need and do not accept or use the product, it will not be sold. This assumes an integral role between the facilitators and delivers of healthcare. In contrast to pharmaceuticals, which have a long research & development (R&D) process (12 years) in which the medicines have proved to be effective it may become a blockbuster in terms of the returns of investments. Proof of efficacy seems to be of less importance, because the efficacy of medical devices also depends on the skills and judgement of the clinician who controls the use of the product on patients (Drummond, Griffin, & Tarricone, 2009).

Fourth is the ability and propensity to make changes in the medical device during clinical evaluation and after the product is marketed. It often happens that a medical device is modified to remove defects and improve its performance, which leads to a lot of competition. Where the pharmaceutical has (almost) a complete product before it starts its evaluations. It is an incremental process, with iterative improvements in performance and safety of existing products of medical devices. Safety concerns are often less obvious with medical devices, because pharmaceuticals tend to have more physiological effects, and the medical devices that do, tend to have long-term physiological effects.

Fifth is that the industry for medical devices also deals with a short product life cycle, as products often are outdated within two years, and reimbursement uncertainty, as third-party payers may not directly reimburse a new product until its value is proven (Borgonovi, Busse, & Kanavos, Financing Medical Devices in Europe, 2008). Next to the short product life cycle it also deals with decrease in price whereas the products of pharmaceutical enjoy their protection and are able to keep their price consistent.

Table 1 Differences between medical device companies and pharmaceutical companies

Medical device companies	Pharmaceutical companies
Market is characterized by a lot of small and medium sized companies	Market a few very large established companies
Basic principle is patentable, but the specific applications not.	Nearly impossible to design and receive patents for a molecule that simulates all the efficacies and side effects of another drug
Incremental process of development, the ability and propensity to make changes during the process to remove defects	Product changes rarely during the life cycle of the product
Efficacy depends not only on the devices but also on skill and experience of the surgeon, it requires often lead users.	Cessation to use if often simple
Short product life cycle in which the price of the product drops fast	Long product life cycle where the prices stay consistent

3. Problem description and Research questions

Making the right choices to become or maintain a good functioning company in the market became even more important when in the late 1990s and early part of the twenty-first century companies faced challenges of speed creating new customized products. This challenge was, for most companies, too big to handle on their own, and to be successful, companies needed to look to external companies (Ahmed & Shepherd, 2010, p. 173). The historical and present developments in the healthcare market and especially in the market of medical devices (dealing with tight regulation, a lot of competition and fast innovation processes) and the inherent tension are factors that influence and challenge the performance of the medical device companies.

This challenge to perform well in the medical device industry will form the basis of the problem description and research question. Before describing the problem description the main definitions will be shortly discussed as well as why for this study is chosen to explore the several of the largest companies.

3.1. Innovation activities

Management of innovations can be done by adopting different *innovation strategies*. Strategies are defined by how the organization will reach its goals and includes a plan for interacting with the competitive market (Daft, 2004). The book "*The management of technological innovation: strategy and practice*" written by Mark Dodgson, David Gann and Ammon Salter (2008), positions innovation strategy at the basis of the companies' overall strategy. Following their description of the strategy of innovations, it [...] involves analysis of companies' business, market and technological environments and consideration of what resources they have to draw upon. It also involves making choices about innovation in uncertain and ambiguous circumstances with diverse strategies for different levels of uncertainty. It entails building the innovative capabilities companies need, to merge skills and resources to analyze, select, and deliver innovation to enhance organizational performance. It requires consideration of how new initiatives in innovation fit with companies' existing portfolios and how innovation strategy complements overall corporate strategy (Dodgson et al., 2008, p. 3).

In the case of medical device companies it is important that the innovation strategy takes into account the requirements placed by the government, patients and doctors. Innovation strategy contains, among other things, the activities of the firm, as the choice of strategy is more difficult to find and results in less qualitative data. This research will focus on the *innovation activities* of the firm. Through the innovation activities it is possible to trace which strategy the firm has chosen.

The importance of the different innovation activities lies in its ability to let a company grow, become profitable and stay in business. It is to the companies' advantage to be able to keep up with the demands of innovations as historical literature is full of companies which could not deliver and went out of business (Dodgson, Gann, & Salter, 2008, pp. 5-6). Specifically for medical device companies the ability to compete depends on their capacity to manage research and development. Companies such as Phillips, Medtronic and Johnson & Johnson, rely on research to create new and improved products to help treating patients.

3.2. Organization structure

R. L. Daft (2008) divides the organization structure in three key components;

> […] it designates formal reporting relationships, including the number of levels in the hierarchy and the span of control of managers and supervisors.
> […] it identifies the grouping together of individuals into departments and of departments into the total organization.
> […] it includes the design of systems to ensure effective communication, coordination, and integration of efforts across departments (Daft, Organization Theory and Design, 2008, p. 91).

The organizational structure of a company requires almost always change to reflect new strategies or responds to changes in other contingency factors such as environment, technology, size and life cycle, and culture (Daft, 2008).

Innovation activities and its organizational structure

To meet the requirements of the health care market, companies use different strategies of innovation and organizational structures to create their portfolio of medical devices. The different strategies of innovation and options for organizational structures are elements that contribute to a stable and growing/failing organization that produces medical devices and eventually, after approval, sell them on the market.

Reviewing research shows a great variation of companies, also pharmaceuticals, that is investigating what effective organization structures (Ahmed & Shepherd, 2010) and innovation strategies (Belderbos et al., 2010, Lavie et al., 2010, Levinthal & March 1993) there are. New in this research area are the medical device companies that deal with slightly different factors such as a high degree of uncertainty of reimbursement and strict regulation, before bringing their products on the market.

3.3. Large companies

To be able to compete for companies at a global level, huge resources and economies of scale are needed. They are able to deliver economic support and social force in difficult times. Huge companies are able to get back to business more quickly after for example environmental disasters, war, or terrorist attacks.

Large companies are often complex and standardized, they are able to stabilize or be the driving force of the market for years. Often it is seen that big companies become committed to their existing products and technologies and are able to improve this through incremental innovation. Those big companies find it hard to focus and support future and radical innovation. They focus on optimization and not innovation. A solution for this dilemma is to combine the large organization with small sized companies, also called subsidiaries. Subsidiaries are often flexible, simple and have a regional reach and a combination between both could lead to the advantage of the large companies as well as the small (Daft, Organization Theory and Design, 2004).

3.4. Problem description, research goal and research questions

The first problem is 'managing the innovation strategies'. Which strategy provides the best fit to what is requested from the market. It is increasingly important that companies develop innovation strategies to manage their technical products to adapt to the challenges presented above.

The second problem arises due to the uncertainty about what factors of companies determine a financially successful strategy. To be able to manage the innovation of technological products successful, companies need insights in what way a company is going to be innovative, how to organize innovation and how companies financially perform.

Belderbos et al. (2010), Uotila et al. (2009) and He and Wong (2004) uncover and define the relationship between innovation activities and commercial performance. Research of Belderbos et al. (2010) was conducted in the sectors: nonelectrical machinery; pharmaceuticals and biotechnology; chemicals; IT hardware; and electronics and electrical machinery. Uotila et al. (2009) and He and Wong (2010) included manufacturing companies. The results do not necessary hold for the sector of medical devices due to differences in regulation, product life cycle and the nature of patent incentives. To date, little research has been conducted to study characteristics of innovation activities and organizational structure of the large medical device companies. This leads to uncertainty among the managers who need to make strategic decisions in a dynamic, fast market of health care.

3.4.1. Research goal

The goal of this research is to provide insights in how the organization structure and innovation activities of a company in the field of medical devices affect their technological and commercial performance.

3.4.2. Research question

The primary research question is: *What influence do innovation activities and the structure of organizations have on the technological- and commercial performance of medical device companies?*

To formulate an answer to the research question, several sub-questions are formulated:

1. What influence does the technological performance have on the commercial performance?
2. What influence do innovation activities have on the technological performance?
3. What influence does the organization structure have on the connection between innovation activities and companies' technological performance?

The variables of the research question form the basis of the sub-questions. In the next chapter the relation of the sub-questions to the research question will be elaborated.

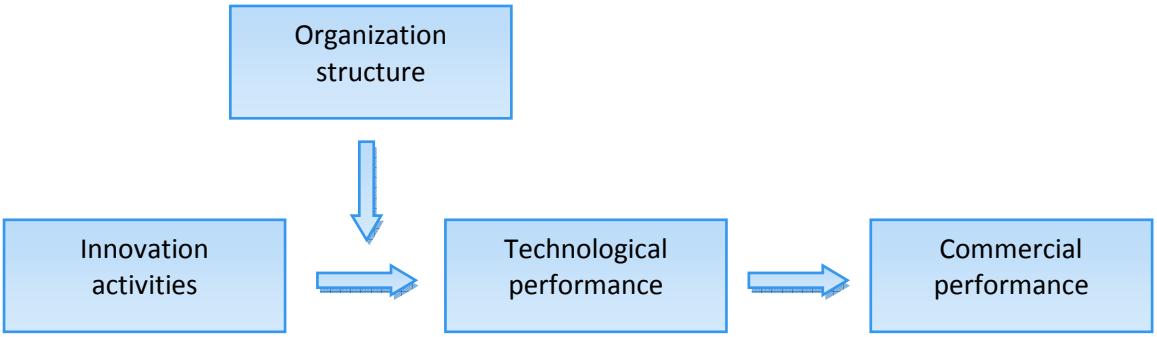
4. Theoretical Framework

First, the theory and indicators of technological- and commercial performance and second the theory and the different indicators for innovation activities; explorative, exploitative and ambidexterity and their effects will be discussed. At last the theory and indicators for the organization structure will be discussed. While describing the theory, the framework will be further developed, and at the end of this chapter the final framework will be presented. The hypothesis for this research will be developed on the technological and commercial performance effects of the identified dimensions of innovation activities and organization structure. [1]

4.1. Managing innovation

'Managing strategic innovation is as much about managing change as it is about managing technology.' (Tushman, Anderson, & O'Reilly, 1997, p. 7) The market of health care is dynamic and from day to day companies face changes in laws, budgets, and what is demanded of them. Back in the 1990s researchers started an attempt to understand why some companies sustain and others fail under given circumstances. To survive over time, companies need to be able to adapt their strategy and structure to the context in which they operate. In short; the context, such as size, technology, origin and control, is closely related to the organizational structure of a company (Pugh, Hickson, Hinings, & Turner, 1969). Discussed in the chapter 'background', is the context in which the medical devices companies operate. These companies operate in the field of medical technologies, a market which deals with a lot of uncertainties, strict regulations and decreasing of budgets. This context creates a basis for the relationship flowchart of this research. All the theory used is subjected to relativity; it can differ on different levels of the individuals, units, organization and its environment. For example, certain knowledge can be familiar for one organization but new at the level of the individual or unit (Lavie, Stettner, & Tushman, 2010). In this research the level of the organization will be investigated.

This research will investigate if a relationship can be found between different *innovation activities* affecting the outcome in *technological performance*. Besides that, it will measure the effect of the *organization structure* as a confounding variable between the relation of innovation activities and technological performance. In consideration of those relationships the research will see whether the different technological performances lead to different outcomes in *commercial performance*. Combining this leads to the following flowchart:



(Figure 1. Relationship framework of organizational structure, innovation activities, technology- and commercial performance)

[1] The variables and their definitions can be found in the glossary, page 53

4.2. Technological and commercial performance

Key to growth and competitiveness in the modern health care market seems to be innovation, which leads to benefits for all stakeholders involved, and has an impact on national economic growth and long-term competitiveness. Stakeholders are realizing the potential benefits of their investments and are focused on indicators to measure the return of their investments (Tin, 2005). That is why more companies, industries and governmental bodies are interested in ways to indicate innovation performance. Often a lot of money is invested before some invention is made and a patent is acquired. In companies this invested money is named research and development expenses. The performance of technology can be measured by the inputs such as research and development expenses or outputs such as patent frequency (Tin, 2005; Griliches, 1994; Henderson & Cockburn, 1996).

In this research the focus for the technological performance will be on the frequency of patent requests, as this will represent the output of exploitative as explorative innovation together. Research of Griliches et al. (1991) examined the relationship between patents and the market value of the firm and found that, in the pharmaceutical industry, a significant change in market value results from changes in patent rate. This difference was not found in the other markets used in this research of Griliches et al., whereas the market of medical devices was not included. These arguments suggest that to stay competitive it is important to invest in research and development and keep the technological performance of a company high. A high degree of technological performance should lead to a better commercial performance as the company is better able to commit to the needs of the market. This leads to the following hypothesis;

H1: A higher number of patent applications increases the sales of the company.

A note must be made that an increase or decrease of commercial performance probably also leads to an increase or decrease in both number of subsidiaries and expenses of research and development. But this aspect lies outside the scope of this research and is therefore not shown in the framework.

4.3. The innovation activities

Staying in business is almost impossible without improvement and innovation of products and services. The innovation strategies of the companies, regarding the choices made in innovation, are carried out through innovation activities. Introduced in the chapter 'Background Information' was the definition for innovation activities used by OECD. That definition can be broadly used in a lot of areas of research, so for this research the definition is redefined to; *"innovation activities are: all scientific, technological, organizational and commercial steps which actually, or intend to, lead to patent requests and eventually new or improved medical devices upon the health care market."*

Innovation activities include process innovation within a company as well as product innovation by the company. Process innovation includes the development production process of the system of process equipment, work force, task specifications, material inputs, work and information flows, etc. while product innovation is a new technology or combination of technologies (Utterback & Abernathy, 1975). This research focuses on the product innovation side, as the patent will almost always apply on the product innovation, and availability of data on process innovation is limited (Dodgson, Gann, & Salter, 2008, p. 77).

4.3.1. Exploration and exploitation

In organization research, innovation activities are, often divided into the concepts of exploration and exploitation. The framework of exploration and exploitation by Jim March in the early 1990s became widely used by scholars as dimensions for innovation activities. Scholars began to have substantial interest in knowledge of organizational learning, knowledge management, innovation, organizational design and strategic alliances (Lavie, Stettner, & Tushman, 2010). Levinthal and March (1993) defined exploration as "a pursuit of new knowledge" and exploitation as "the use and development of things already known". The framework assumes a trade-off inherent to exploration and exploitation. It concerns choices between stability and adaptability, resource-allocation constrains, and desirable organization outcomes. Factors such as environment, organization structure, size, lack of resources, culture, and managerial biases influence an companies' propensity to explore, exploit or strive towards a balance (Lavie, Stettner, & Tushman, 2010). Despite the straightforwardness of March's framework, the answers in literature remain incomplete and at times ambiguous. To define the concepts more precisely several 'central questions' need to be answered (Gupta, Smith, & Shalley, 2006).

The first question is how to define the terms exploration and exploitation. This research focuses on the macro levels of analysis, the exploration and exploitation at the level of the company. At this level, exploration is often seen as a way of product diversification, risk taking, internationalization, variation in organizational forms and experimentation with new knowledge. Exploitation reveals itself in the choice to focus on one or several technologies, playing safe and concentration. Lavie et al. (2010) questions if and how one can benefit from drawing analogies betweens such different conceptualizations. Literature shows that generalization of findings about the antecedents and consequences of exploration and exploitation is almost impossible, as the concepts are used in different contexts using different interpretations. That is why it is important for future research to specify the domain in which the research takes place and for this research it will be in the context of the product and process technology for large medical device companies.

Now that the domain of this research is conceptualized, the next point is if there is a difference between exploration and exploitation and whether refinement of existing knowledge is considered to be exploration or exploitation (Gupta, Smith, & Shalley, 2006). The multidimensionality of knowledge development in amount and activity challenges the conceptualization. According to Gupta et al. (2006) it is more logical to differentiate between the concepts by focusing on the type and amount of learning rather than on the presence of learning. The presence of learning is permanent as there is no such thing as perfect replication in the social system and would lead to high count of explorative point.
Exploitation persists within an existing technological trajectory and leverages its existing skills and capabilities and operations and it is building on the companies' existing knowledge base. A shift away from a companies' current knowledge base and skills, such as new technical skills, market expertise, or external relationships is seen as an act of exploration (Lavie, Stettner, & Tushman, 2010).

The second question mentioned by Gupta et al. (2006) relates to whether exploration and exploitation are two ends of a continuum, or two different and orthogonal aspects of the organization. There are cases in which an organization, a single domain, produces a new technology for the first time; an explorative technological activity. However as time proceeds the company is able to improve the technology by developing exploitative routines as it becomes more familiar with producing the product. When research involves more than a single domain, the concepts exploration and exploitation will most generally be orthogonal. This is because high levels of the exploration in one domain can coexist with high levels of exploitation in another domain (Gupta et al., 2006). Taking the period of five years (see definitions of explorative and exploitative) tries to empathize the continuum of the transitivity of exploration to exploitation (Lavie et al., 2010).

