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THE MEDICAL DEVICE INDUSTRY MARKET DEVELOPMENT ANALYSIS

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Abstract

The basis and interest for this thesis is the global economic situation of especially the high technology industry. In the traditional fields of high technology and more recently, in the field of ICT, there is a clear transition of work and markets toward the continents with lower development and production costs and those that are in the need of new technologies. This transition has evidently hit the developed countries (i.e. Western Europe and the USA) the hardest.

Even though the other fields of technologies are clearly in transition, the statistics show that the medical device industry is in its highest growth in history. In fact, in 2012 the field grew at a pace of over 25 % annually in Finland and at double digits globally. In Finland, the medical device industry currently accounts for nearly 40 % of the total high technology market exports. This is remarkable to note, as this industry is relatively compact in size in comparison to the other high technologies.

The objective of this research was to define the medical device technologies, to analyze the medical device technology market and, finally, to analyze reasons for its predicted continuous growth. This thesis covers the driving factors of this field of technology that predict the current trend in its market growth. This thesis also covers the aspects of medical devices and the medical device development processes, including the main differentiating factors compared to other fields of high technology products, especially those in the consumer markets. Finally, this study estimates the future economic growth of the medical device industry globally with special reference to Finland.

The economic methods in this research are based on regression analysis of the medical device industry in the BRIC nations (Brazil, India, Russian Federation and P. R. China) and selected OECD countries. The variables used in the research include the trade balance, age structure, medical device technology status and GDP related factors, i.e. GDP in current USD and total health expenditure as percentage of GDP. Technology-wise, the research is based on the global trends in the medical device industry and the growing needs for new medical devices in general.

The results and analyses indicate that the driving factors behind the predicted market growth can be explained by the science-push and demand-pull models. The time series and panel analyses indicate that the medical device industry could also serve as a global market opening technology. Furthermore, the results show that the growth of this industry is highly affected by population growth and age structure that increase the demand for new technologies to prevent and treat illnesses. Also, it was found that the medical device industry is not so greatly affected by global financial disruptions. Finally, the results show that the increase of medical device technologies clearly shortens the length of hospital stay which has been previously found to be a major factor in the rise of healthcare costs especially in the developed countries. This industry is thus evidently both a technology-push and a demand-pull based industry which is expected to grow due to the demand for higher quality healthcare while being less affected by general economic situations.

Keywords

Medical device industry, Economic growth, Demand pull, Science push, Regression analysis

Additional information

ACKNOWLEDGMENTS

As my background is in the field of biomedical engineering, I have been involved in numerous projects in developing new methods and technologies in medical device industry. Through my career in product development and in international business development, I have also seen the medical device industry growth in Asia, in the USA and in Europe. While being enthusiastic researcher and market analyst, my goal was to really understand the national and international economic relations and models. The time spent in studying at the Oulu Business School has certainly fulfilled this keen interest on learning the economic factors.

I wish to express my sincerest thanks to my supervisor, Professor Rauli Svento, for his invaluable support and advice in the process of this research and in my studies in economics. Especially his guidance in the statistical analyses and modeling of this thesis are highly appreciated.

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1 INTRODUCTION

The global financial crisis and the transfer of traditional industry toward countries with lower development and manufacturing costs have dramatically affected the economy globally and especially that of Finland. In fact, in Finland the trade balance has shown a deficit in recent years. The statistics also show a clear decline in especially the overall high technology industry with the exports decreasing with respect to imports.

However, while the traditional technologies are struggling, the statistics indicate that for example the medical device industry has been at record growth during the financial crisis of 2008-2011 and beyond. These economic indicators serve as the basis of interest for this report.

The objective of this study is to define the medical device technologies, to analyze the medical device technology market and, finally, to analyze reasons for its continuous growth. This thesis covers the driving factors of this field of technology that enable the current trend in its market growth. Furthermore, this thesis covers the aspects of medical devices and the medical device development processes, including the main differentiating factors compared to other fields of high technology products, especially those of the consumer markets. Finally, this thesis estimates the economic future of the medical device industry in Finland and globally.

This study presents medical device industry growth estimations based on regression analyses in selected countries. The variables of interest include the trade balance, age structure and overall GDP related factors that support the theories for either a continuing growth for of the medical device industry or the decline of the industry. Technology-wise, the research is based on the global trends in the medical device industry and the growing needs for new medical devices in general.

The global economic estimations are based on the statistics obtained from the public databases of the Organization for Economic Cooperation and Development (OECD), the World Health Organization (WHO), the Global Health Observatory (GHO) and the World Bank as well as the United Nations Commodity Trade (UN Comtrade) database. The statistics of current technological situation are from the Finnish Customs and the Statistics Finland (Tilastokeskus) databases.

The data was obtained for developed countries including Canada, Czech Republic, Finland, the United States of America (USA), United Kingdom (UK), Germany and Japan. As a comparative analysis, the estimate of the future was also based on the BRIC countries (Brazil, Russian Federation, India and the People's Republic of China) representing the developing countries. The selection criteria for including these countries in the estimations were based on current situation of the leading developed countries regarding medical device technology and that the data was fully available for them. The selection of the BRIC as representatives of developing countries was based on their common similarity as relatively advancing economies. Also, incomes in these countries are similarly distributed to the well-off and the less well-off population segments (Haring 2013).

The questions that this study covers and that serve as the basis for this research are:

- What is this tremendous annual growth, especially in the last few years, based on and how can the medical device industry grow, even though the other fields of technology are clearly struggling?
- What are the driving factors economically and technology-wise behind this phenomenon?
- How can the future be estimated and are there significant indications that support the theories for the continuing growth estimates?

The organization of this report is such that Chapter 2 introduces the current status of the economy in Finland in the fields of technologies through trade balance analysis. Chapter 2 also contains comparative analysis between the traditional high technology industries and the medical device industry. The medical device industry is introduced in Chapter 3 with key differentiating factors in the product development and regulations compared to those of consumer products. The global medical device industry market is covered in Chapter 4 with selected parameters indicating the unique characteristics that are the basis of this field of technology. Chapter 5 introduces the models of innovation management based product development with selected fundamental medical device technologies. These models form the basis of the economic factors that are behind the growth of the medical device industry and that are expected to drive the growth of the industry globally. Chapter 6 deals with the research data and analysis methods that are used in the economic analysis estimating the factors driving the growth of the industry. Chapter 7 contains the industry analysis with methods of regression models. Chapter 8 is the discussion part, in which the results of the regression analysis, the theoretical aspects and current market analysis are covered in the estimation of the future of the medical device industry. Finally, Chapter 9 concludes this study with indications for ideas on future research.