The use of 'patent requests' as an indicator of innovation activity is proposed by Tidd (2001). He reviewed the main measures used for innovation by looking at their strength and weaknesses. He concludes that there is no single best measure of innovation, but that some indicators work better in certain fields of industry than others, for example, patents for mechanical technologies. As medical devices are defined as *instruments, apparatus, appliance, software, material or other articles* (Directive 2007/47/EC, 2007) and are often mechanical, the choice is made to use patent data. The patent data will provide useful information to examine relationships between innovation activities, the organization structure, the technological performance and the commercial performance of the company. Taking into account the arguments of Tidd (2001), Gupta et al. (2006) and Lavie et al. (2010), the definitions presented in the research of Belderbos et al. (2010) are suited for this research. Developing and producing medical devices is seen as the technical activities of the company. Belderbos et al. (2010) defines the concepts as follows;

Explorative technological activities: *the development of ideas that are situated in technological domain where the company has not patented technology during the past five years.*
Exploitative technological activities: *acts of creation in technological domains where the company has patented technology in the previous five years* (Belderbos, Faems, Leten, & van Looy, 2010).

The hazards of focusing on exploitation or exploration or a balance

Companies are facing trade-offs when they make resource-allocation decisions to support exploration or exploitation. Exclusion of exploration will lead to unnecessary costs of innovation, little room for new ideas and distinctive competence and will finally result in companies which find themselves trapped in a suboptimal stable equilibrium. The choice for exploration leads to a tradeoff between neglecting the short term productivity, in addressing the currently available knowledge to supply to the immediate need, and focusing on the long-term innovation by supporting the search for new knowledge and future opportunities (March, 1991). This could lead to bankruptcy in the near future before the organization is even able to put their new knowledge on the market.

Also it is possible that the organization chooses to allocate their resources solely on exploitation activities, for the refinement of existing technologies and the leveraging of existing competencies. Here the organization fails to develop new long-term skills and capabilities, which leads to not being able to see to the future dynamic needs of the society.

Given those hazards of solely focusing on exploration or exploitation, organization research discusses the need for both explorations as exploitations (Levinthal & March, 1993; March, 1991; Ancona et al., 2001). How to achieve this balance is the third question of Gupta et al. (2006). In their article they discuss two points: punctuated equilibrium and ambidexterity. Punctuated equilibrium is defined as temporal cycling through periods of exploration and exploitation. When analyzing exploration and exploitation is done within a single domain, and the concepts are rightly conceptualized as the mutually exclusive ends of a continuum, the individual or subsystem must resort to punctuated equilibrium. The opposite is when analysis involves multiple, loosely connected domains, then punctuated equilibrium does not apply.

4.3.2. Ambidexterity

The concept punctuated equilibrium does not apply in this research as this research involves large companies with multiple- and often loosely connected domains, it is now time to look more closely at the concept of ambidexterity. The continuously changing world confronts companies with operating partly in times of relatively stability and incremental innovation, and partly in times of radical changes. In the short run an organization will deal with constantly having to be able to fit or align the strategy, structure, and culture, where on the long run the organization is required to destroy the very alignment that has made the organization successful, to be able to stay competitive. To overcome this paradox an organization needs to be ambidextrous. Ambidextrous organization should be able to implement both incremental as radical innovation. Companies succeed on the long-term when they evolve by periods of incremental change but also involved with radical innovation (Tushman & O'Reilly III, 1996). The organization exists with highly differentiated but weakly integrated subunits. It exists of small and decentralized exploratory units, with loose cultures and processes, and larger centralized exploitation units, with tight cultures and processes (Benner & Tushman, 2003).

In 1996, Tushman & O'Reilly mentioned that Johnson & Johnson is able to successfully balance these tensions. The organization was able to compete in existing markets by incremental innovations and in new markets and technologies through radical innovation. When analysis involves multiple and loosely connected domains and exploration and exploitation are conceptualized as orthogonal, logic dictates that ambidexterity can be viewed as the appropriate adaptive mechanism for balancing the need for both exploration and exploitation (Gupta, Smith, & Shalley, 2006). If the success of Johnson & Johnson is still valid and is also the case for the department of medical devices the concept of ambidexterity will be used to examine it. Belderbos et al. (2010), Uotila et al. (2009) and He and Wong (2004) found a positive relationship between ambidexterity and financial performance. Uotila et al. (2009) en Belderbos et al. (2010) are both providing evidence for an inverted u-shape between the relative share of the firm's exploration activities and the financial performance.

As the importance of the inverted u-shaped relation with financial performance is proven, this research will focus on the question if the balance between exploration and exploitation is also important to the technological performance. It could be that when a company only focuses on exploitation the numbers of patents drop because there is no longer an incentive to develop the products any further. Therefore it could the balance between exploration and exploitation influences the number of patent applications.

H2: An inverted U-shape relationship exists between the exploration share of innovation activities in a company and number of patent applications.

4.4. Organization structure

Organizational structure refers to the sum of the ways in which an organization divides and coordinates its labor into distinct tasks (Mintzberg, 1979). The ways can be designated in formal reporting relationships, indentifies units in the organization and includes the design of systems. Identifying the units can be conceptualized in a lot of different ways, such as matrix-, functional-, vertical and horizontal-structures. Companies can integrate different structures to execute their operations which define the distribution of power, resources, and responsibilities across different functions and units. In terms of innovation strategies it can mean that this does not all take place between the boundaries of the company. The firm can choose to develop new products in collaboration with other companies, or create spin offs or subsidiaries of the main company. These different organizational structures can correspondingly facilitate innovation strategy. For instance, research of Belderbos et al. (2009) provides evidence for a relationship between collaboration between companies and commercial performance of companies.

One of the conceptualizations is the differentiation within a company that also relates to the structure of the parent company and its subsidiaries. A parent company is a company that owns enough voting stock in order to control management and operation by influencing or electing its board of directors. An organization is called a subsidiary of the parent corporation, when;

- it controls the composition of the board of directors of the first-mentioned corporation
- it controls more than half of the voting power of the first-mentioned corporation; or
- it holds more than half of the issued share capital of the first mentioned corporation
- the first mentioned corporation is a subsidiary of any corporation which is that other corporation's subsidiary.

In the late 1990's, when companies faced challenges of a dynamic market and speed creating of new products, scholars started to focus on the role of subsidiaries as they were viewed to play an important role to the parent firm's advantages. Subsidiaries can create advantages by using the potential to access and use the knowledge of parent company as well as the local knowledge, being close to customers and other companies. Research from Birkinshaw et al. (1998) showed that subsidiaries can not only contribute to firm-specific advantage creation, they can also drive those processes. Researchers Almeida & Phene (2004) show that the subsidiaries are widely classified as those with an exploitation mandate (exploit exciting knowledge of the parent organization) and those with an exploration mandate (augment exciting knowledge of the parent organization). Hence this study will focus on the role the parent company and its subsidiaries play in innovation by exploration or exploitation, which will be conceptualized as ambidexterity.

Research of Birkinshaw et al. (1998) points out that those subsidiaries can contribute to firm-specific advantages when they specialize in a certain field of technology. The parent company develops the improvements of the products and let the subsidiary develop and manufacture new products and sell the improved as well as the new products to its local consumers. Researchers Almeida & Phene (2004) and Birkinshaw et al. (1998) suggest that subsidiaries can provide in the development of new or improved products by combining the local resources and knowledge, resources and knowledge of the parent company. This is making them beneficial to the parent company.

The last consideration mentioned by Gupta et al. (2006) is that long-term survival may be feasible without balance at the level of the individual domain. That is by focusing it solely on exploration or solely on exploitation. The individual domains are often part of a bigger social system, and are interdependent upon each other. Under certain conditions it is a possibility that the balance between exploration and exploitation occurs not at level of the individual domain but within the bigger social system. In this case one domain specializes itself in exploration and another in exploitation, while the balance occurs through exchanges with in the bigger social system (Gupta, Smith, & Shalley, 2006). March (1991), and Benner and Tushman (2003) both signaled the possibility that under well-specified conditions, specialty rather than duality may be viable. In case of large companies, subsidiaries are seen as the individual units of a larger social system; in this case the parent organization.

The subsidiaries can be seen as units of the company, which can be concentrated or differentiated in the organizational structure. Integration refers to the mechanisms that are able to address both exploitative and explorative activities within the same units (Raisch et al., 2009). Argued by critics is that exploring fundamentally different knowledge is difficult when individual or units relies on the same basic experiences, values and capabilities (Inkpen & Tsang, 2005, March 1991). The other side is differentiation, which refers to the subdivision of exploitative and explorative activities into distinct organizational units. Structural differentiation helps ambidextrous companies maintain different competencies with which to address inconsistent demands from the market (Raisch et al., 2009). When focusing on structural organization it is important not to neglect the need for concentration among top management teams to ensure the company remains efficient (Gilbert, 2006). In this context of this research subsidiaries are more flexible and are better able to pursue exploration than the bigger parent organization.

Companies can choose to let the subsidiaries do the explorative work and later on improve the product themselves. By not taking the risks as parent organization, this provides safety and less commercial risks. However if a company has many subsidiaries it could lose the connection and its ability to control the subsidiaries. Losing the connection and control could lead to the point where they do not strive towards the same goals and lose the benefits from being parent and subsidiary.

In short, the structural differentiation suggests that the distribution of explorative innovation activities within an organization influences the relationship between an organization's ambidexterity and technological performance. More specific; if more subsidiaries are explorative it could lead to a positive influence on the relationship. To test this, the next hypothesis is formulated:

H3: A lower degree of concentration of consolidated explorative subsidiaries within an organization has a positive influence on the relationship between the exploration share and the number of patent applications.

4.5. Framework

The relationship between innovation activities, technological performance and commercial performance is already proven in earlier research. New is the question if the differentiation of explorative subsidiaries has a positive influence on this already proven relationship. This offers the following framework:

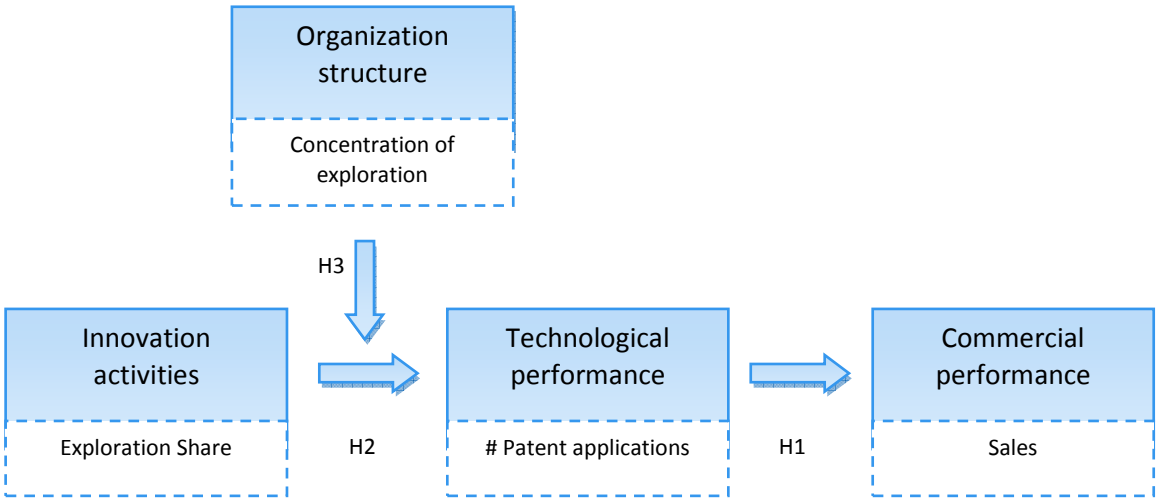


Figure 2. *Relationship framework of organizational structure, innovation activities, technological- and commercial performance*

5. Methods

The investigation entails the profiling and benchmarking of multibillion companies in the medical devices industry between the years 2002 and 2009. To be able to do the analysis a longitudinal panel research design is created. In this section the variable selection, data collection methods and statistical analysis will be described respectively.

5.1. Variables

To be able to create a database first the variables need to be clear. In this paragraph the variables are operationalized and it is described how they are calculated. The variables are described in the order of the framework on page 19.

5.1.1. Innovation activities

The *innovation activities* are determined by the degree of ambidexterity of the companies. Ambidexterity is seen as the balance between explorative and exploitative innovations activities in a company. The degree of ambidexterity will be measured by using patent data. This is chosen because of the availability of regular detailed and long-term data the ability to compensate the weaknesses of R&D statistics and possible levels of comparison on country, industry, technological field and firm (Tidd, 2001). To calculate this balance the degree of explorative activities will be calculated by the use of the technology domain in which a patent is situated.

A patent exists of one or more International Patent Classification System (IPC)-codes. The IPC-codes represent a technology domain in which the patent is situated. The patent is labeled explorative when one of the IPC-codes of the patent is new to the company in year *t,* if the company and its consolidated subsidiaries did not patent in the same IPC code in the past five years, *t-5 to t-1* (Ahuja & Lampert, 2001). The assumption is that when the company starts the exploration of a new technology domain it stays relatively new and unexplored for period of three years. Therefore the technology domain keeps its explorative status for a three year time period (Belderbos, Faems, Leten, & van Looy, 2010). The data sample of patents exists of five years more than the commercial data (2002-2008). This is necessary to be able to classify the patents in domains of explorative or exploitative patents.

5.1.2. Technological performance

The *technological performance* can be measured by the several indicators such as research and development expenses or patent frequency (Tin, 2005; Griliches, 1994; Henderson & Cockburn, 1996). Research & development expenses are an input variable, expenses are necessary to create the environment in which technology can be developed. In the content of this research the technological performance is seen as an outcome variable and a mediating variable, therefore the number of patent applications of the company as an indicator for technological performance is chosen. The frequency in which a company applies for patents is a measure of the inventive activities and its capacity to use its knowledge to create better or new products. In this research the technological performance is measured per year by the number of patents applications of a company and its consolidated subsidiaries (Leten, Belderbos, & Looy, 2007).

5.1.3. Organization structure

Discussed earlier is that it is expected that companies who organize their explorative activities among a lot of subsidiaries benefit as it creates better opportunities to explore new technology domains. To calculate an indicator for the concentration of explorative activities among the company and its subsidiaries the two main traditional measures can be used; the *concentration ratio* and the *Herfindahl index*. The first one calculates the percentage of the share held by the largest subsidiaries of the company. The definition does not make use of the share of all the subsidiaries in the company and therefore does not provide a distribution of size (Industry Concentration, 1999-2010). The Herfindahl index provides a better scale as it uses the market shares of all the subsidiaries of the company.

The Herfindahl index is defined as:

$$(\Sigma i \, (Ni/N)^2))$$

i = squared values of exploration patent per subsidiary and parent company as a fraction of its total exploration patents applications of the company
Ni = Explorative patent applications of subsidiary or parent company
N = All explorative patent applications of the company

The Herfindahl index is the sum of squared values of explorative patent applications per subsidiary and parent company as a fraction of its total exploration patents of the company. The shares of exploration are squared so it places more weight on the subsidiaries which are larger. When a company has only exploration patent applications in its parent company or in one subsidiary, the Herfindahl index will be one. If the company uses different segments for its exploration patents, for example among nine subsidiaries and the parent company which all contribute for 10% of the exploration patens, its Herfindahl index is 0.1. This means that when the Herfindahl index falls the degree of differentiation within a company increases (Lang & Stulz, 1994).

The concentration of explorative subsidiaries is tested in the model as a moderator. This variable is created in two ways. The first one is calculated by taking the values of the exploration share times the value of the concentration of exploration. To correct for multi-correlation the moderator is further calculated by the z-scores of the independent variable and the moderator. When this moderator is significant it means that the way in which the exploration share influences the technological performance is depended of the value of the moderator. To make sure that the concentration of exploration is a moderator and not a main effect on the technological performance this will be tested as well (Braumoeller, 2004). For this the values of the concentration of exploration will be used.

There are seven cases in which the company does not have any explorative patent in a year. In that case, the value of concentration of exploration would be 0. Those cases will be excluded for the test of the hypothesis.

5.1.4. Commercial performance

The performance of a company expressed in money can be measured in different ways. Therefore, the financial performance of a company is seen as a multidimensional concept. One of the measures is the *commercial performance* (sales) of a company. The *sales* of an organization is defined as the gross inflow of economic benefits during the period arising in the course of the ordinary activities of the entity when those inflows result in increases in equity, other than increases relating to contribution from equity participants.

Measurement of sales are often easily available and do not suffer, unlike profitability measures such as ROA, etc., from measurement problems (He & Wong, 2004). The growth of sales is an indicator of other dimensions of the company's performance for long term profitability and survival (Henderson A. , 1999).

5.1.5. Control variables

Control variables are aspects of an experiment that are held constant, have clear measurement options or might have an influence on the model. Taking these aspects into consideration aims at reducing the chance that the observed relationship is an effect of the independent variable and not an effect of other variables (Brysbaert, 2006). In this research four control variables will be used.

- *R&D intensity* (R&D expenses/total sales). By lack of financial data solely on the segment medical devices. The data of the R&D expenses and total sales are retrieved from the data of the total company. When a company has a high degree R&D expenses it shows that the company offers resources for invention and innovation. To take in consideration the size of the firm the R&D expenses are divided by the sales of the company (R&D intensity).

- *Patent propensity* (All patents/R&D expenses). One company is better than the other in transforming the R&D expenses in patent applications. This degree of efficiency is visible in the patent propensity, which shows how many patents are applied for in comparison to the R&D expenses. *Companies with a higher R&D intensity and patent propensity are expected to have a better financial performance (Griliches, Hall, & Pakes, 1991).*

- *Employees*, to control for the size of the company controlled by the logarithmic transformation of the number of employees (Ahuja & Lampert, 2001).

- *Technology diversification*, the differentiation between products, some of the companies are selling their products to all different kind of technology fields, where others focus solely on one specialism or specific instrumentation. As large sized companies tend to have a highly diversified technology portfolio, it is important to take this variable in consideration as the research includes companies who focus solely on medical devices and companies who produce in complete different sectors as well.

Prior research shows that the technology diversification relates to the technological performance in an inverted u-shape (Leten, Belderbos, & Looy, 2007). The research indicates that a too highly diverse company profits from until the disadvantages are too high and it does not increase the technological performance anymore. Using this variable helps controlling for this the variations of technology activities some companies may have and gives a indication whether those companies are still profit from the diversification or not.

Technological diversification is calculated by:

$DIV = 1 / (\Sigma i (Ni/N)^2)$.

i = squared values of number of IPC-codes of the patents of the company as a fraction of its total number of IPC-codes of all the patents of the company
Ni = Number of patents per IPC-code
N = Total number of IPC-codes

Table 1. The main variables and the method of calculation

Variables	Parameter	Indicators	Calculation
Innovation activities	Exploration share	Ratio of explorative medical patents on the total of applied explorative and exploitative medical patents [a]	A patent requested in year t is considered explorative if the same ICPC code has not been applied for in the year's t-5 to t-3. The ratio of explorative patents is calculated as the number of explorative patents divided by the total number of patents.
Organizational structure	Concentration of Exploration	Ratio of concentration of explorative (medical) patents in subsidiaries and the parent company	Of all the explorative patents of a company the Herfindahl index is calculated.
Technological performance	# Patents Applications	Medical Patent frequency per year [a]	Count of patents during the years 2002-2008
Commercial performance	Sales	(Medical Devices)[b] Sales in millions of US ($)	(segment) sales of medical devices during the years 2002-2008
Control variables:	R&D intensity	Ratio of R&D expenses / Total sales (millions of US ($))	Values of R&D expenses divided through the total sales of the company.
	Patent Propensity	Number of Patents / R&D expenses (millions of US ($))	Count of patents : values of R&D expenses
	Size	Number of employees	Number of employees of the years 2002-2008
	Technology diversification	Ratio of diversification of the patents	1/Herfindahl index of the different categories in which the patents of the total company are situated

[a] Calculations of the variable is conducted with medical patents

[b] If available the information of the segment Medical Devices is incorporated in the dataset

5.2. Process of data collection

Before the process of data collection starts a selection of the large sized companies is made. After this selection the financial data and patents are gathered. The process of this data collection is described in this paragraph.

5.2.1. Selection of the main companies

Since 2003 Medical Product Outsourcing (MPO) brings out reports about the key players in the medical devices industry. The report makes its top 30 selection on basis of companies' sales of medical devices of the previous year (Delporte, Barbella, & Stommen, 2010).. The medical device companies that were amongst the top 30 companies, in the area of sales in any year from 2002 to 2009 were included in the data collection scope of this research.

According to Medical Product Outsourcing (Rodman Publishing, 2011) forty companies made revenues over a billion in the industry of the medical devices during the years 2002 -2009. Companies who have medical devices and other outputs of which the sales are not clearly separated in the commercial year report will stay included. An overview of the companies with their main branches in which they are operating can be found in attachment A.

5.2.2. Collecting financial data

After selecting the companies the creation of the database was started. The financial data, which is necessary to collect the data commercial performance (i.e. sales) data and calculate the control variables, is retrieved from the financial year reports. Those reports are available on the website www.sec.gov. The website is from the United States Government, the Security and Exchange Commission (SEC). The commission attempts to protect investors, maintain a fair and efficient market, and facilitates in capital information. The government of the U.S. rules that the information of companies on the market should provide access to certain basic facts about their company before the investor buys a stock.

To provide this information public companies are required to file documents about their financial performances to the commission. These documents are available through the EDGAR database. Through this database the data of the companies is retrieved. Of the forty companies eight did not provide their financial data as they are not on the stock market and therefore not obligated to provide this data. Those eight were excluded in this research. The data retrieved from those financial year reports exists of sales, R&D expenses, assets and the names of the consolidated subsidiaries.

5.2.3. Retrieving patent data

To be able to calculate the exploration share of the innovation activities and the concentration of exploration of subsidiaries of patent application data of the companies is used. The patent data is retrieved from the database from the European Patent Office (EPO) which is present at the University of Leuven. To collect these patents the 32 names, all the different variations of the companies' name and subsidiaries are collected are run through the EPO database. After selecting to name variations the patent data is retrieved. The data shows a decline in the last years especially in the year 2009. This decline becomes through the incompleteness of the data, it takes around 18-30 months before an application of the patent becomes visible for the public. As the data is retrieved from the 2010 version from the EPO, it is seen that already quite a lot patents of the year 2008 are available but the year 2009 shows a massive decline and is taken out of the dataset.

Patent application data is used instead of patent grants, which is a better indicator of the companies' successful technology activities. Granting of a patent takes an average of 5 ½ years, making it an incomplete and incompatible indicator for studies with recent data. Patents applications provide a broader indicator of the variety of the technological activities of the companies (Belderbos, Faems, Leten, & van Looy, 2010). In this research a total 26496 patents are granted, the average granting time took 5 years, with 21% of grants having a granting period of seven years or longer. Exclusion of the not granted patents is due to the long granting period not ideal as this research has a scope from nine quite recent years.

Selection of medical patents

EPO uses a technology classification system called the International Patent Classification System (IPC). The IPC code begins with a letter-number-number-letter code, which has 628 variations. Behind the first part it differentiates into several 10,000's of subclasses. Those subclasses are classified by three to five numbers. The focus in this research is on medical devices therefore a separation is made in the dataset. The first dataset consists of all the patents and the second of medical patents. The medical patents are separated by the IPC-code section 'A61'. A61 stands for; A=human necessities and 61=medical or veterinary science; hygiene. ('A61D' stands for veterinary instruments, implements, tools, or methods, this is not present in the sample of this research) (International Patent Classification (IPC), 2011). After exclusion of the other patents, 17269 patents of the 48734 patents remain which belong to the 32 companies for the period 2002-2008.

5.3. Creation of the database

To test the relationships of the presented framework a longitudinal panel research design is chosen. A longitudinal panel research design facilitates in tracking change at the overall and individual level. The design is important in research examining the relationships of strategy and the performance level of the company because it enables the use of econometrical methods that control the endogeneity and unobserved heterogeneity (Uotila, Maula, Keil, & Zahra, 2009). Chosen for the time period of nine years is because large companies are often willing to engage in long-term innovation projects (5 years or longer) (He & Wong, 2004). By taking a time period of nine years makes the change that we miss those long innovation projects smaller and still have a database with the latest information.

Different steps will be taken to create a longitudinal database in SPSS of the key players in the industry of the medical devices. The remaining 48734 retrieved data from EPO at Leuven are still not ready to use without further processing. This process is done in excel. To be able to identify which patent is explorative and which is exploitative a macro is written on the basis of the definition of exploration and exploitation. The macro selects which patent is explorative or exploitative and to which subsidiary and parent company the patent belongs. When this macro is processed the variables for SPSS are calculated and put in SPSS.

5.3.1. Quality of the data

Before the analysis is started several checks need to be done to make sure the quality of the data is correct. Hereby the data of the Phillips and Medtronic are converted in US $. The exchange rate of the last day of the book year of the company will be used. The analysis will be done with all the companies who provide data that is specified for medical devices.
Three companies, which are also producing other products i.e. pharmaceuticals, in this dataset do not provide segment sales data on medical devices. These are Applera, Baxter International and Hospira. Because this research focuses on medical devices those companies are excluded for this model.

Table 2. Acquiring companies

Company name	Acquiring company	Year of acquisition
Applera Corporation	Invitrogen	2008
Bausch & Lomb	Warburg Pincus	2007
Guidant Corporation	Boston Scientific	2006
Kodak Health Group	Carestream Health, Inc.	2007
Tyco Healthcare	Covidien	2007

(Companies that were taken over during the years 2002-2008)

During the 9-year scope of this research four companies were taken over by other companies. Covidien formerly Tyco Healthcare is analyzed under the same name. The remaining companies stay in the dataset until the year of acquisition. Only the years after which the company was taken over are left out. Dade Behring is taken out of the dataset, because the company applied for (44) patents during the years 1997 – 2000 and our starting point of analysis is 2002. This leaves us with a total dataset of 27 companies.

5.4. Analysis of the database

After the database is created, the analysis is started and the hypotheses are tested. This is done by using SPSS, to be able to make the necessary calculations. The sample used in this research is not randomly chosen and is therefore necessary to be able to fix variable 'company'.

Most analytical procedures in software packages make the assumption that the observations in a data file represent a simple random sample from the population of interest. This assumption is untenable for this research. The companies are not randomly selected and one company has more than one data point. Using General Linear Model with the fixed factor company creates not only no significant results, it shows that everything depends on the variable company and employees. Addition to this is that the R Square is extremely high with a percentage of 99%.

Table 3. Example of results General Linear Model with sales being the dependent variable[a]

Source	Type III Sum of Squares	F	Significance level
Corrected Model	63,014	360,004	0,000
Intercept	0,062	12,097	0,001
Technology Diversification	0,002	0,341	0,560
Employees	0,223	43,351	0,000
Patent Propensity	0,006	1,109	0,294
R&D intensity	0,001	0,145	0,704
# Patents Applications	0,001	0,263	0,609
Company	7,416	49,671	0,000
Error	0,813		
Total	3046,832		
Corrected Total	63,827		
R Squared =0,987 (Adjusted R Squared = 0,985)			

[a] Dependent Variable: logarithmic transformed sales with two year lag. The data of this research is used for this example.

Showed in table 3 is a high r-squared and a significant relationship between company and employees and the dependent variable. Further investigation leads to the conclusion that the variance of sales within those companies is so small and probably creates this bias. This problem is created by one of the assumptions of this model, which assumes that we have knowledge about the error process. When the research has few enough parameters for the error process it does not create an issue. However, this is not the case in time series cross section models (characterized by repeated observations on fixed unites with often a number of cases between the 10-100), where the error process has a large number of parameters. This overestimation leads to the wrong conclusions (Beck & Katz, 1995). Therefore the General Linear Model (GLM) could provide insufficient output.

To ensure this research is valid the Complex Samples option in SPSS is used to cluster the data on the level of the companies. Important with clustering is that the units within the cluster should be as heterogeneous as possible for the characteristics of interest. As one cluster will exist of only one company the likelihood that this way of analyses introduces correlations among the sampling units, is small. The option of clustering samples in SPSS is not used often, therefore the GLM with fixed factor at company level and the option of clustering the companies are both explored. The results of both analyses will be presented in the next chapter.

5.4.1. Testing the correlations and hypothesis

The correlations of the different variables will be tested to see whether the possible relations are really able to predict the outcome. Cohen (1988) is one of the researchers who provides guidelines for the interpretation of a correlation, but also notes that these criteria are selective to the context of the research. In this research the line between a stronger and a weaker correlation is drawn up 0,4. The point 0,4 is chosen as there are much more external factors that influence the investigated relations which are not incorperated in this research.

Which statistical tests will be done will be elaborated per hypothesis;

H1: A higher number of patent applications increases the sales of the company.
First a closer look will be taken to see if there is a strong or weak correlation between the main variables: number of applied patents and the sales. Second the hypothesis will be confirmed if a positive significant linear relationship between the count of applied patents and the sales is found. Here, the technological performance is indicated by the total number of patents between 2002-2008. The commercial performance is represented by the yearly number of sales with a lag of one and two year.

H2: An inverted U-shape relationship exists between the exploration share of innovation activities in a company and number of patents applied for.
First a closer look will be taken to see if there is a strong or weak correlation between the main variables: exploration share and the number of applied patents. To be able to test whether an inverted u-shaped relationship exist, it is necessary to calculate the quadratic term of the exploration share. When the linear term of the exploration share is positive and the quadratic term of exploration share is negative, it gives an indication of an inverted u-shaped relationship. The inverted u-shape then suggests that a balance between exploration and exploitation is necessary. When both of the terms provide a significant relationship to the technological performance the hypothesis is confirmed.

H3: A lower degree of concentration of consolidated explorative subsidiaries within an organization has a positive influence on the relationship between the exploration share and the number of patent applications.
First a closer look will be taken to see if there is a strong or weak correlation between the main variables, degree of concentration of explorative subsidiaries, exploration share and the number of patent applications. The variable 'concentration of exploration' is tested as a moderator of the exploration share and is tested as a main effect to the number of patent applications.

5.4.2. Benchmark

In addition to testing the three hypotheses a simplified benchmark will be performed. *'Benchmarking is the ongoing structured and objective process of measuring and improving products/services, practices and processes against the best that can be identified worldwide in order to achieve and sustain competitive advantage'* (Gringer & Goldsmith, 1995). By identifying the best practices, it becomes a development process in which companies can learn from better performing companies how they can improve themselves. It provides information on what can be achieved in the market, how to achieve that and where the company is in relation to these criteria.

In this study the groups or companies that have the highest values on the variables indicated by this research are compared to the lower performing companies. The group of companies is small, but also within this group it is possible to see if a group or company is more efficient in the way they organize and structure their activities and transform it in outputs such as technological and commercial performance. By creating a benchmark the influence of a certain degree of exploration/exploitation balance and concentration of exploration is visible in the degree of performance of the companies.

The average of the main variables will be calculated over the years 2002-2008. The companies will then be ranked on their performance on the output variables technological (i.e. number of patent applications) and commercial (i.e. sales) performance.

6. Results

In this chapter, the analysis of the data will be described. First description information about the sales of the companies will be provided. Second the results of the analysis will be described in which all three hypotheses are tested. Third in this chapter will be a benchmark.

6.1. General information

Of the 27 remaining companies a longitudinal database is made, with the information retrieved from EPO and the financial year reports. To provide an impression of the companies involved in this research is in table 4 an overview provided with their average sales over the years 2002-2008. If companies have published separate financial data for the medical devices, it has been used in this report. If, not the overall net sales is used. The companies General Electric and Siemens have the highest overall sales with an average of respectively 155228 and 97246 million dollar. Varian Medical and Invacare the lowest with an average of respectively 1426 and 1446 million dollar sales. Looking at the sales in medical devices the situation changes. In this case, the companies Johnson & Johnson and General Electric are on top with an average of respectively 18375 and 14102 million dollar. Lowest average sales are for the companies the same companies, Varian Medical and Invacare.