2 TECHNOLOGY INDUSTRY OVERVIEW OF FINLAND

2.1 Technology industry

Finland's long tradition of economic growth has evidently relied on expert knowledge in the broad fields of technology. Our strong technological know-how was first based on forestry and rough machinery beginning in the 1950's (Kokkinen 2011). Then, during the early 1990's the economic growth was largely due to massive investments in the development of ICT technologies and IT clusters with multi-national companies such as Nokia and KONE opening the global economy to other Finnish high technology companies (Kokkinen 2011). After the most recent global financial crisis that began in 2008, it has become clear that the development of traditional industry is facing harsh global competition especially in the manufacturing and marketing of goods.

As the developing countries (including the BRIC countries, namely Brazil, Russian Federation, India and P. R. China) have large populations and large markets with low labor and manufacturing costs, the leading global companies are moving their production to these locations (Schmutz and Santerre 2012). A report by the Finnish Technology Association (Ala-Kojola 2013) indicates that the USA and Europe had a total share of over 70 % of the overall technology production in the 1950's in comparison to the People's Republic of China's share of less than 10%. Since then the share of the USA and Europe has been decreasing while China's share has been increasing with a slope of roughly 1. Currently, the share of the technological manufacturing is at approximately 42 % in the USA and Europe combined, while China alone accounts for over 45 %. The report clearly visualizes the trend of the production shift in a 60-year follow-up study.

Net export dramatically affects the possible development of the national gross domestic product (GDP). Especially countries such as Finland with few natural resources, relative to the market size and geopolitical location, are highly reliable on exports. In the fall of 2013 the GDP of Finland was at a decreasing pace of – 0.6 %. If Finland's core high technology industry cannot keep up with the pace in the global markets and regulations (including domestic and international), a great opportunity for steady growth may be missed.

Until the mid-2000's, the trade balance of Finland was growing at an increasing rate with the imports and exports reaching their highest values in 2008. After the latest financial crisis, however, economic growth in the field of technology has clearly come to halt. In fact, for the last two years the net export of Finland has been negative. In order for a country to maintain its competitiveness, the trade balance should have steady state growth in the long term.

Figure 1 illustrates the overall imports, exports and trade balance of Finland from the 1970's to the present. The data for this simplified graph were collected from the Finnish Customs statistics source (Finnish Customs 2013). A substantial increase can be seen in the global trade until 2008, after which the growth clearly halted with slight increase after 2010. Even though the export (red line) and import (blue line) graphs show a growing general trend during this time period, the trade balance (green line) of Finland is clearly of great concern. Each nation's economic growth relies highly on exports, with the trade balance expected to rise. The current status in Finland has a negative trend. This is largely due to the fact that the imports are exceeding the exports as presented in the graph.

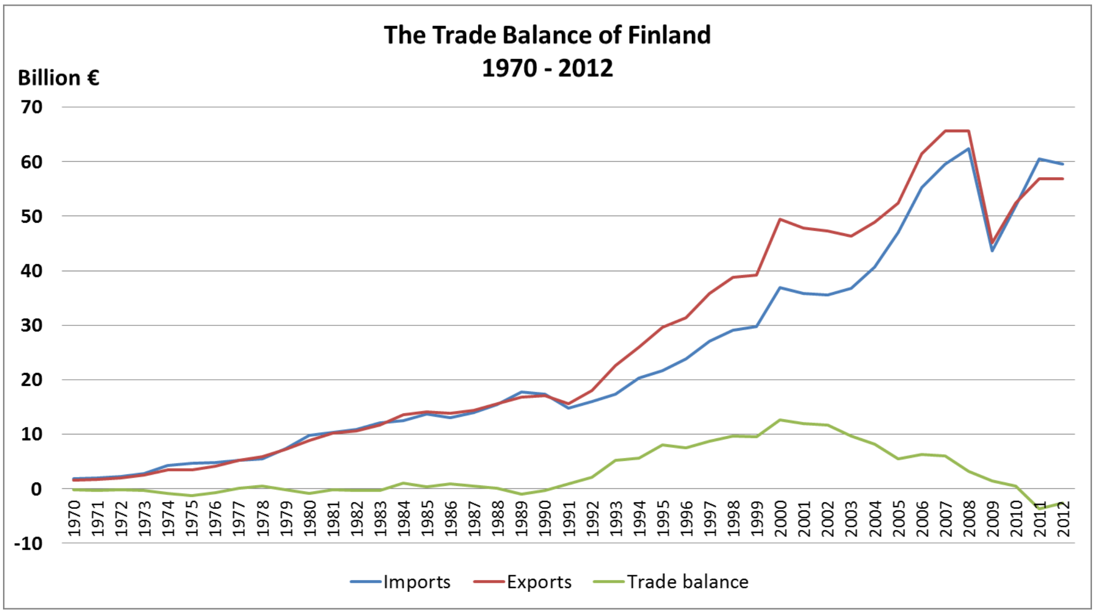

Figure 1. The time series analysis of imports, exports and trade balance in Finland 1970 – 2012.

2.2 High technology industry

Figure 2 contains comparative data of the high technology trade balance from the years of interest, i.e., 1995 – 2012 (Finnish Customs 2013). This graph quite clearly illustrates the economic situation of the current trends in the field of traditional high technology. The time period begins at a point where the trend balance of both exports and imports was at net zero, indicating that the economic growth was looking for new openings. The effect of the ICT industries is seen as the two peaks in the exports, first in 2000-2001 and again in 2007-2008. From 2008 on, however, we see the effect of the latest financial crisis with especially the exports decreasing at a dramatic pace.

This graph also contains the percent of the share that the high technology industries account for in the trade balance during this time period as bar columns on the background. In the graph, the solid lines represent the imports (blue), exports (red) and trade balance (green) with the percent share of high technology in comparison to the total imports and exports in Finland. The scale on the left is used for the high technology trade balance in Euros and the scale on the right for the percent share in comparison to the trade balance of the total trade balance. This data further shows the negative trend of the high tech industry trade balance.