Table 4. Average sales over the years 2002-2008 in millions of US dollars

	Company	MD[1]	Overall	Segment
1	JOHNSON AND JOHNSON	18375	50598	wide variety
2	GE HEALTH CARE	14102	155228	wide variety
3	MEDTRONIC	11216	11216	Wide variety
4	SIEMENS HEALTHCARE	10705	97246	Imaging & IT, Workflow & Solutions and Diagnostics
5	ABBOTT LABORATORIES	10309	22472	Wide variety
6	CARDINAL HEALTH	9396	71108	Wide variety
7	COVIDIEN (Tyco '07)	8823	28217	Wide variety
8	PHILIPS HEALTHCARE	8286	36834	Cardiac care, acute care and home healthcare
9	BOSTON SCIENTIFIC	6076	6076	Wide variety
10	STRYKER	4842	4842	Orthopedic
11	3M HEALTHCARE	4061	21199	Wide variety
12	GUIDANT CORP.	3564	3564	Cardiology and vascular products
13	ZIMMER	3008	3008	Orthopedic
14	BECTON DICKINSON	2953	5466	Wide variety
15	ST. JUDE MEDICAL	2882	2882	Cardiology and vascular products
16	SMITH AND NEPHEW	2671	2671	Orthopedics, endoscopy, advanced wound management
17	DANAHER	2512	8295	Dental and life sciences and diagnostics
18	KODAK HEALTH GROUP	2509	13468	Imaging systems
19	BECKMAN COULTER	2499	2499	Laboratory tools
20	ALCON	2063	4498	Ophthalmic surgical and vision care products
21	FRESENSIUS MEDICAL	2009	7492	Dialysis treatment
22	CR BARD	1825	1825	Vascular, urology, oncology and surgical specialties
23	BIOMET	1799	1799	Orthopedic
24	DENTSPLY INT.	1787	1787	Dental products
25	BAUSCH AND LOMP	1617	2143	Eye products
26	INVACARE	1446	1446	Non-acute medical equipment
27	VARIAN MEDICAL	1426	1426	Radiotherapy

[1] MD, Medical Devices

6.2. Statistical analysis

In this paragraph shows the results of the statistical analysis executed with computer program SPSS. The variables patent propensity number of patent applications, exploration share and concentration of exploration are calculated solely on the basis of the medical patents. Where available the segment sales of medical devices are used. [2]

6.2.1. Descriptive Statistics

The variables presented in table 5 shows the main variables used in the analysis to test the model presented in the theoretical framework. A logarithmic transformation is used for the variables that otherwise do not meet the criteria for the analyses. The variables sales, patent propensity, technological performance, exploration share and moderator are adjusted to the data of segment medical devices.

The table shows between which numbers the data is distributed, the mean and its skewness. The skewness is a measure for the asymmetry of a distribution. A normal distribution is symmetric and has a value of zero. Negative values indicate a left tail and positive values indicate a right trail of the normal distribution. The variables technology diversification, patent propensity and exploration share are higher skewed. The exploration share has an average of 33,2 % which is higher in comparison to earlier research of Belderbos et al. (2010) which had an average of 19,4%. The difference of 13,8% could be explained by a different time frame, the data of Belderbos et al. (2010) refers the 1996-2003 and this research to 2002-2008. Second is the difference in companies, they focus on a wide variety of companies, while this research focuses solely on companies who produce medical devices. To be able to provide of what is demanded in a dynamic environment the medical device companies should be able to adapt quick, which could also be the reason why the average exploration share is much higher.

Table 5. Descriptive Statistics [a]

	N	Min	Max	Mean	Std. Dev	Skewness
Sales one year lag	173	3,018	4,372	3,632	0,344	0,377
Sales two year lag	170	3,092	4,391	3,668	0,335	0,377
Technology Diversification	175	1	17,730	4,061	4,019	1,611
Employees	175	8,922	14,071	11,223	1,314	0,493
Patent Propensity	175	0,004	0,955	0,214	0,215	1,438
R&D intensity	175	0,001	0,168	0,064	0,037	0,308
# Patent Applied for	175	0,693	6,548	3,806	1,280	-0,007
Exploration Share	175	0,030	1,	0,332	0,221	1,490
Concentration of Exploration	175	0,020	1	0,506	0,293	0,414

[a] The variables Sales MD one year lag, Sales two year lag and Number of patent applications are logarithmic transformed. MD, Medical Devices. R&D, Research and Development. St Dev, standard deviation.

[2] *The analyses are done also with the three companies which were excluded because they did not provided specific sales information, these analysis and its results are available in appendix D.*

6.2.2. Correlations

Correlations of the variables used for the model are presented in table 6. This table presents Pearson's correlations. The table will be used as an indication for stronger or weaker correlations. For this study is chosen that a correlation higher than 0.4 is strong and below is weaker.

The control variables (numbers 3-6)

The variable technology diversification (3) shows a positive and significant correlation with sales, employees and a negative, significant correlation with the patent propensity and R&D intensity. It does not show any strong correlation with the main variables of this research, number of patent applications, exploration share and the concentration of exploration. The variable employees (4) has high correlation between almost every variables. The model used in this research already controls for the different companies and therefore is chosen to leave the control variable employees out of further analyses. Interesting is the degree of the medical patent propensity (5), which shows a negative significant relationship with all the variables. The R&D intensity (6) is correlating positive significant with variables sales and number of patent applications, but is negative with the other control variables, exploration share and concentration of exploration.

Variables of interest

As expected the correlation between one and two year lag of sales and the correlation between exploration share and its quadratic term is strong. The correlation of the sales two year lag with the other variables is a bit stronger than sales one year lag. The variables sales and number of patent applications has furthermore a negative correlation with the patent propensity, exploration share and concentration of exploration.

The variable exploration share and its quadratic term have no significant relation with the control variables technology diversification and R&D intensity. With the other variables the exploration share and its quadratic term show a negative significant relationship. The variable concentration of exploration shows a negative significant relationship with the sales, employees and number of patent applications and a positive significant relation to exploration share.

Table 6. Pearson Correlations[a]

	1	2	3	4	5	6	7	8	9	10
1 Sales one year lag	1									
2 Sales two year lag	0,98**	1								
3 Technology Diversification	0,20**	0,21**	1							
4 Employees	0,77**	0,78**	0,56**	1						
5 Patent Propensity	-0,26**	-0,27**	-0,39**	-0,35**	1					
6 R&D Intensity	0,17*	0,19**	-0,21**	-0,11*	-0,29**	1				
7 # Patent applications	0,68**	0,69**	-0,01	0,44**	0,16*	0,38**	1			
8 Exploration Share	-0,42**	-0,42**	0,03	-0,23**	-0,22**	-0,12	-0,65**	1		
9 Exploration share²	-0,35**	-0,35**	-0,02	-0,24**	-0,22**	-0,02	-0,60**	0,96**	1	
10 Concentration of Exploration	-0,36**	-0,39**	0,11	-0,22**	-0,13	0,10	-0,31**	0,22**	0,26**	1
N	173	170	175	175	175	175	175	175	175	175

[a] The variables Sales one year lag, Sales two year lag and Number of patent applications are logarithmic transformed. R&D, Research and Development * Significance at 5% level; ** Significance at 1 % level

6.2.3. Hypothesis 1

The first hypothesis '*A higher number of patent applications increases the sales of the company.*' medical devices segment. The correlation between the number of patent application is strong positive and significant with sales with a degrees of 0,68 (one year lag) and 0,69 (two year lag).

None of the control variables are significant without the number of patent applications, except for patent propensity with the fixed factor analysis at company level. When the number of patent applications is added the technology diversification is still not significant and the term is so small that it seems to have almost no influence on the model. The patent propensity becomes after addition of the number of patent applications negative significant. This is an interesting result as it was expected to have a positive influence. These results indicate that when the company is more efficient and increases their patent propensity it is negatively associated with the commercial performance of the company. This gives the impression that not the quantity but the quality if the patents could be of importance. This is an intriguing result which should be investigated further. The R&D intensity shows also a not expected negative relationship and is not significant in where the companies are included as a fixed factor. These results indicate that companies who increase their intensity of R&D can expect it to have a negative impact on the commercial performance of the company. This could be explained by reasoning that the R&D expenses are not increasing as fast as sales of the company. When the company has a good quality product which sells well, the company does not have to increase its R&D expenses in order to increase its sales, in short-term.

The number of patent applications is positively significant. These results support the hypothesis. Companies with a higher technological performance of medical patents perform in short-term better on commercial performance.

Differences in the use of the fixed factor or clustered standard errors statistical analysis are clearly visible. In de model with the clustered standard errors the addition of number of patent applications increases the r-square with 57,7% and 56,6% (respectively sales with one and two year lag). In the model with the fixed factor at company level this is 1,4% and 0,3% (respectively sales with one and two year lag). The influence of the number of patent applications is in table 7a more than ten times as high as in table 7b. [3] This indicates that there is a difference in using the company as a fixed factor or using clustered standard errors, but both methods show a positive relation.

[3] *Interesting is that in the basic model the R-Squared has a small decrease with from a one to a two year lag, where as the medial model has a small increase. Such difference indicate that it takes more time before medical patents and its product become a resource of income for the company (results of the basic model are available in appendix C).*

Table 7a. Commercial Performance as function Technological Performance[a]

Sales	1 year lag		2 year lag	
Technology diversification	0,015	-0,005	0,016	-0,004
	(0,013)	(0,012)	(0,013)	(0,013)
Patent Propensity	-0,238	-0,843**	-0,229	-0,795**
	(0,220)	(0,134)	(0,224)	(0,144)
R&D Intensity	1,551	-3,246*	1,725	-2,999*
	(1,987)	(1,275)	(1,985)	(1,306)
# Patent applications		0,241**		0,234**
		(0,030)		(0,031)
Constant	3,526**	3,122**	3,547**	3,147**
	(0,191)	(0,128)	(0,189)	(0,131)
Number of observations	173	173	170	170
Number of Companies	27	27	27	27
R-Squared	0,101	0,678	0,115	0,681

[a] The variable # Patent applications is logarithmic transformed. Dependent variable = Sales with one and two year lag. Clustered standard errors at company level.

* Significance at 5% level; ** Significance at 1 % level

Table 7b. Commercial Performance as function Technological Performance with the variable company as a fixed factor[a]

	1 year lag		2 year lag	
Technology diversification	0,000	-0,001	0,010	0,009
	(0,009)	(0,008)	(0,007)	(0,007)
Patent Propensity	-0,213**	-0,388**	-0,171**	-0,290**
	(0,066)	(0,079)	(0,053)	(0,064)
R&D Intensity	-0,174	-0,312	-0,277	-0,381
	(1,301)	(1,246)	(1,040)	(1,010)
# of patent applications		0,102**		0,069**
		(0,027)		(0,023)
Constant	3,591**	3,265**	3,619**	3,398**
	(0,087)	(0,120)	(0,069)	(0,099)
Number of observations	173	173	170	170
Number of Companies	27	27	27	27
R-Squared	0,921	0,935	0,953	0,956

[a] The variable # of patent applications are logarithmic transformed. Dependent variable = MD Sales with one and two year lag. Fixed factor at company level.

* Significance at 5% level; ** Significance at 1 % level

6.2.4. Hypothesis 2

The second hypothesis '*An inverted U-shape relationship exists between the exploration share of innovation activities in a company and number of patent applications.'* is tested by the linear and quadratic term of the exploration share. The correlations of both the linear as the quadratic term to the number of patent applications is strong with a negative significant degree of -0,65 (linear) and -0,60 (quadratic) .

The results of third column in table 9a and 9b (p. 37) show a not significant negative linear term and a negative quadratic term, except for the linear term in table 9a. This indicates that there is no inverted u-shaped relationship in relation to the number of patent applications, therefore hypothesis is not confirmed. These results do not support the hypothesis. As the linear term of exploration share is negative it suggests that medical device companies could better focus their activities on exploitation when they want to increase their number of patent applications. This could indicate that all the companies of this research have already passed the point where exploration has positive benefits. Implying that further research for new products is not beneficial for medical device companies.

The importance of a balance between explorative and exploitative activities is stressed by numerous scholars (e.g., Benner and Tushman, 2003; Levinthal and March, 1993; March 1991) and is supported by quantitative research by Belderbos et al. (2010) and Uotila et al. (2009). Earlier research provided an inverted U-shaped relationship between the share of exploration in a company and its financial performance.

In this research the inverted U-shaped relationship is tested between the explorative activities of the company and its number of patent applications. As these results are different than expected, the analysis is repeated with a change in the dependent variable to commercial performance. Table 8 shows the results of this extra analysis. These analysis show the opposite of what was expected. It shows a significant u-shaped relationship with sales. The different shape could suggest that the indicator 'sales' for the performance for the company does not comparable with the financial performance of the research of Uotila et al. (2009) and Belderbos et al. (2010). The inverted u-shaped found earlier is compared to an indicator which takes the stock

Table 8. Exploration share as a function of commercial performance

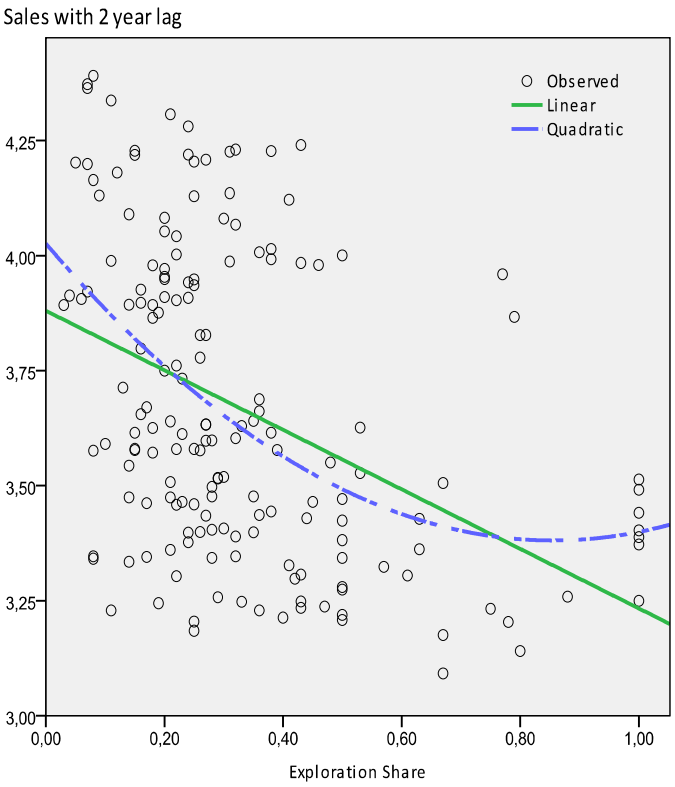
	Sales with two year lag			
	Clustered standard errors		Fixed factor at company level	
Technology diversification	0,016	0,011	0,010	0,009
	(-0,013)	(0,012)	(0,007)	(0,006)
Patent Propensity	-0,229	-0,483*	-0,171**	-0,138**
	(-0,224)	(0,178)	(0,053)	(0,048)
R&D Intensity	1,725	-0,036	-0,277	-1,031
	(-1,985)	(1,704)	(1,040)	(0,948)
Exploration share		-1,695*		-0,629**
		(0,473)		(0,127)
Exploration share^2		0,968**		0,491**
		(0,425)		(0,154)
Constant	3,547**	4,136**	3,619**	3,749**
	(-0,189)	(0,200)	(0,069)	(0,132)
Number of observations	170	170	170	170
Number of Companies	27	27	27	27
R-Squared	0,115	0,350	0,953	0,962

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development.

* Significance at 5% level; ** Significance at 1 % level

values (Tobin's Q) of a company in consideration as explorative patens are often considered of more value it shows in the indicator. In case of the sales this does not happen, as it is an outcome of the products sold during that period. As it takes often many years before a medical product is developed and allowed to enter the market the lag of one or two year is small and therefore creates a bias. This u-shaped impact could be a reaction on the dynamics and increasing strictness of regulations which is making it more difficult to enter the market with new products. Therefore it is for companies more beneficial to improve their approved and already entered products instead of trying to explore new products.

Graph 1 Exploration share as a function of commercial performance



The control variables show a different reaction when the dependent variable is changed. They are positive with the dependent variable number of patent applications, but negative, except for technology diversification, with the dependent variable sales. This implies that a higher medical patent propensity and R&D intensity increases the technological performance but do not increase the commercial performance. Two more analysis are done as these results do not meet the line of expectations a fourth control variable is added and the quadratic term of exploration is tested.

Adding a control variable

Some of the companies are solely focused on medical devices but others also supply for the pharmaceutical industry. Companies which also produce in the pharmaceutical industry are dealing with a different organization context than companies that only market themselves in the medical devices industry. This new variable is created on the basis of the product descriptions found in the financial year reports. The results of these analyses are available in appendix D table 1. This analysis does not show a different relation to the earlier results. This is to be expected as the control variable technology diversification should already control for the fact that some companies have wide variety of products and others focus solely on medical devices.

Quadratic term of technology diversification

Research of Leten, Belderbos & Looy (2007) provides prove for a inverted u-shaped relation ship between technology diversification and number of patent applications. Again the same analysis is repeated but now with the control variable technology diversification in its quadratic term. These last analysis also do not lead to a different outcome. The table is available in appendix D table 2.