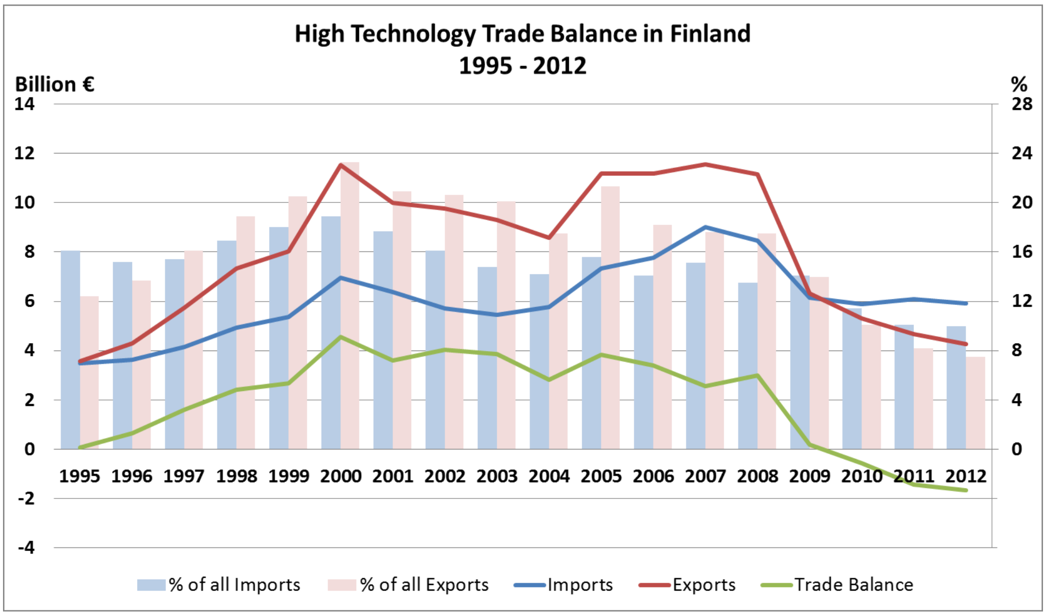

Figure 2. The time series analysis of imports, exports and trade balance of the Finnish high technology industry 1995 – 2012.

A major factor in Finland for the deficit of the high technology industry trade balance has also been the increase in global competition. Also the new organization structures and global positioning of the leading companies especially in the IT sector has been a notable factor behind this trend. Especially the effect of Nokia's struggles can clearly be seen in Finland's economy. While the R&D sites of Nokia in Finland are decreasing, the global sites especially in the Beijing area in China and the San Diego area in the USA are growing rapidly.

Based on the statistics (Saarinen 2013), in 2000, Nokia as a company accounted for roughly 4 % of the total GDP of Finland. Beginning at the end of 1990's, it was a huge factor in generating the highest trade balance surplus of the mid 2000's. Since 2008 on, however, Nokia's effect on the GDP has dramatically decreased. In fact, in 2012 the share of Nokia of the total GDP in Finland was negative since the losses incurred by the company in Finland were greater than the salaries and other positive factors contributing to the national GDP as seen in Fig. 3. This trend has had a great impact in the overall trade balance and GDP of Finland as seen in the statistics above. The correlation on the trade balance in Finland is evident when comparing these statistics to Figures 1 and 2.

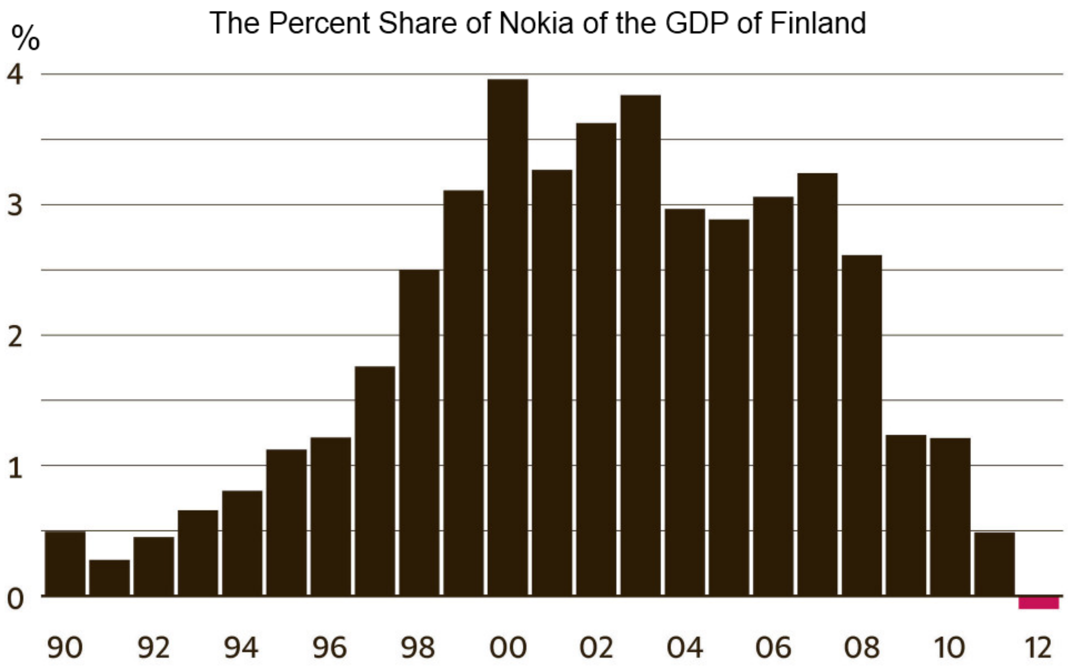

Figure 3. The percent share of Nokia of the GDP of Finland (Saarinen 2013).

Clearly, as the traditional fields of high technology are in transition, possibilities of growth are opened for new technologies. Many fields of technology can utilize the infrastructure, inventions and educated people from the core IT industry. Other factors in driving new technologies are based on the population age structure, education, geopolitical location (Kokkinen 2011) and increased incidences of diseases.

The time series analysis (Figure 4) clearly shows how one relatively compact field of the high technology industry, the medical device industry, could in many cases be an opening industry to the global markets. The medical device industry in general is not as highly affected by the global financial situations as are other fields of high technology.

This difference is apparent from a comparison between consumer goods and medical devices. While both the demand and supply of consumer goods is decreasing, the medical device market is experiencing a record upward trend. The basic differentiator for medical devices in general is that while the population is ageing, also more awareness is given to health. This eventually leads to the increase in the demand for medical products. Also, as new products are in demand, the technology will be further developed, serving as science push for the total medical device market.