Table 9a Technological Performance as function of companies Innovation Activities

	Number of patent applications					
	Hypothesis 2			Hypothesis 3		
Technology diversification	0,084	0,057	0,056	0,068	0,069	0,069
	(0,042)	(0,033)	(0,034)	(0,041)	(0,041)	(0,041)
Patent Propensity	2,546**	1,385*	1,386*	1,433**	1,449*	1,449*
	(0,898)	(0,629)	(0,627)	(0,609)	(0,613)	(0,613)
R&D Intensity	19,294**	14,408**	14,464**	15,818**	15,490**	15,490**
	(5,469)	(4,311)	(4,415)	(4,426)	(4,415)	(4,415)
Exploration share		-3,202**	-3,098*	-2,859**	-3,269**	-2,962**
		(0,417)	(1,267)	(0,326)	(0,811)	(0,332)
Exploration share^2			-0,104			
			(1,159)			
Concentration of Exploration				-1,049*	-1,242	-1,038*
				(0,441)	(0,611)	(0,441)
Moderator					0,606	
					(1,262)	
Moderator (z-values)						0,046
						(0,096)
Constant	1,689	3,426**	3,405**	3,695**	3,834**	3,731**
	(0,618)	(0,508)	(0,503)	(0,533)	(0,594)	(0,533)
Number of observations	175	175	175	175	175	175
Number of Companies	27	27	27	27	27	27
R-Squared	0,276	0,551	0,551	0,604	0,604	0,553

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development. Clustered standard errors at company level.
* Significance at 5% level ; ** Significance at 1 % level

Table 9b Technological Performance as function of companies Innovation Activities with the company variable as fixed factor

	Number of patent applications					
	Hypothesis 2			Hypothesis 3		
Technology diversification	0,013	0,003	0,003	-0,002	0,001	0,001
	(0,026)	(0,025)	(0,025)	(0,024)	(0,024)	(0,024)
Patent Propensity	1,734**	1,749**	1,744**	1,645**	1,656**	1,656**
	(0,196)	(0,185)	(0,187)	(0,184)	(0,184)	(0,184)
R&D Intensity	3,293	1,848	1,899	1,740	2,881	2,881
	(3,608)	(3,409)	(3,433)	(3,333)	(3,451)	(3,451)
Exploration share		-0,684**	-0,604	-0,772**	-0,443	-0,704**
		(0,153)	(0,467)	(0,153)	(0,305)	(0,162)
Exploration share^2			-0,085			
			(0,469)			
Concentration of Exploration				-0,375**	-0,199	-0,371**
				(0,135)	(0,195)	(0,135)
Moderator					-0,514	-0,039
					(0,413)	(0,031)
Moderator (z-values)						
Constant	3,092**	3,307**	3,295**	3,585**	3,407**	3,495**
	(0,245)	(0,236)	(0,246)	(0,251)	(0,289)	(0,261)
Number of observations	175	175	175	175	175	175
Number of Companies	27	27	27	27	27	27
R-Squared	0,955	0,96	0,96	0,962	0,963	0,963

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development. Fixed factor at company level.
* Significance at 5% level; ** Significance at 1 % level

6.2.5. Hypothesis 3

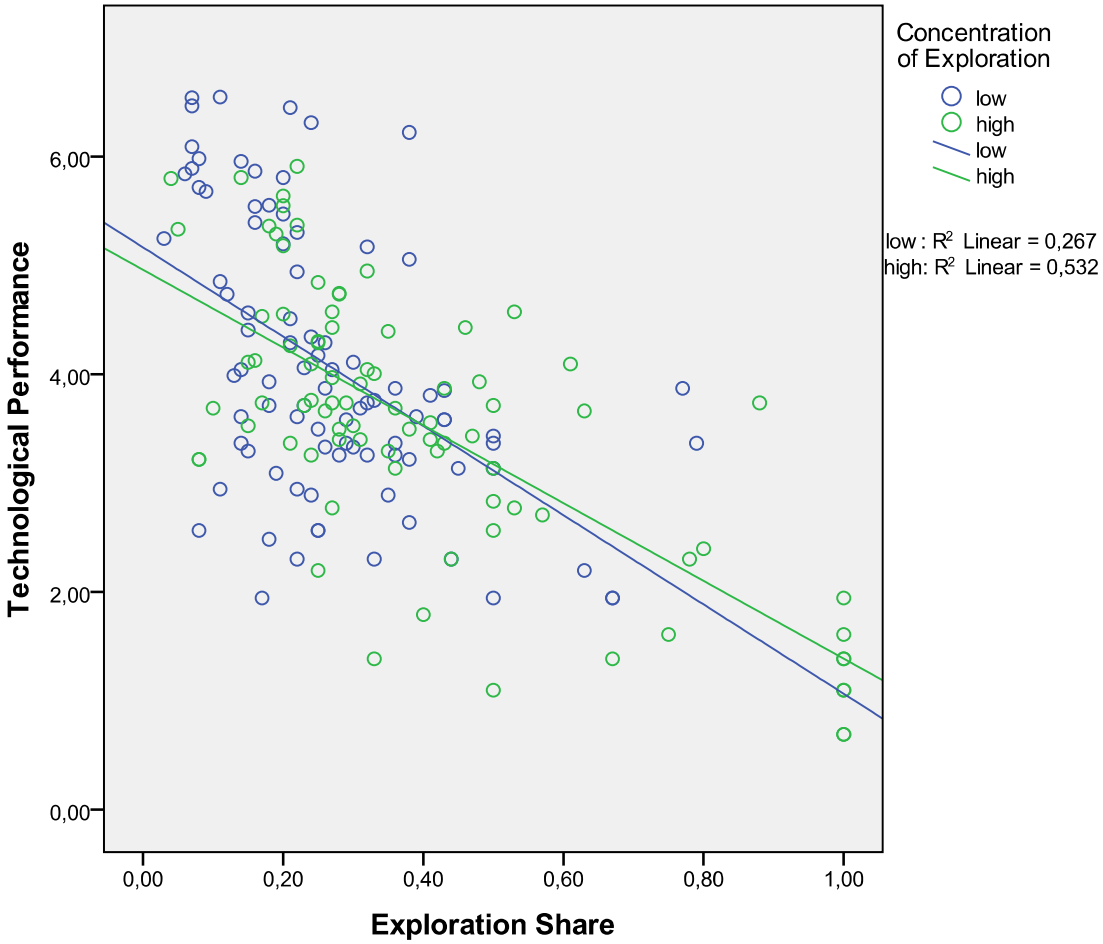
At last the third hypothesis; '*A lower degree of concentration of consolidated explorative subsidiaries within an organization has a positive influence on the relationship between the exploration share and the number of patent applications.'* is investigated. The correlation between the concentration of exploration and the number of patents applied for (-0,31), exploration share (0.22) and exploration share^2 (0,26) are weak significant.

There was no significant relationship found for the inverted u-shape of exploration share, the quadratic term of exploration share is not used in the analysis of this hypothesis.

Here is first tested if the concentration of exploration has a main effect on the number of patent applications. There is a significant main effect on the number of patent applications, this indicates that there is no interaction effect. To be sure the analysis was still executed. The interaction effect is measured by two variables. Both the moderator as the moderator with z-values does not show any significant relation. These results do not support the hypothesis.

Further analysis is done and the graph 2 (p. 39) presents these results. This graph shows a differentiation between the 50% companies with the lowest concentration of exploration and the 50% highest. The linear line with the lowest scores has a r-square of 26,57% and the highest a r-square of 53,2%. The blue line, indicating the low values of concentration of exploration, is above the green line until the crossing point. Indicating that companies with an exploration share lower than approximately 0,4 can better spread their activities which lead to more patents. After the 0,60 exploration share it is better to concentrate the explorative activities. This graphs shows that the results of table 8a and 8b do not account for all the companies. As shown these result can only be interpreted with caution.

Graph 2 Organization structure



The technological performance is logarithmic transformed

6.3. Benchmark

Earlier in this research is shown that the variable 'company' has a high correlation to all the variables. With this in mind the two different ways of doing analyses are presented. In this last piece of analysis a closer look is taken at the separate companies. This is done to try to create more insight in the strategy and structure of the best performing groups and individual companies.

6.3.1. Ranking

To create this insight a ranking is made on the level of number of patent applications (table 10a) and sales with a two year lag(table 10b). With this ranking the best performances are made visible. In both cases Johnson & Johnson, Medtronic and Philips Healthcare are in the top five. In the case of the highest application of patents has Boston Scientific the second ranking and in the sales with a two year lag is GE Health care. This could suggest that GE Health Care and Siemens Healthcare have a higher quality of patent application or is better able to make more money on their invented products than Boston Scientific and Abbott Laboratories. The complete ranking is available in appendix E tables 1-2 .

Table 10a Best technological performing companies

	Company	# Patents applications	Sales	Exploration share	Concentration of exploration
1	JOHNSON AND JOHNSON	587	21329	0,17	0,10
2	BOSTON SCIENTIFIC	309	7447	0,10	0,52
3	MEDTRONIC	308	13359	0,12	0,29
4	PHILIPS HEALTHCARE	225	9484	0,21	0,85
5	ABBOTT LABORATORIES	176	8935	0,23	0,14

Table 10b Best commercial performing companies

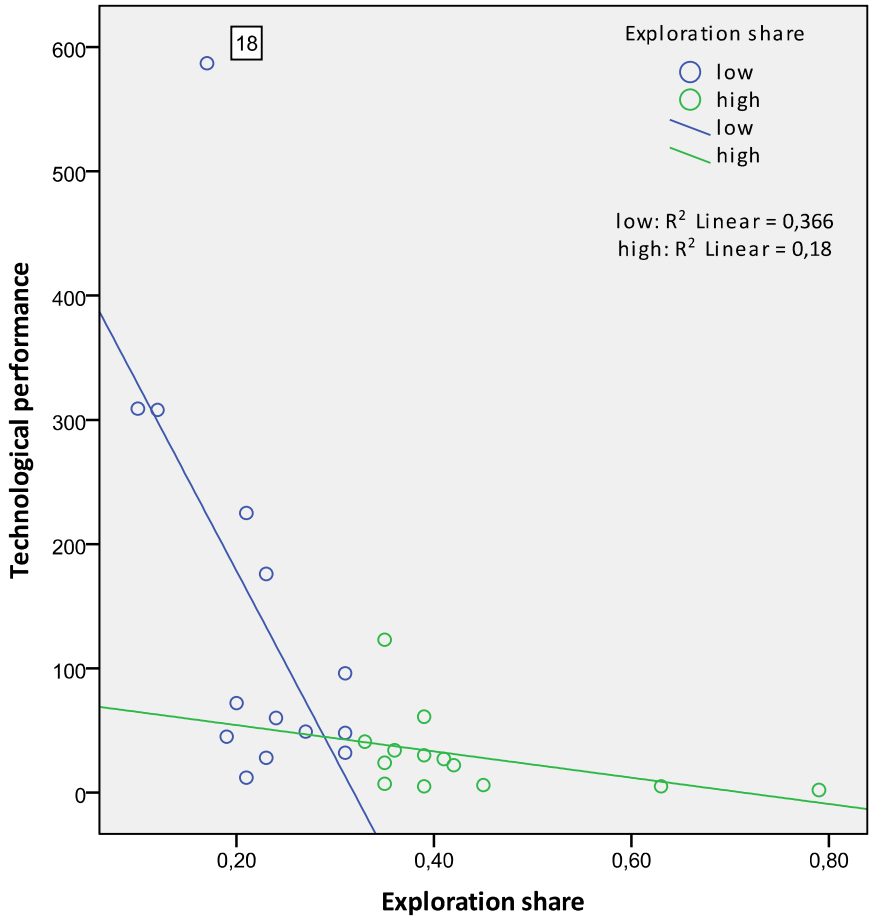
	Company	Sales	# Patents applications	Exploration share	Concentration of exploration
1	JOHNSON AND JOHNSON	21329	587	0,17	0,10
2	GE HEALTH CARE	16067	60	0,24	0,34
3	MEDTRONIC	13359	308	0,12	0,29
4	SIEMENS HEALTHCARE	13043	48	0,31	0,36
5	PHILIPS HEALTHCARE	9484	225	0,21	0,85

6.3.2. Exploration share of the best performing companies

In the table it is visible that the exploration shares of the best performing companies is below the average of 33,2%. This could indicate that a lower exploration share benefits as well the technological performance as the commercial performance. The indication partly holds up when graphs are created. In these graphs a separation is made between the companies with a lower average exploration share (blue dots and line) and a higher average exploration (green dots and line).

Graph 3 (p. 44) shows the negative relationship of exploration share and number of patent applications. The blue line shows a faster downward line with a high number of patent applications and the opposite accounts for companies with a lower share of patents and a higher share of exploration, the green line.

Graph 3. Exploration share as a function of technological performance



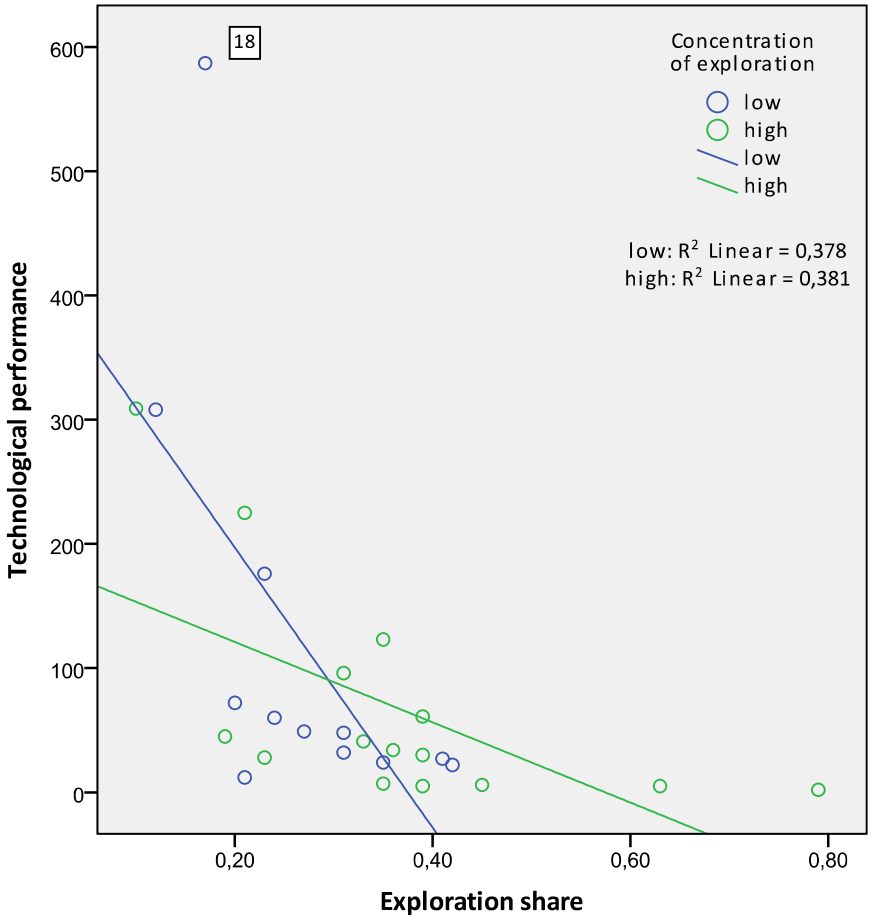
6.3.3. Concentration of exploration of the best performing companies

The table's 9a + b show opposite signals of concentration of exploration which has an average of 0,506. The data shows in both tables that at least one company (i.e. Boston Scientific and Philips Healthcare) in the top five has a high degree of concentration. This indicates that the *some* of the best performing companies have a lower degree of concentration of exploration. Which could mean that an organization structure where the exploration is differentiated among more subsidiaries is better for companies its commercial performance.

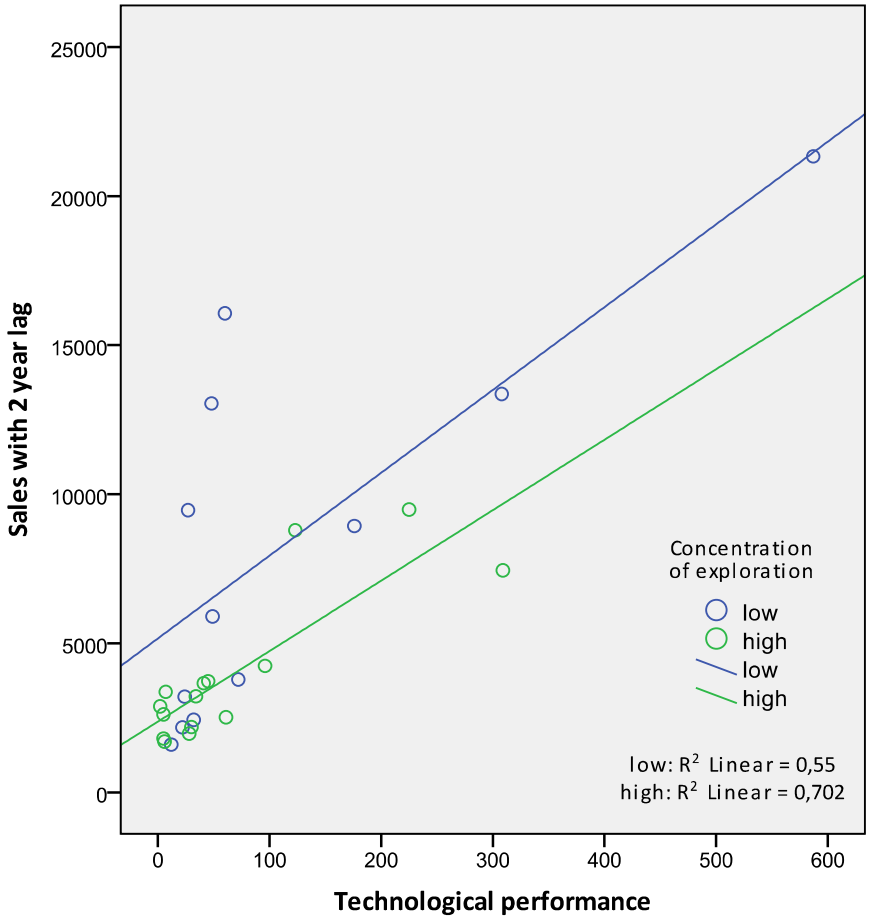
Graph 4 (p. 45) shows a differentiation between companies with a low and high degree of concentration of exploration, with a linear line between the number of patent applications and exploration share. The blue suggests that until the crossing point with the green line a company could better differentiate its explorative innovations activities.

Graph 5 (p.45) shows again the relation between number of patent applications and sales, with the differentiation of low and high degree of concentration of exploration. This graph indicates that a lower degree of concentration leads to a higher linear equation line. This indicates that companies who have their explorative innovation activities spread among more subsidiaries are performing better than companies who do less. *Already showed in earlier analyses the results are not significant so it must be interpreted carefully.*

Graph 4. Concentration of exploration as a function of technological performance and exploration share



Graph 5. Concentration of exploration as a function of commercial performance and technological performance



7. Discussion

The upcoming chapter will discuss the limitations of this research methods and results. The result of the analyses from this study and its limitations leads to some discussion and more questions.

7.1. Limitations of the research

As discussed in the chapter 'methodology', this research should control for the data per company. This could be done be several statistical analyses of which the general linear model was preferred, but showed a high r-square. Therefore is chosen to use two different statistical analyses, one whereby the variable 'company' is fixed and the other where the standard errors are clustered by the different companies. The main differences are visible in the r-squares. The results of the investigated hypothesis however did not differ. Besides this main limitation of statistical analysis five smaller methodology point need to be elaborated.

The first point is that this research is conducted among the 27 best players selected on their commercial performances. This is not representative for the market of medical devices which also has lots of medium and small sized companies. This research provided insights in the strategies used by the large established medical device companies.

The second point is that sales is not a value with a lot of prospect, therefore as in earlier research is done (e.g. Belderbos et al. 2009) , Tobin's Q provides a better variable. The Tobin's Q uses market share price, which are not available separately for the different segments in the stock market. A patent has its return in values of sales years later after the application of the patent, amongst others due to CE-marking. Using the Tobin's Q variable was for this specific research not possible because there is no information available about the medical devices segment of companies who also produce other products.

Third, is the point that the scope of this research in years was too small to look into the concept of punctuated equilibrium. This is a concept in which companies have several years of exploration activities and then several years of exploitation activities. Assumed is that in these 27 companies this would take place less visibly than in smaller companies.

Fourth is the method of marking when a patent is explorative or exploitative. To mark which patent is explorative and which patent is exploitative several options can be used. In this research the patent is marked explorative when it consisted one technology domain (one IPC-code) in which the company had not applied for a patent in the past five years. Another method could be that a patent is only market as explorative when all its technology domains are new. The last method is to calculate the ratio of explorative versus explorative patents. These last methods could lead to different outcomes in research as the average of explorative patens will drop.

Fifth, is that the set of data could be incomplete and could have a double count. It takes 18-30 months that application of the patent becomes visible for the public. The dataset used for this research included data until the year 2009. This leaded earlier on in this research to the exclusion of the year 2009, because the decline was too extreme in that. The decline due to this is also visible in the years 2007 and 2008. This could have an impact on the results of this research. The double count is visible in the basis patent dataset. The overall patents (n=48734) have 1059 patents that are count double, this leads is 2% of the total. The chance is probably 50% that those patents are marked by the wrong name, which leads to a 1% error in the results published in this report.

7.2. Validation

The internal validation of this research is partly discussed in the paragraph above. It becomes clear that the indicator to sales is too big of a step between the tested relationship of innovation activities and commercial performance. The innovation activities and the technological performance probably relate better to the stock values of an organization as the patents represents future products and not the products now on the market.

The external validity is questionable. The generalisability of the outcomes of this research only account for best performing companies in the medical device industry. This investigation can create a better insight in the most successful organization structures and innovations activities of companies who produce medical devices.

8. Conclusion

In this chapter the sub-questions (and their corresponding hypotheses) and the main research question of this research are answered. Also the implications for literature and practice will be elaborated while the questions are answered.

The companies of this research belong in the top 30 of best commercial performing medical device companies during the years 2002-2008. To see why these companies perform so well on sales, research is conducted to see if they execute the same way of innovation activities and where these innovation activities take place. The goal of this research was to provide insights in how the organization structure and innovation activities of a company in the field of medical devices affect their technological performance and commercial performance. This research indicates that the relationships between innovation activities, technological performance, organizational structure and commercial performance are different than expected. Several sub-questions and hypothesis are created to answer the main question of this research.

Increase of sales by increasing the technological activities

The first question *´What influence does the technological performance have on the commercial performance?´* and hypothesis is to investigate the expected positive relationship of technological performance on commercial performance. This expectation is confirmed. This means that if companies want to improve their sales and stay competitive in medical devices they should invest in innovation by applying patents for their invention.

Decrease technological performance by an increase of exploration

The second question *´What influence do innovation activities have on the technological performance?´* and hypothesis is created to investigate if a good balance between exploration and exploitation leads to higher technological performance. To perform analysis which searched for an inverted u-shaped relation of exploration share as a function of technological performance it was expected to find a certain degree of ambidexterity. Instead of a balance a negative relationship of exploration share to technological performance is found. This suggests that large medical device companies can better focus on exploitation to increase their technological performance.

Spreading exploration activities

The last question *´What influence does the organization structure have on the connection between innovation activities and companies' technological performance?´* and hypothesis is created to analyze the expected positive influence that concentration of explorative activities has on the relationship between the innovation activities and the technological performance. The statistical analysis rejects this hypothesis. The analyses show that the concentration of exploration has a direct effect on the technological performance. The value of the direct effect is negative which indicates that companies who want to increase their technological performance should spread their explorative activities.

Benchmark

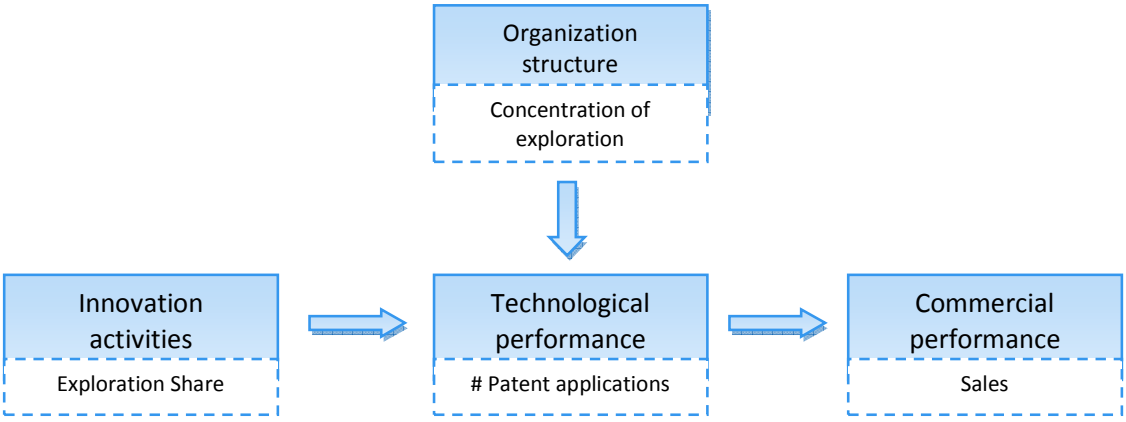
Insight in the performances of the companies of this research is created by performing a benchmark. The benchmark showed on both dependent variables, technological and commercial performance, that Johnson & Johnson is the best competitor on the market of medical devices. The company has an average exploration share of 0,17 and a concentration degree of 0,10. Compared to other companies only Medtronic and Boston Scientific have a lower degree of exploration, but a higher degree of concentration. It could suggest that those two companies should increase their exploration activities and differentiate those activities. All the other companies should increase their exploitation and should spread their explorative activities between more subsidiaries.

Based on the results of the sub-questions and the simplified benchmark the main research question can be answered ***'What influence do innovation activities and the structure of organizations have on the technological- and commercial performance on medical device companies?'*** The explorative innovation activities and organization structure (concentration of exploration) have a negative influence on the technological performance and the technological performance has a positive influence on the commercial performance, in the short-term. These results suggest that medical device companies who want to increase their performances on short-term sales and technology should invest in exploitation activities, but if they do invest in explorative activities it is better to differentiate.

The results of this present research contribute to the literature of innovation activities and organization structures in several ways. First, research of large sized medical device companies remains scarce. To provide research in this group of companies it is made clear that they react differently to the assumed balance of exploration and exploitation. It indicates that by the use of the technological performance as a dependent variable does not provide evidence for such a balance, as showed in Belderbos et al. (2010) and Uotila et al. (2009). Second, it provides evidence that in the group of large sized medical device companies the concentration of exploration has a negative main effect on technological performance.

In sum these results of this research are providing indications for a different theoretical model than is tested in this research. The new model has still the same basis as the old model but indicates also a line between innovation activities and commercial performance.

Figure 3. Suggested new model as theoretical framework



8.1. Recommendations further research

First recommendation is to investigate the different control variable patent propensity that showed other results than expected. The patent propensity has a negative significant relation to its sales for those medical device companies. By doing further analysis with this variable it may become clear why this shows no significant relationship.

The correlations showed interesting results, especially the control variable technology diversification which had no significant and a weak correlation to the variables of interest. Explanation could be that most of the companies in the scope of this research have their focus on medical devices. This is in need of further investigation as it becomes not really clear why there is such a weak relation.

Already mentioned in the discussion is the limited number of companies in this research. It was not possible to compare these well performing companies with companies which have fewer sales. To do a good benchmark it would have been better to have also a control group of medium and small sized companies. Then a more in-depth analysis can be executed to investigate if the larger companies have a different strategy of innovation. The not expected negative influence of the exploration activities can also relate to the small sample. Also for this relationship it could be of interest to create a bigger sample of with more medium and small sized companies.

In addition to the existing literature it is of interest to further investigate the way exploration is organized in the company. This effect did not show a moderating but a main effect on technological performance. The case is often that companies cannot enforce their employees to create new inventions but by dedicating more research in what is the most effective structure, companies are able to create the best environment in which exploration and exploitation can evolve itself. There is the desire that the research findings in this report encourage further research in these issues.

References

Ahmed, P., & Shepherd, C. (2010). *Innovation Management; Context, strategies, systems and processes.* Harlow, England: Pearson Education Limited.

Ahuja, G., & Lampert, C. (2001). Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal* , 22: 521–543.

Almeida, P., & Phene, A. (2004). Subsidiaries and Knowledge Creation: The Influence of the MNC and Host Country on Innovation. *Strategic Management Journal* , 847-864.

Ancona, D., Goodman, P., Lawrence, B., & Tushman, M. (2001). Time: A new research lens. *Academy of Management Review* , 26: 645-663.

Beck, N., & Katz, J. (1995). What to do (and not to do) with Time-Series Cross-Section Data. *The American Political Science Review, Vol. 89, No. 3* , 634-647.

Belderbos, R., Faems, D., Leten, B., & van Looy, B. (2010). Technological Activities and Their Impact on the Financial Performance of the Firm: Exploitation and Exploration within and between Firms. *Journal of Product Innovation Management* , 869-882.

Benner, M., & Tushman, M. (2003). Exploitation, exploratoin, and process management: the productivity dilemma revisited. *Academy of Management Review* , 238:256.

Birkinshaw, J., Hood, N., & Jonsson, S. (1998). Building firm-specific advantages in multinational corporations: the role of subsidiary initiative. *Strategic Management Journal* , 221-241.

Borgonovi, E., Busse, R., & Kanavos, P. (2008). Financing Medical Devices in Europe. *Eurohealth Vol 14 No 3* , 1-3.

Borgonovi, E., Busse, R., & Kanavos, P. (2008). Financing medical devices in Europe: Current trends and perspectives for research. *Eurohealth* , 1-3.

Braumoeller, B. (2004). Hypothesis testing and multiplicative interaction terms. *International Organization 58 (Fall)* , 807-820.

Brysbaert, M. (2006). *Psychologie.* Gent: Academia Press.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Cookson, R., & Hutton, J. (2003). Regulating the economic evaluation of pharmaceuticals and medical devices: a European perspective. *Health Policy* , 167-178.

Daft, R. (2004). *Organization Theory and Design.* Mason, Ohio: South-Western.

Daft, R. (2008). *Organization Theory and Design.* Mason, USA: Cengage Learning .

Delporte, C., Barbella, M., & Stommen, J. (2010). A Transformational Year for the industries largest firms. *Medical Product Outsourcing* .

Directive 2001/83/EC as amended by Directive 2004/27/EC. (2004). *OJ L 136* , 34-57.

Directive 2007/47/EC. (2007). *Official Journal of the European Union* , 23-24.

Dodgson, M., Gann, D., & Salter, A. (2008). *The management of technological innovation: strategy and practice.* New York, United States: The Oxford University Press Inc.

Dorsey, E., de Roulet, J., Thompson, J., Reminick, J., Thai, A., White-Stellato, Z., et al. (2010). Funding of US biomedical research. *The Journal of the American Medical Association* , 13;303(2):170-17.

Drummond, M., Griffin, A., & Tarricone, R. (2009). Economic Evaluation for Devices and Drugs—Same or Different? *Value in Health* , 402-406, Volume 12 , Number 4.

EMA/CAT and Medical Devices' Notified Body (EMA/CAT-NB) Collaboration Group. (1995-2011). Retrieved 2011 йил 21-Juli from European Medicine Agency: http://www.ema.europa.eu/ema/index.jsp?curl=pages/contacts/CAT/people_listing_000086.jsp&murl=menus/about_us/about_us.jsp&mid=WC0b01ac058029021c&jsenabled=true

European Commission: Enterprise and Industry. (2011). Retrieved 2011 йил 02-May from CE-marking: http://ec.europa.eu/enterprise/policies/single-market-goods/cemarking/index_en.htm

European Health and SMEs:Big Challenges, Small & Medium Sized Solutions. (2011, March 22). Retrieved May 16, 2011, from Eucomed: http://www.eucomed.org/uploads/Modules/Publications/110322_european_health_and_smes2011.pdf

European Medicine Agency; Mision statement. (1995-2011). Retrieved 2011 йил 23-June from http://www.ema.europa.eu/ema/index.jsp?curl=pages/about_us/general/general_content_000106.jsp&murl=menus/about_us/about_us.jsp&mid=WC0b01ac0580028a44

FD&C Act SEC. 201. [21 U.S.C. 321]. (2009, 07 13). Retrieved 04 07, 2012, from FDA: http://www.fda.gov/RegulatoryInformation/Legislation/FederalFoodDrugandCosmeticActFDCAct/FDCActChaptersIandIIShortTitleandDefinitions/ucm086297.htm

Financing Medical Devices in Europe. (2008). Retrieved May 16, 2011, from Together for Health Innovation: http://www.together4healthinnovation.eu/index.php?page=financing-of-medical-technologies-2

Gilbert, C. (2006). Change in the presence of residual fit: Can competing Frames Coexist? *Organization Science* , 150-167, Vol. 17, No. 1, January–February.

Griliches, Z. (Mar., 1994). R & D, Patents, and Productivity. *The American Economic Review* , 1-23, Vol. 84, No. 1,.

Griliches, Z., Hall, B., & Pakes, A. (1991). R&D, patents and market value re-visited. *Economics of Innovation and New Technology* , 183-202.

Gringer, P., & Goldsmith, R. (1995). Generating major change in companies. *Strategic Management Journal* , special issue; 131-146.

Gupta, A., Smith, K., & Shalley, C. (2006). The interplay between exploration and exploitation. *Academy of Managemnet Journal* , Vol. 49. 4. 693-707.