As the graphs in Figure 1 and Figure 2 show, the economy of Finland is facing its highest crisis in foreign trade in decades. However, as shown in Figure 4, the medical device industry has been growing at a steady pace from the early 1990's. This phenomenon has been occurring all over the world and the field clearly is worth deeper analysis. Figure 4 contains the trade balance evolution of the medical device industry as solid lines, with the percentage of share of the high technology industries in the bar columns in the background.

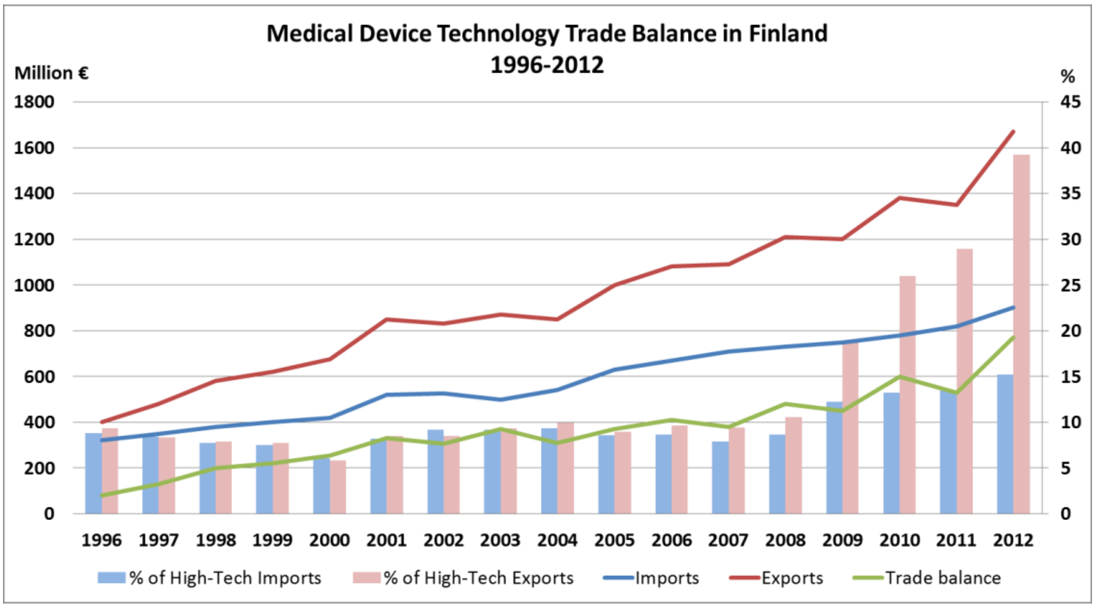

Figure 4. The time series analysis of imports, exports and trade balance of the Finnish medical device industry 1996 – 2012.

What this graph clearly indicates is that the global financial crisis that began in 2008 actually did not have a similar effect on the medical device industry as in the other fields of high technology. Instead, the medical field has experienced its highest increase especially in exports, with the trade balance reaching a new all-time record in Finland in 2012. The graph also indicates that the percentage share of the medical device industry in comparison to other high technology imports has been growing and currently accounts for nearly 40 % of all high technology imports. The analyzed data was obtained from the Finnish Customs statistics source (Finnish Customs 2013) and the Finnish Health Technology Association (FiHTA 2012).

3 DEFINITION OF MEDICAL DEVICE TECHNOLOGIES

"It may seem a strange principle to note, but the primary duty of a hospital is to do the sick no harm." (Florence Nightingale, 1860)

The World Health Organization (WHO) defines a medical device as: any instrument, machine, appliance, implant, in vitro reagent or calibrator, software, material or other similar or related article, intended by the manufacturer to be used alone, or in combination, for human beings for one or more of the specific purposes including diagnosis, monitoring, and prevention of diseases (WHO 2003). Thus, any device that has an intended use for analyzing data gained from a human, changing human anatomy or analyzing substrates from a human are considered medical devices.

With products such as cardiac pacemakers, orthopedic shoes, dental floss, surgical instruments, MRI and CT scanners and even Band-Aids, the field covers a huge variety of devices and systems. It is estimated that there exists over 500 000 different medical devices on the market. These products are further categorized into 20 000 generic groups. In the broad categorization, the segment is divided into medical device technology and in-vitro medical devices (MedTech Europe 2012). These segments are such that the in-vitro devices are used in analyzing human substances, while the medical devices group includes all other products and devices.

Table 1 indicates the further classification of the medical devices. It shows the 16 product group categorization as determined by the Global Medical Devices Nomenclature (GMDN) Agency (MedTech Europe 2012, GMDN 2010).

Table 1. Classification of medical devices.

CODE	CLASSIFICATION	EXAMPLE PRODUCTS
01	Active implantable technology	Cardiac pacemakers, neurostimulators
02	Anesthetic and respiratory technology	Oxygen masks, anesthesia breathing units
03	Dental technology	Dentistry tools, tooth floss, tooth brushes
04	Electromechanical medical technology	X-Ray machines, CT scanners, MRIs
05	Hospital hardware	Hospital beds
06	In-vitro diagnostic technology	Pregnancy test, blood glucose strips

07	Non-active implantable technology	Cardiac stents, hip or knee replacements
08	Ophthalmic and optical technology	Spectacles, contact lenses
09	Reusable instruments	Sterilizable surgical instruments, endoscopes, stethoscopes
10	Single use technology	Syringes, needles, surgical gloves and gowns
11	Technical aids for disabled	Wheelchairs, hearing aids
12	Diagnostic and therapeutic radiation technology	Radiotherapy units
13	Complementary therapy devices	Suction cups, bio-energy mapping systems
14	Biological-derived devices	Biological heart valves
15	Healthcare facility products and adaptations	Gas delivery systems
16	Laboratory equipment	Most IVD which are not reagents

The driving factor in assessing the intended use for a medical device is the effect on the patient. The most important values that are evaluated deal with risks and patient safety of the devices. Any device used in the patient environment contains risks for hazards and harms. However, when the risks are manageable and the benefits using a medical device clearly exceed them, the device development is justified and markets are open.

The driving economic factor behind utilizing new products especially in the surgical fields is the estimation of the device's costs and outcome compared to healthcare without the device (Blume 1992). The key aspects of the assessment are the speed and quality of the procedure and the difference in the length of the hospital stay (LOS) for the patient after the operation, as discussed already in the 1980's by Drummond (1987). Blume (1992) also indicated that new technology adoption is clearly profitable when the length of operations decreases and thus the personnel are involved for a shorter time in the procedures. All of these qualitative components affect the total costs of each procedure.