He, Z., & Wong, P. (2004). Exploration vs. Exploitation: An Empirical Test of the Ambidexterity Hypothesis. *Organization Science* , 15:481-494.

Health Care Systems. (2011). Retrieved 2011 йил 8-September from BusinessDictionary.com: http://www.businessdictionary.com/definition/health-care-system.html

Henderson, A. (1999). Firm Strategy and Age Dependence: A Contingent View of the Liabilities of Newness, Adolescence, and Obsolescence. *Administrative Science Quarterly* , 281-314.

Henderson, R., & Cockburn, I. (1996). Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery. *The RAND Journal of Economics* , 32-59, Vol. 27, No. 1.

IJzerman, M., & Steuten, L. (2011). Early assesment of medical technogies to inform product development and market access. A review of methods and applications. *Applied Health Economics and Health Policy* , 331-347(17).

Industry Concentration. (1999-2010). Retrieved 2012 йил 16-March from QuickMBA: http://www.quickmba.com/econ/micro/indcon.shtml

Inkpen, A., & Tsang, E. (2005). Social Capital, Networks, and Knowledge Transfer. *Academy of Management Review* , 146–165, Vol. 30, No. 1, .

International Patent Classification (IPC). (2011). Retrieved 2011 йил 15-December from World Intellectual Property Organization: http://www.wipo.int/ipcpub/#refresh=page&notion=scheme&version=20120101&symbol=A61

Jansen, J., van de Vrande, V., & Volberda, H. (2008). *Meer rendement uit R&D, nederlandse life sciences en medische technologie.* Rotterdam: Erasmus University Rotterdam.

Jefferys, D. (2001). The regulation of medical devices and the role of the Medical Devices Agency. *British Journal of Clinical Pharmacology* , 229–235.

Lang, L., & Stulz, R. (1994). Tobin's Q, Corporate Diversification and Firm Performance. *Journal of Political Economy* , 1248-1280.

Lavie, D., Stettner, U., & Tushman, M. (2010). Exploration and Exploitation Within and Across Organizations. *The Academy of Management Annals* , Vol. 4, No.1, 109-155.

Leten, B. v., Belderbos, R., & Looy, B. v. (2007). Technological Diversification, Coherence, and Performance of Firms. *Journal of Product Innovation Management* , pages 567–579, Volume 24, Issue 6,.

Levinthal, D., & March, J. (1993). The Myopia of Learning. *Stategic Management Journal* , 95-112.

Lobmayr, B. (2009). Markets, Innovation and Competition - Industrial dynamics in high risk medical devices., (pp. 2-3). Copenhagen, Denmark.

Maarse, H., & Bartholomée, Y. (2007). A public–private analysis of the new Dutch health insurance. *Eur J Health Econ* , 8:77–82.

March, J. (1991). Exploration and Explotation in Organization Learning. *Organization Science* , pp. 71-87, Vol. 2, No. 1.

Mintzberg, H. (1979). *The structuring of Organizations: A Synthesis of the Research.* Prentice-Hall.

OECD. (2005 йил 09-September). *Glossary of Statistical Terms*. Retrieved 2011 йил 23-June from OECD: http://stats.oecd.org/glossary/detail.asp?ID=6863

Pugh, D., Hickson, D., Hinings, C., & Turner, C. (1969). The Context of Organization Structures. *Administrative Science Quarterly* , 91-114.

Raisch, S., Birkinshaw, J., Probs, G., & Tushman, M. (2009). Organizational Ambidexterity: Balancing Exploitation and Exploration for Sustained Performance. *Organization Science* , 685-695, Vol. 20, No. 4, July–August.

Rodman Publishing. (2011). *The top 30*. Retrieved 2011 йил 15-June from MPO: Medical Product Outsourcing: http://www.mpo-mag.com/articles/2010/07/the-top-30

Sorenson, C., Tarricone, R., Siebert, M., & Drummond, M. (2011). Applying health economics for policy decision making: do devices differ from drugs? *Eurospace oxford journals* , 54-58.

Steuten, L. (2012, March 28). *Centralised procurement – a blessing or a curse?* Retrieved April 2012, 9, from Eucomed: http://www.eucomed.org/blog/111/59/blog/2012/03/28/Centralised-procurement-a-blessing-or-a-curse/

Tidd, J. (2001). Innovation management in context: environment, organization and performance. *International Journal of Management Reviews* , 169-183.

Tin, K. (2005). *Measuring Innovation Performance.* Singapore: Information Services Division, National Library Board.

Tushman, M., & O'Reilly III, C. (1996). Ambidextrous Organizations: Managing Evolutionary and Revolutionary Change. *CaliFronia Mangement Review* , 8-30 , VOL 38 No. 4.

Tushman, M., Anderson, P., & O'Reilly, C. (1997). Technology Cycles Innovation Streams, and Ambidextrous Organizations: Organization Renewal Through Innovaiton Streams and Strategic Change.

In M. Tushman, & P. Anderson, *Managing Strategic Innovation and Change* (pp. 3-23). New York: Oxford University Press.

Uotila, J., Maula, M., Keil, T., & Zahra, S. (2009). Exploration, Exploitation, and Financial Performance: Analysis of S&P 500 Corporations. *Strategic Management Journal* , 30: 221-231.

Utterback, J., & Abernathy, W. (1975). A Dynamic Model of Process and Product Innovation. *OMEGA* , Vol.3, No. 6, pp 639-656.

Wyke, A. (2011). *Economist view on EU healthcare.* Economist Intelligence Unit.

Glossary

Terminology	Definition
Ambidexterity	Balance between explorative and exploitative innovations activities in a company.
CE mark	Conformité Européene mark
EMA	European Medicines Agency
EPO	the European Patent Office
Exploitative innovation activities	Acts of creation in technological domains where the company has patented technology in the previous five years
Explorative innovation activities	Development of ideas that are situated in technological domain where the company has not patented technology during the past five years.
FDA	Food and Drug Administration in the U.S.
Innovation activities	All scientific, technological, organizational and commercial steps which actually, or intend to, lead to patent requests and eventually new or improved medical devices upon the health care market.
Innovation strategies	Analysis of companies' business, market and technological environments and consideration of what resources they have to draw upon. It also involves making choices about innovation in uncertain and ambiguous circumstances with diverse strategies for different levels of uncertainty.
IPC	International Patent Classification System
OECD	Organization for Economic Co-operation and Development
Organization structure	The sum of the ways in which an organization divides and coordinates its labor into distinct tasks. In this study the focus is on the differentiation or concentration of explorative subsidiaries of a company
Patent propensity	The efficiency of research and development expenses on applied patents
Punctuated equilibrium	Temporal cycling through periods of exploration and exploitation.
R&D intensity	Expenses on research a development divided by the total sales of the company
Technological performance	Number of applied patents during a year
Technology diversification	The differentiation of technological domains within a company

Appendix

A. Overview of the products of the companies

Overview of the top companies operating in the Medical Devices Industry from 2002 until 2009

	Company Name	Product/Branches	Customers/Users[d]
1	**3M Healthcare**	Medical and surgical supplies, skin health and infection prevention products, drug delivery systems, dental and orthodontic products, health information systems and anti-microbial solutions.	Medical clinics and hospitals, pharmaceuticals, dental and orthodontic practitioners, and health information systems.
2	**Abbott Laboratories**	Diagnostic systems and tests, vascular products; Broad line of coronary, endovascular, and vessel closure devices for the treatment of vascular disease.	Diagnostic products: Blood banks, hospitals, commercial laboratories, clinics, physicians' offices, alternate-care testing sites, and plasma protein therapeutic companies Vascular products: hospitals from Abbott-owned distribution centers and public warehouses.
3	**Agfa Health care**	No information found on subsidiaries or financial data.	
4	**Alcon**	Ophthalmic surgical and vision care products	
5	**Applera**	Instrument-based systems, consumables, software, and services for academic research, the life science industry, and commercial markets, commercializing innovative technology solutions for DNA, RNA, protein, and small molecule analysis.[e]	Academic and clinical research, pharmaceutical research, and manufacturing, forensic DNA analysis, and agricultural biotechnology.
6	**B.Braun**	No information found on subsidiaries or financial data.	
7	**Bausch & Lomb**	Contact lenses, lens care products, ophthalmic pharmaceuticals, cataract and vitreoretinal surgery, and refractive surgery	Local drug stores to hospital chains to independent practitioners and group purchasing and other managed care organizations
8	**Baxter International**	Products that save and sustain the lives of people with hemophilia, immune disorders, infectious diseases, kidney disease, trauma, and other chronic and acute medical conditions.	Hospitals, kidney dialysis centers, nursing homes, rehabilitation centers, doctors' offices, clinical and medical research laboratories, and by patients at home under physician supervision.
9	**Beckman Coulter**	Laboratory tools to enable research into fundamental processes of human biology, develop vaccines and drugs to treat disease, conduct clinical trials and related research activities and perform tests	Hospitals, laboratories, research centers and physician's offices

[d] Products and sales from the year 2009, except if otherwise are mentioned.

[e] Products and sales from the year 2008.

		ranging from simple patient blood analysis to complex diagnosis.	
10	**Becton Dickinson**	Development, manufacture and sale of medical devices, instrument systems and reagents.	Healthcare institutions, life science researchers, clinical laboratories, the pharmaceutical industry and the general public.
11	**Biomet**	Surgical and non-surgical products	Orthopedic surgeons and other musculoskeletal medical specialists.
12	**Boston Scientific**	Interventional medical specialties including cardiac rhythm management, electrophysiology, interventional cardiology, peripheral interventions, neurovascular, endoscopy, urology, women's health and neuromodulation.	Physicians
13	**Cardinal Health**	Distributes a broad range of medical, surgical and laboratory products. Also develops, manufactures and sources own line of medical and surgical products. These products include: sterile and non-sterile procedure kits; single-use surgical drapes, gowns and apparel; exam and surgical gloves; and fluid suction and collection systems.	Distributes to hospitals, surgery centers, laboratories, physician offices and other healthcare providers.
14	**Covidien (Tyco '07)**	Medical products such as endomechanical instruments, soft tissue repair products, energy devices, oximetry and monitoring products, airway and ventilation products, products used in vascular therapies, nursing care products, medical surgical products, SharpSafety products and original equipment manufacturer products (OEM)	Hospitals
15	**CR Bard**	Vascular, urology, oncology and surgical specialties	Hospitals, individual healthcare professionals, extended care facilities and alternate site facilities
16	**Dade Behring**	Medical diagnostic instruments, reagents and consumables, and maintenance services	Clinical laboratories
17	**Danaher**	Dental and life sciences and diagnostics	Clinical and research medical professionals
18	**Dentsply International**	Dental consumable products, dental laboratory products and dental specialty products	Domestic and foreign distributors, dealers and importers and dental laboratory or dental professionals.
19	**Drager Medical AG & Co.**	No information found on subsidiaries or financial data.	
20	**Fresenius Medical**	Kidney dialysis, and clinical laboratory testing services, and manufacturing and distributing products and equipment for dialysis treatment.[f]	

[f] 2003

21	**Gambro**	Renal care and blood component technology	
22	**GE Health care**	Medical imaging and information technologies, medical diagnostics, patient monitoring systems, disease research, drug discovery and biopharmaceutical manufacturing technologies	
23	**Guidant Corp.**	Designs and manufactures artificial pacemakers, implantable defibrillators, stents, and other cardiovascular medical products.	
24	**Hospira**	Generic injectable pharmaceuticals, manufacturing generic acute-care and oncology injectables, as well as integrated infusion therapy and medication management systems.	hospitals and alternate site providers, such as clinics, home healthcare providers and long-term care facilities
25	**Invacare**	Non-acute medical equipments including wheelchairs, mobility scooters, walkers, pressure care and positioning, as well as respiratory products	
26	**Johnson & Johnson**	Ethicon's surgical care, aesthetics and women health products; Ethicon Endo-Surgery's minimally invasive surgical products; Cordis' circulatory disease management products; LifeScan's blood glucose monitoring and insulin delivery products; Ortho-Clinical Diagnostics' professional diagnostic products; DePuy's orthopedic joint reconstruction, spinal products and sport medicine products and Vistakon's disposable contact lenses.	Customers are wholesalers, hospitals and retailers and the products are used by physicians, nurses, therapists, hospitals, diagnostic laboratories and clinics.
27	**Kodak Health Group**	Laser printers with dry film technology, computer radiology systems, digital radiology systems, picture archiving and communications systems, systems for mammography and other imaging solutions for the medical and dental imaging fields.	
28	**Medtronic**		
29	**Olympus Medical**	No information found on subsidiaries or financial data.	
30	**Philips Healthcare**	Cardiac care, acute care and home healthcare	Academic, enterprise and stand-alone institutions, clinics, physicians, home healthcare agencies and consumer retailers
31	**Siemens Healthcare**	Imaging & IT, Workflow & Solutions and Diagnostics	Customers include providers such as hospital groups and individual hospitals, group and individual medical practices, reference and physician office laboratories and outpatient clinics.

32	**Smith & Nephew**	Orthopedics, endoscopy and advanced wound management	
33	**St. Jude Medical**	Cardiac resynchronization therapy devices for heart failure. Artificial pacemakers and implantable cardioverter defibrillators (ICDs) for treating cardiac rhythm disorders Diagnostic and therapeutic electrophysiology catheters Introducers, catheters, and vascular closure devices for cardiology and vascular access. Mechanical and tissue heart valves plus valve repair products. Spinal cord stimulators for intractable pain.	
34	**Stryker**	Orthopedic Implants and Medical Surgery Equipment	
35	**Synthes**	No information found on subsidiaries or financial data.	
36	**Terumo**	No information found on subsidiaries or financial data.	
37	**Toshiba**	No information found on subsidiaries or financial data.	
38	**Varian Medical**	Equipment and software products for treating cancer with radiotherapy, stereotactic radio surgery, brachytherapy, x-ray tubes for original equipment manufacturers (“OEMs”); replacement x-ray tubes, flat panel digital image detectors for filmless x-ray imaging, linear accelerators, digital image detectors, image processing software and image detection products, proton therapy products and systems for cancer treatment.	
39	**Zimmer**	Orthopedic reconstructive implants, dental implants, spinal implants, trauma products and related surgical products	Orthopedic surgeons, neurosurgeons, oral surgeons, dentists, hospitals, stocking distributors, healthcare dealers and, in their capacity as agents, healthcare purchasing organizations or buying groups

B. No fixed factor or clustering of standard errors at company level

The results presented in this appendix are the analysis done with no correction at company level at all. The results are comparable of those with the clustered standard errors, but differ on the estimations of those standard errors.

Table 1. Addition to table's 7a and 7b Commercial performance as a dependent for Technological performance[a]

	1 year lag		2 year lag	
Technology diversification	0,015*	-0,005	0,016*	-0,004
	(0,007)	(0,004)	(0,007)	(0,004)
Patent Propensity	-0,238	-0,843**	-0,229	-0,795**
	(0,138)	(0,090)	(0,134)	(0,087)
R&D Intensity	1,551*	-3,246**	1,725*	-2,999**
	(0,773)	(0,540)	(0,753)	(0,531)
# Patent applications		0,241**		0,234**
		(0,014)		(0,014)
Constant	3,526**	3,122**	3,547**	3,147**
	(0,088)	(0,058)	(0,086)	(0,057)
Number of observations	173	173	170	170
Number of Companies	27	27	27	27
R-Squared	0,101	0,678	0,115	0,681

[a] The variables Total Sales one year lag, Total Sales two year lag and Number of Patent applications are logarithmic transformed. Dependent variable = total sales with one or two year lag. R&D, Research and development

* Significance at 5% level

** Significance at 1 % level

In table one the control variable technology diversification and R&D intensity show a significant relation to the commercial performance both with one year and two year lag. When the technological performance is added the technology diversification is no longer significant. The other variables are significant at the 1% level. This implies also the positive significant relation of technological performance to sales.

Table 2. Addition to tables 8a and 8b Technological performance as function of Innovation activities[a]

	Number of Patent applications					
	Hypothesis 2			Hypothesis 3		
Technology diversification	0,084**	0,057**	0,056**	0,070**	0,069**	0,069**
	0,024	0,019	0,019	0,019	0,018	0,018
Patent Propensity	2,546**	1,385**	1,386**	1,504**	1,449**	1,449**
	0,460	0,381	0,382	0,376	0,361	0,361
R&D Intensity	19,294**	14,408**	14,464**	15,925**	15,490**	15,490**
	2,528	2,055	2,140	2,088	2,037	2,037
Exploration share		-3,202**	-3,098**	-2,904**	-3,269**	-2,962**
		0,314	1,119	0,326	0,749	0,350
Exploration share2			-0,104			
			1,070			
Concentration of Exploration				-0,672**	-1,242**	-1,038**
				0,242	0,391	0,222
Moderator						
					0,606	
Moderator (z-values)					1,012	0,046
						0,077
Constant	1,689**	3,426**	3,405**	3,482**	3,834**	3,731**
	0,292	0,287	0,360	0,282	0,361	0,283
Number of observations	175	175	175	175	175	175
Number of Companies	27	27	27	27	27	27
R-Squared	0,276	0,551	0,551			

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development. Clustered standard errors at company level.

* Significance at 5% level

** Significance at 1 % level

Table two shows no different results than the previous analysis. The exploration share has significant negative linear relationship to technological performance. Here also the quadratic term of exploration share is not significant and there for not used in the analysis of hypothesis three. For the third hypothesis is again showed that there is no moderating effect of concentration of exploration but a main effect on technological performance.

C. Additional analyses hypothesis 2

Table 1. Analysis controlled for portfolio of products

	Number of Patent applications			
	Medical devices		MD and other products	
Technology diversification	-0,120	-0,093	0,094	0,084
	0,106	0,063	0,070	0,046
Patent Propensity	2,008*	0,990	22,331**	18,293**
	0,876	0,552	5,137	3,965
R&D Intensity	12,550	10,297**	16,426	11,892
	4,779	4,252	17,509	9,189
Exploration share		-1,033		-7,843**
		1,474		1,852
Exploration share^2		-1,682		4,580*
		1,256		1,945
Constant	2,660**	3,659**	1,065**	3,508**
	0,612	0,571	1,676	1,016
Number of observations	126	126	49	49
Number of Companies	19	19	8	8
R-Squared	0,323	0,595	0,605	0,797

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development. Clustered standard errors at company level.
* Significance at 5% level
** Significance at 1 % level

Table 2. Quadratic term of technological performance

	Number of Patent applications			
	Clustered standard errors		Fixed factor at company level	
Technology diversification^2	0,006*	0,004*	0,000	0,000
	(0,002)	(0,002)	(0,001)	(0,001)
Patent propensity	2,475**	1,348*	1,731**	1,744**
	(0,854)	(0,587)	(0,196)	(0,187)
R&D Intensity	18,458**	13,892**	3,116	1,941
	(5,385)	(4,267)	(3,625)	(3,446)
Exploration share		-3,167*		-0,602)
		(1,271)		(0,466)
Exploration share^2		-0,002		-0,088
		(1,162)		(0,467)
Constant	1,908**	3,556**	3,121**	3,296**
	(0,522)	(0,472)	(0,237	(0,239)
Number of observations	170	170	170	170
Number of Companies	27	27	27	27
R-Squared	0,289	0,556	0,955	0,960

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development.
* Significance at 5% level; ** Significance at 1 % level

D. The basic model

This model contains all the data information of the company in total. The variables are calculated by the using the overall number of patents and sales.

Descriptive Statistics

The variables presented in table 1 show the main variables used in the analyses of the basic model. A logarithmic transformation is used for the variables that otherwise did not meet the criteria for the analyses. The variables Technology Diversification, Patent Propensity and R&D intensity are higher skewed, which is in line with prior studies. The exploration share has an average of 45,2% which is more than twice as high in comparison to earlier research of Belderbos et al. (2010) which had an average of 19,4%.

Table 1. Descriptive Statistics for Dependent, Control and Explanatory variables [a]

	N	Min	Max	Mean	Std. Dev	Skewness
Total Sales one year lag	198	3,018	5,261	3,895	0,583	0,672
Total Sales two year lag	194	3,092	5,261	3,929	0,576	0,660
Technology Diversification	202	1,000	17,730	3,950	3,825	1,704
Employees	200	8,922	14,071	11,153	1,286	0,529
Patent Propensity	202	0,018	1,099	0,296	0,239	1,124
R&D intensity	202	0,001	0,226	0,066	0,041	0,959
# Patent applications	202	1,386	7,698	4,321	1,479	0,508
Exploration share	202	0,100	1	0,452	0,211	0,672
Concentration Explorative Subsidiaries	202	0,050	1	0,524	0,295	0,121

[a] The variables Total Sales one year lag, Total Sales two year lag, Employees and Number of patent applications are logarithmic transformed.

Correlations of the variables used for the basic model are presented in table 2. As expected the correlation between one and two year lag of total sale and the correlation between exploration share and its quadratic term is strong. Interesting is that the two year lag seem to have a smaller correlation of most of the variables. The variable 'concentration of exploration' does not show any significant relationships with the number of patent applications and exploration share. This could suggest that the moderator variable in this research will have no significant influence. The control variable employee has high correlation between almost all other variables. The model used in this research already controls for the different companies and therefore is chosen to leave the control variable employees out of further analyses.

Table 2. Pearson Correlations for the basic model [a]

	1	2	3	4	5	6	7	8	9	10
1.Total Sales 1 year lag	1									
2.Total Sales 2 year lag	0,99**	1								
3.Technology Diversification	0,49**	0,49**	1							
4.Employees	0,93**	0,93**	0,52**	1						
5.Patent Propensity	-0,07	-0,07	0,17*	-0,04	1					
6.R&D Intensity	-0,15*	-0,13	-0,13	-0,19**	-0,31**	1				
7. # Patent applications	0,68**	0,68**	0,54**	0,70**	0,27**	0,25**	1			
8.Exploration share	-0,25**	-0,25**	0,04	-0,20**	-0,08	-0,33**	-0,51**	1		
9. Exploration Share[2]	-0,26**	-0,25**	0,02	-0,21**	-0,10	-0,27**	-0,47**	0,97**	1	
10.Concentration Exploration	-0,27**	-0,28**	0,12	-0,20**	-0,02	0,11	-0,09	0,11	0,13	1
N	**198**	**194**	**202**	**200**	**202**	**202**	**202**	**202**	**202**	**202**

[a] The variables Total Sales one year lag, Total Sales two year lag, Employees and Number of patent applications are logarithmic transformed. R&D, Research and Development

* Significance at 5% level

** Significance at 1 % level

Table 3a. Commercial performance as a dependent for Technological performance

	1 year lag		2 year lag	
Technology diversification	0,077**	-0,002	0,076**	-0,002
	(-0,019)	(-0,012)	(-0,018)	(-0,012)
Patent Propensity	-0,481	1,178	-0,458	-1,126**
	(-0,295)	(-0,174)	(-0,296)	(-0,179)
R&D Intensity	-2,063	-7,968	-1,827	-7,747**
	(-2,57)	(-2,028)	(-2,600)	(-2,037)
# Patent applications		0,380**		0,373**
		(-0,034)		(-0,034)
Constant	3,870**	3,132**	3,888**	3,167**
	(0,249)	(-0,151)	(-0,246)	(-0,15)
Number of observations	198	198	194	194
Number of Companies	30	30	30	30
R-Squared	0,286	0,77	0,28	0,759

[a] The variables Total Sales one year lag, Total Sales two year lag and Number of patent applications are logarithmic transformed. Dependent variable = total sales with one or two year lag. Clustered standard errors at company level. R&D, Research and development

* Significance at 5% level

** Significance at 1 % level

Table 3b. Commercial performance as a dependent for technological Performance with fixed factor on companies' level[a]

	1 year lag		2 year lag	
Technology diversification	0,002	-0,001	-0,002	-0,004
	(0,007)	(0,007)	(0,007)	(0,007)
Patent Propensity	-0,357**	-0,525**	-0,271**	-0,356**
	(0,046)	(0,058)	(0,043)	(0,057)
R&D Intensity	0,285	-0,772	0,52	-0,143
	(0,678)	(0,687)	(0,738)	(0,783)
# Patent applications		0,113**		0,058*
		(0,026)		(0,025)
Constant	3,621**	3,296**	3,635**	3,475**
	(0,053)	(0,09)	(0,054)	(0,088)
Number of observations	198	198	194	194
Number of Companies	30	30	30	30
R-Squared	0,98	0,982	0,983	0,984

[a] The variables Total Sales one year lag, Total Sales two year lag and Number of patent applications are logarithmic transformed. Dependent variable = total sales with one or two year lag. The companies are included as fixed factors. R&D, Research and development

* Significance at 5% level

** Significance at 1 % level

The first hypothesis '*A higher number of patent applications increases the sales of the company.'* is tested with a one and a two year lag on the total sales and without and with the standard errors clustered (table7a) and the company as a fixed factor variable (with 3b).

The technology diversification shows only in table 3a significant results without the addition of technological performance. The patent propensity shows in all cases a negative but significant relation. The R&D intensity shows also a not expected negative relationship and is not significant in where the companies are included as a fixed factor. As showed earlier, using the company as a fixed factor relates in a high r-square. Adding the variable number of patent applications results only in an increase of r-square of 0,1-0,2% in one and two year lag of the dependent variable sales. This is in contrast to where the variable company is not used as a fixed factor but the standard errors are clustered. There, in table 7a, the increase is 48,4% and 47,9% respectively with the dependent variable total sales one and two year lag. The variable of interest, technological performance, has a positive significant impact on the total sales of the company. This confirms the first hypothesis and implies that an increase in technological performance leads to an increase in commercial performance.

The second hypothesis was tested by linear and quadratic term of the exploration share. These results do not confirm the hypothesis: '*An inverted U-shape relationship exists between the exploration share of innovation activities in a company and number of patent applications'.* These results show that companies of the medical devices relate do not have a significant inverted u-shaped relationship to the number of patent applications. Table's 4a+b show an unexpected negative and significant relation with the linear term of exploration share. This implies that companies with a high share of exploration are doing less good than companies with a low share of exploration patents.

The third hypothesis is; '*A lower degree of concentration of consolidated explorative subsidiaries within an organization has a positive influence on the relationship between the exploration share and the number of patent applications.'* The concentration of exploration has no significant main effect or interaction effect on technological performance.

Table 4a. Technological performance as function of innovation activities

	Number of Patent applications					
	Hypothesis 2			Hypothesis 3		
Technology diversification	0,209**	0,213**	0,214**	0,220**	0,226**	0,226**
	(-0,042)	(0,026)	(-0,025)	(0,026)	(0,024)	(0,024)
Patent Propensity	1,886**	1,342**	1,338**	1,367**	1,420**	1,425**
	(-0,626)	(0,469)	(-0,464)	(0,476)	(0,486)	(0,488)
R&D Intensity	15,078*	9,127*	8,502**	10,110	9,539	9,43
	(-6,393)	(4,472)	(-4,218)	(4,956)	(4,699)	(4,687)
Exploration share		-2,975**	-5,273**	-2,804**	-4,150**	-2,999**
		(0,373)	(-1,483	(0,337)	(0,851)	(0,327)
Exploration share^2			2,16			
			(1,248)			
Concentration of Exploration				-0,710	-1,782	-0,734
				(0,450)	(0,912)	(0,430)
Moderator					2,295	
					(1,378)	
Moderator (z-values)						0,155
						(0,085)
Constant	1,934**	3,823**	3,772**	4,016**	4,627**	4,11**
	(0,542)	(0,423)	(-0,757)	(0,476)	(0,678)	(0,464)
Number of observations	202	202	202	202	202	202
Number of Companies	30	30	30	30	30	30
R-Squared	0,477	0,63	0,636	0,649	0,657	0,659

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development. Clustered standard errors at company level.
* Significance at 5% level; ** Significance at 1 % level

Table 4b. Technological performance as function of innovation activities with the variable company as a fixed factor

	Number of Patent applications					
	Hypothesis 2			Hypothesis 3		
Technology diversification	0,028	0,035	0,034	0,030	0,030	0,030
	(0,020)	(0,020)	(0,021)	(0,021)	(0,021)	(0,021)
Patent Propensity	1,502**	1,541**	1,559**	1,513**	1,515**	1,516**
	(0,130)	(0,130)	(0,134)	(0,131)	(0,132)	(0,131)
R&D Intensity	9,428**	9,698**	9,864**	9,539**	9,507**	9,466**
	(1,636)	(1,627)	(1,651)	(1,622)	(1,636)	(1,636)
Exploration share		-0,262*	-0,572	-0,251	-0,294	-0,263
		(0,131)	(0,510)	(0,130)	(0,260)	(0,134)
Exploration share^2			0,282			
			(0,448)			
Concentration of Exploration				-0,214	-0,251	-0,224
				(0,131)	(0,238)	(0,133)
Moderator					0,072	
					(0,383)	
Moderator (z-values)						0,010
						(0,024)
Constant	2,860**	2,897**	2,948**	3,044**	3,067**	3,058**
	0,141	0,141	0,163	0,166	0,207	0,170
Number of observations	202	202	202	202	202	202
Number of Companies	30	30	30	30	30	30
R-Squared	0,975	0,976	0,975	0,976	0,976	0,976

[a] The dependent variable = number of patent applications, which is logarithmic transformed. R&D, Research and Development. Fixed factor at company level.
Significance at 5% level; ** Significance at 1 % level

E. Table's of benchmark

Table 1. Companies ranked on their average technological performance

	Company	Number of Patent applications	Sales with two year lag	Exploration share	Concentration of exploration
1	JOHNSON AND JOHNSON	587	21329	0,17	0,10
2	BOSTON SCIENTIFIC	309	7447	0,10	0,52
3	MEDTRONIC	308	13359	0,12	0,29
4	PHILIPS HEALTHCARE	225	9484	0,21	0,85
5	ABBOTT LABORATORIES	176	8935	0,23	0,14
6	COVIDIEN (Tyco Healthcare'07)	123	8791	0,35	0,54
7	3M HEALTHCARE	96	4241	0,31	0,84
8	ST. JUDE MEDICAL	72	3785	0,20	0,37
9	ALCON	61	2519	0,39	0,94
10	GE HEALTH CARE	60	16067	0,24	0,34
11	STRYKER	49	5900	0,27	0,27
12	SIEMENS HEALTHCARE	48	13043	0,31	0,36
13	ZIMMER	45	3728	0,19	0,58
14	GUIDANT CORP.	41	3659	0,33	0,80
15	SMITH AND NEPHEW	34	3219	0,36	0,60
16	FRESENSIUS MEDICAL	32	2431	0,31	0,48
17	CR BARD	30	2189	0,39	0,59
18	DENTSPLY INTERNATIONAL	28	1972	0,23	0,56
19	CARDINAL HEALTH	27	9463	0,41	0,20
20	DANAHER	24	3208	0,35	0,17
21	BIOMET	22	2178	0,42	0,30
22	INVACARE	12	1601	0,21	0,42
23	BECTON DICKINSON	7	3370	0,35	0,49
24	BAUSCH AND LOMP	6	1704	0,45	0,55
25	KODAK HEALTH GROUP	5	2613	0,39	0,54
26	VARIAN MEDICAL	5	1805	0,63	0,73
27	BECKMAN COULTER	2	2881	0,79	0,73

Table 2. Companies ranked on average sales with a two year lag

	Company	Sales with two year lag	Technological Performance	Exploration share	Concentration of exploration
1	JOHNSON AND JOHNSON	21329	587	0,17	0,10
2	GE HEALTH CARE	16067	60	0,24	0,34
3	MEDTRONIC	13359	308	0,12	0,29
4	SIEMENS HEALTHCARE	13043	48	0,31	0,36
5	PHILIPS HEALTHCARE	9484	225	0,21	0,85
6	CARDINAL HEALTH	9463	27	0,41	0,20
7	ABBOTT LABORATORIES	8935	176	0,23	0,14
8	COVIDIEN (Tyco Healthcare'07)	8791	123	0,35	0,54
9	BOSTON SCIENTIFIC	7447	309	0,10	0,52
10	STRYKER	5900	49	0,27	0,27
11	3M HEALTHCARE	4241	96	0,31	0,84
12	ST. JUDE MEDICAL	3785	72	0,20	0,37
13	ZIMMER	3728	45	0,19	0,58
14	GUIDANT CORP.	3659	41	0,33	0,80
15	BECTON DICKINSON	3370	7	0,35	0,49
16	SMITH AND NEPHEW	3219	34	0,36	0,60
17	DANAHER	3208	24	0,35	0,17
18	BECKMAN COULTER	2881	2	0,79	0,73
19	KODAK HEALTH GROUP	2613	5	0,39	0,54
20	ALCON	2519	61	0,39	0,94
21	FRESENSIUS MEDICAL	2431	32	0,31	0,48
22	CR BARD	2189	30	0,39	0,59
23	BIOMET	2178	22	0,42	0,30
24	DENTSPLY INTERNATIONAL	1972	28	0,23	0,56
25	VARIAN MEDICAL	1805	5	0,63	0,73
26	BAUSCH AND LOMP	1704	6	0,45	0,55
27	INVACARE	1601	12	0,21	0,42