What is seen as a trend especially in the demanding operations of neurosurgery, ear nose and throat (ENT) surgery and in orthopedics, is that the length of the hospital stay has decreased dramatically from an average of two weeks to two days with the image guided surgery (IGS) equipment (Grunert *et al.* 2003, Davis *et al.* 2013, Koivukangas 2012).

3.1 Medical Device Regulations

According to the WHO, each nation is responsible for placing policies and regulations that address all elements regarding the development of medical devices. The main elements of the technological life cycle include: high quality and good manufacturing practices, and affordable prices with safe, appropriate use all the way to safe disposal after the use (WHO 2013).

The WHO and Global Health Observatory (GHO) have put a lot of emphasis in generating common regulatory and approval practices globally. A major challenge in achieving harmonized standards can found in the statistics, which indicate that 37 % of the surveyed 161 countries do not have lists of different types of medical devices or any standardized practices for medical device design (GHO 2013).

The other major challenge in harmonizing the standard practices is that the nations and continents with the longest history in manufacturing medical devices have already implemented their own regulations. Thus, there are currently five main national and regional regulatory bodies for medical device compliance assessment. The main regulatory bodies are: the Food and Drug Administration (FDA) in the USA, the European Commission (EC) in the EU, the China Food and Drug Administration (CFDA) in China, the Canadian Agency for Drugs and Technologies in Health (CADTH) in Canada and the Pharmaceutical and Medical Devices Agency (PMDA) in Japan.

a) European Union, EEC
   The medical device design is controlled by the European Commission (CE) Directives in the European Union. The regulatory framework is categorized into three main Directives of devices. Council Directive 93/42/EEC relates to all medical devices, Council Directive 98/79/EC relates to in-vitro diagnostic devices and Directive 90/385/EEC to active implantable medical devices, respectively. Further amendments and regulations are mandated depending on the medical device's intended use, operating system and power output.

b) USA, FDA

The FDA regulates all medical devices intended to be marketed in the USA. There are two main paths for entering the USA markets: the 510(k) approval and the pre-market approval (PMA). The main difference between the FDA and the EEC is that while the CE mark confirms that the product is safe to use, the FDA also requires the effectiveness of the product according to the intended use defined by the manufacturer.

c) China, CFDA

The medical device regulation work is under massive reform in China. Recently, the regulatory body was named as the CFDA. Until 2012, the regulatory body was known as the SFDA (State Food and Drug Administration). The regulations are also under reform with an intention to modify them to comply more flexibly with the regulations of the USA and the EU.

While being mostly identical in their purposes, these regulations still deviate in certain aspects. The greatest difference between these different design processes deals with evidence-based clinical trials assessment. While most of the international regulatory bodies mandate that the device must be safe to use, the FDA also mandates clinical evidence on the effect of the device or method.

All the different regulatory bodies mandate that any medical device needs to be classified according to similar categorization. There are three main categories of medical devices, Class I, Class II and Class III. In the EU, class II is further divided into IIa and IIb. Class I devices usually are not in contact with the human. The analysis is done from human substrate in a medical device, with the blood glucose meter as an example of Class I medical devices. Class II devices are in contact with the human and either modify the tissue or its functionality. Class III devices modify the human tissue and can be implanted into humans. The classification further mandates possible specific regulations, such as IEC 60601, namely that all medical devices with electronics need to comply with IEC 60601.

In controlling the medical device design, two main quality management systems (QMS) are set for the companies developing them: 21CFR820 by the FDA (FDA 2013a), and ISO 13485 by the EU (ISO 13485). The QMS refers to the processes that the manufacturers follow in product development, manufacturing, marketing and after sales. As risk management is a high priority, it is also regulated and strictly controlled in the product design. ISO 14971 is a standard that regulates the risk management process globally. When QMS are implemented, this standard must be complied to and followed.

Figure 5 presents the common medical device development route for the CE mark in the European Union. The development process begins with the device classification. Then, through essential requirement procedures, the conformity is assessed according to regulation. The MDD and IVDD at the bottom of the Figure indicate Medical Device Design with the regulating directive underneath and In-vitro Device Design, respectively. The blue colored text depicts the MDD directive and orange the IVDD directive regulations.

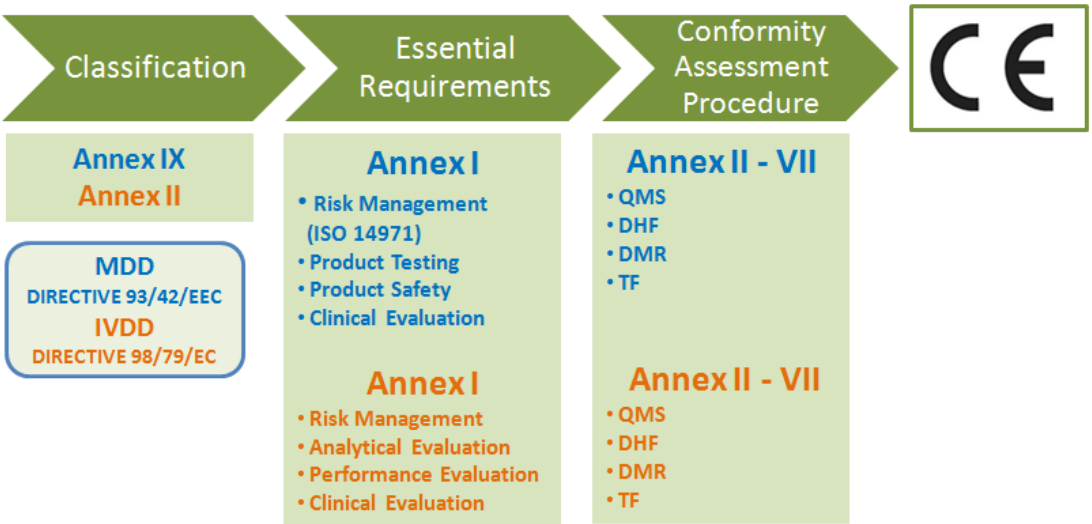

Figure 5. The route for medical device approvals in the EU and for the CE marking.

The key elements of the medical device approval processes:

(1) Classification

The medical device is classified according to the rules set by the regulatory body. The device classification plays a major role in the marketing clearance application, since the final product can only be marketed according to this classification. A classification used by the EU can be found from the European Commission website (EC 2013).

(2) Essential Requirements

The essential requirements contain vital information about the device as mandated by the authorizing body and the product requirements as specified by the manufacturer of the device. It also contains the device testing and final product verification and validation against the requirements and specifications.

(3) Conformity Assessment Procedure

The conformity assessment procedure is the final step in labeling a medical device in the EU region. This step is highly controlled by the national regulatory bodies such as Valvira in Finland. In this procedure, the product specific documentation and company QMS are reviewed and assessed against the regulatory requirements.

A general medical device design process is shown in Figure 6 as a waterfall model. The design process begins by specifying the medical device with desired functionality, usability and regulatory requirements as covered earlier. The outcome of this step is a finalized project plan that contains all the vital information on the device that the final product is validated against. The project plan also contains information on the regulatory requirements that the final product needs to comply with. After finalizing the project plan, the process goes through the development cycle. This cycle includes the prototyping and possible clinical trials. The design inputs are gained from the project plan and the medical device regulations. After design implementation and prototyping, the design output is a fully functioning initial product. The design output is then verified against the design input defined in the specifications of the project plan. This iteration may take years of research and design before the final product is finally ready for the market.

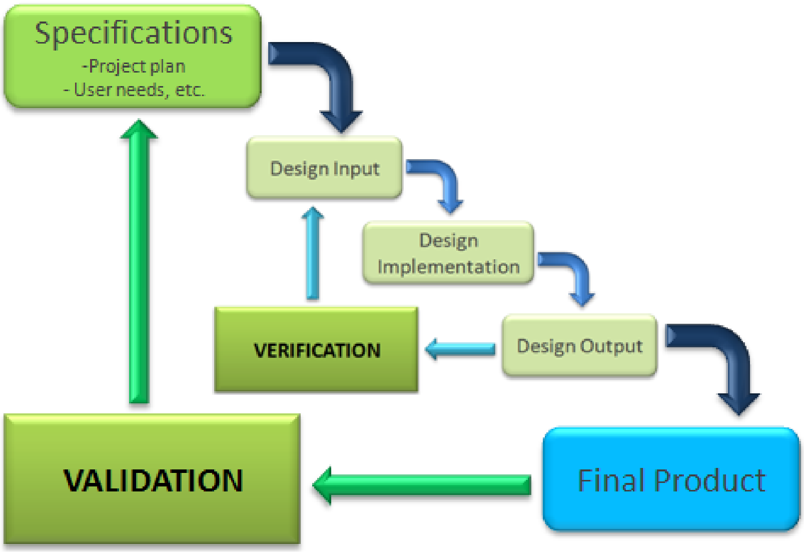

Figure 6. Medical device design process waterfall model (FDA 2013b).

3.2 Medical Device vs. Consumer Product

With especially the ICT sector offering new solutions rapidly for a number of different devices and machines, also the differences between medical devices and consumer products seems to fade in certain applications. However, as discussed earlier, any product that analyses or modifies a human, or human substrates, needs to be classified as a medical product and designed accordingly from the beginning of the development process. This chapter introduces important differences between the common consumer products and medical devices.

The main difference in the medical device design process and that of the consumer products is that it is mandatory to inform the national authorities about new product ideas at the latest before the clinical trials are set. Also, the manufacturer of a medical device is responsible for the product ten years after the last device has been sold. Thus, reliability and effectiveness with safety are the driving factors in medical device development. The main differences between consumer products and medical devices in an ordinary design process are illustrated in Figure 7.

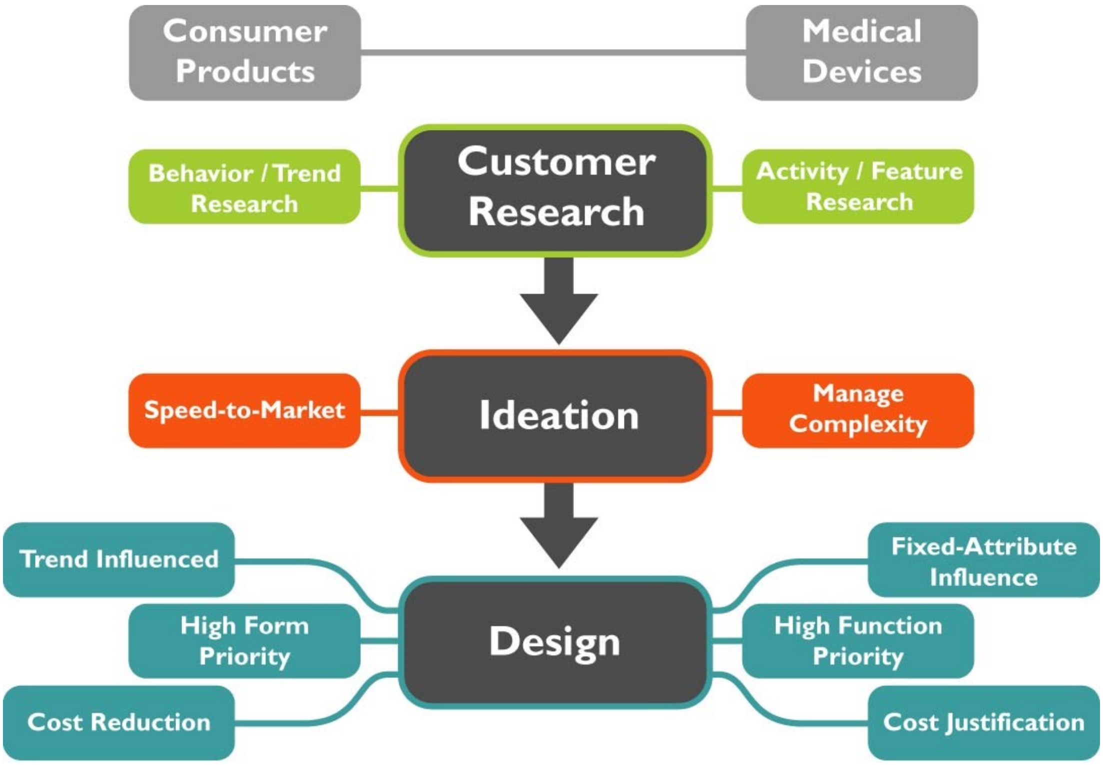

Figure 7. Main differences between consumer product and medical device design (Trig Innovation 2011).

As the Figure illustrates, the consumer product design and development begins with market trend and human behavioral analysis with speed-to-market as the driving factor. A current topic in consumer products is also cost reduction of products with high emphasis put on the manufacturing and device functionality for minimizing the costs. The visual design is also a key issue in the development of the product, with safety issues slightly on the background.

Medical device design, on the other hand, is highly patient and doctor usability guided. Speed-to-market is important, but as the device needs to pass the strict regulations of patient and user safety issues, simplification of the design becomes a critical driving factor. Another main difference is in the costs of medical devices. Instead of cost reduction, medical devices in general are designed with cost justification. This means that the costs can be reduced, but safe control and use must be guaranteed.

4 MEDICAL DEVICE INDUSTRY AND MARKET RESEARCH

4.1 Medical device market globally

Globally, the medical device market has been growing at an annual rate of 6.1 % during the last five years and it is expected to hit a total value of $230 billion in 2017. The clear impact of major medical device companies with respect to the global market share of several nations is seen in Figure 8. The Figure indicates that as the major companies are based in the USA and EU region, so also the share of the total market is highly controlled by the same nations and regions. The Figure also shows that the USA has a share of over 40 % and the EU a share of roughly 25 % of the global market.

However, as a new device is usually purchased to replace an existing one rather than becoming itself the first one in a clinic in the more developed countries, the new markets are opening elsewhere (Blume 1992, Girling *et al.* 2012). Clearly, the developing nations, especially the BRIC countries (Brazil, Russia, India and China) are becoming the consumers of new devices and applications at an increasing pace (Schmutz and Santerre 2012). These nations are still largely at a stage of purchasing their first products and devices, opening totally new, huge markets also for the medical device manufacturers (Girling *et al.* 2012, Haring 2013, Schmutz and Santerre 2012). There is a high and increasing demand for new products with over 60 % of the world's population living in the BRIC countries. A recent report (Business Monitor 2014) indicates that the pace of medical devices sales in these countries is at a 10 % annual increase, being roughly double that of the developed countries.

As the growing demand of medical devices is clearly in the developing nations and regions, the medical device market is in a transition toward methods and devices that must sustain the quality and performance of current devices, but the costs must be substantially lowered (Adner and Snow 2011, Berlin 2011, Schmutz and Santerre 2012). According to Krishnan and Atal (2012), the costs of current thigh end medical devices could be lowered by 40 % without damaging the functionality of the products.

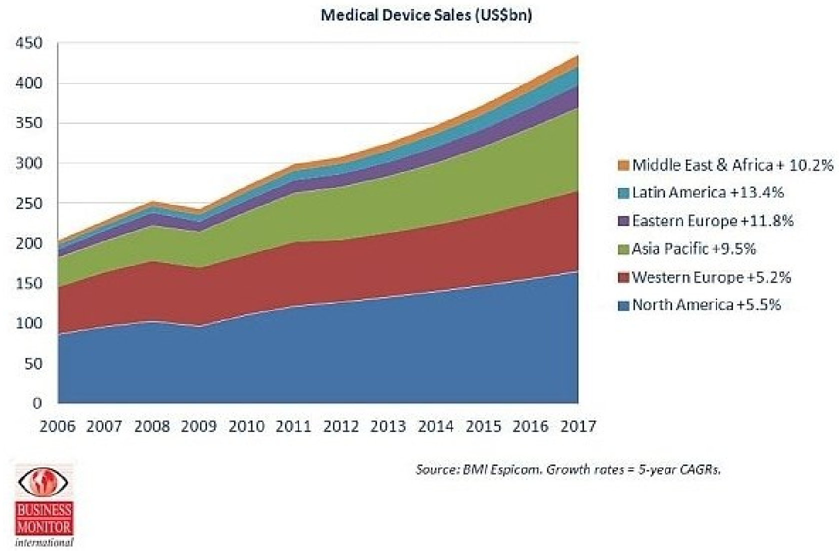

Figure 8. Global medical devices sales (Business Monitor 2014).

The core business segments of the medical device industry as defined in Chapter 2 are highly controlled by major companies (Fig. 9.). Based on this, the regional and national level of trade seems to be relatively similar globally (Fig. 10.).

The 40 major companies that account for 90 % of the medical device industry market are based in the USA and Europe with Johnson&Johnson, Medtronic and GE Healthcare as the leading companies in the USA and Siemens Healthcare and Philips Healthcare in Europe. The graph in Figure 8 illustrates the market share of the 10 leading companies in the industry that account for 43 % of the total market.

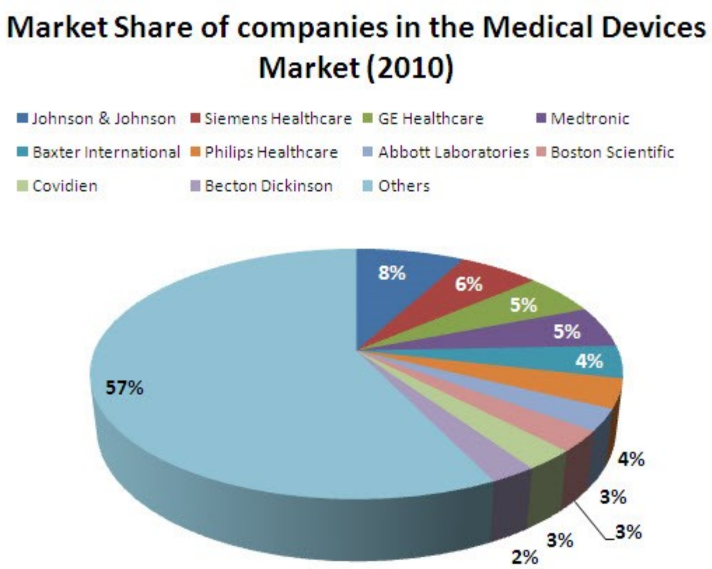

Figure 9. Global market share of major companies in the medical device industry (Boston Scientific 2013).

4.2 Medical device industry trade balance

Trade balance data was obtained for selected countries and regions of interest. These include USA, EU-27, Japan and the BRIC countries. Selected countries from Europe have also been included with own statistics. These countries are Finland, Germany and United Kingdom. The trade balance statistics were obtained from the UN Commodity trade database with the following parameters:

UN Comtrade http://comtrade.un.org	*Imports and exports of medical devices with following filters:* - Classification = HS as reported - Commodities = 9018 and 902214 - Reporters = Brazil, China, EU-27, Finland, Germany, India, Japan, Russian Federation, USA - Years = 1990 – 2012 - Trade partners included all countries in the world - Trade flow = Exports and Imports

Commodity 9018 = Instruments and appliances used in medical, surgical, dental or veterinary sciences, including scintigraphic apparatus, other electro-medical apparatus and sight-testing instruments, Commodity 902214 = Medical X-ray apparatuses.

Medical device exports 1990 – 2012

The medical device exports in the world are illustrated in Figure 10. The statistics indicate that the growth in exports has a notable difference between the more developed countries (USA, EU and Japan) and the BRIC countries that represent the economically highest growing regions of the developing countries. The exports in the developed countries have been experiencing a trend of high increase especially since the beginning of 2000s. The statistics also indicate that the exports of medical devices, apart from India, have been at a steady level in the BRIC countries without any notable increase throughout the analyzed time series.

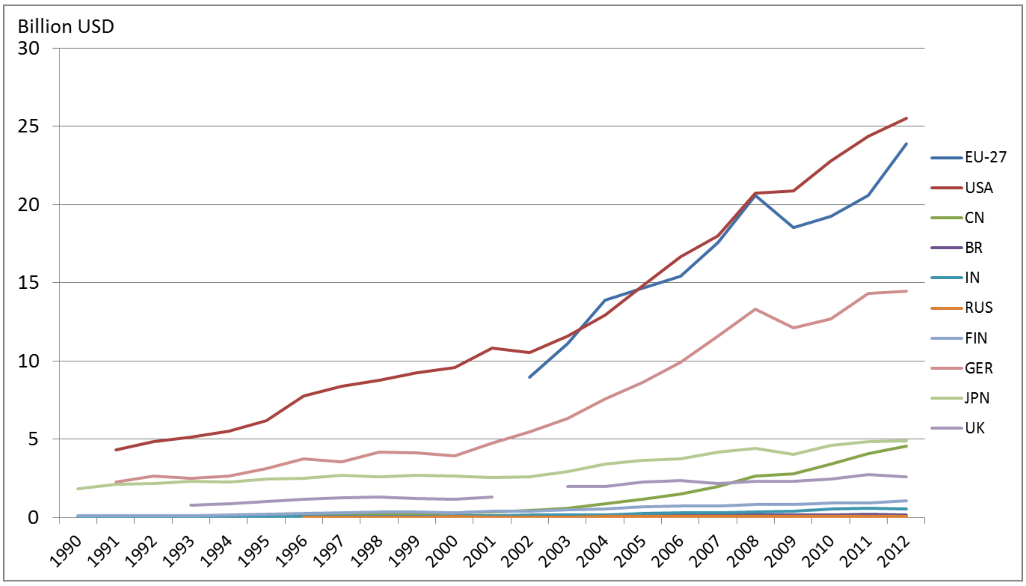

Figure 10. Medical technology exports globally (time series analysis), 1990 - 2012.

Medical device imports 1990 – 2012

The statistics of medical device imports show an interesting phenomenon. It can be seen in Figure 11 that while the imports have experienced a huge growth globally, the growth is clearly decreasing and nearly halted in the developed countries. In the meantime, however, the imports are dramatically increasing in the BRIC countries. On the one hand, these time series statistics comply with the expectations of increasing demand in the developing countries, and thus on the other hand, support the theories of expected growth in the medical device market in general.

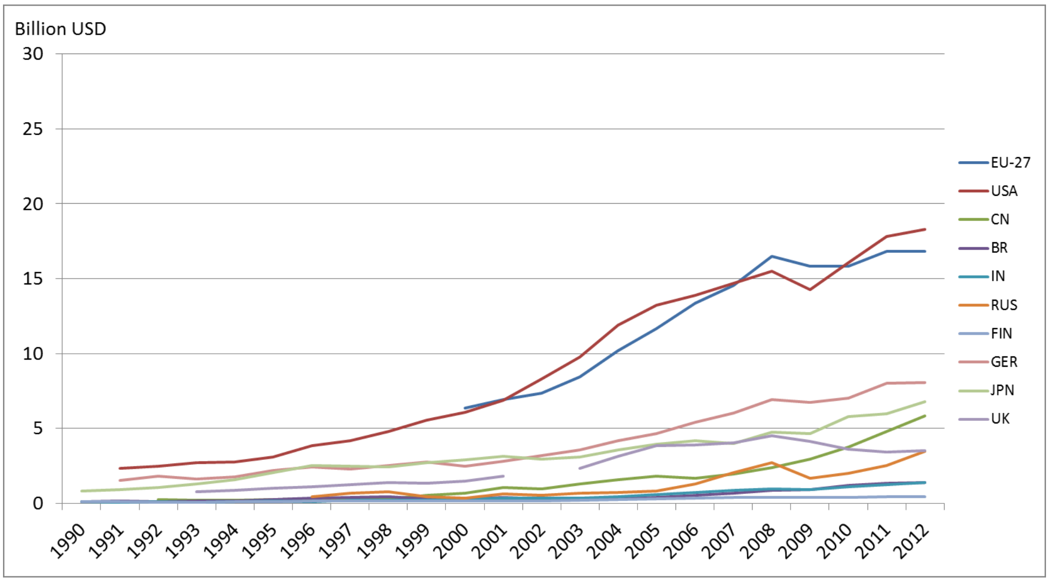

Figure 11. Medical technology imports globally (time series analysis), 1990 - 2012.

4.3 Medical device market in Finland

The year 2012 was a huge turning point in the medical devices industry in Finland. Even though the financial crisis still affected the global economy, the growth in Finnish exports in this industry was expanding markedly, at a 23 % annual rate. Especially the medical equipment segment reached the new record level of annual growth at 28.7 % on the EUR 1.65 billion total market for total medical technology (FiHTA 2013).

Figure 11 illustrates the growth of the medical device industry in Finland from 2006 to the present. It contains data of the imports, exports and trade balances with the total market share of the total high technology industry in this time period. This was done using the data from Finnish Customs 2013 and FiHTA 2012, which was obtained for analysis according to a time series model.

What can be seen is that while the high technology industry in general is clearly declining, the medical device industry while growing rapidly. The graph also shows how the medical device industry forms a major part of the total trade balance for high technology industry. While having a share of roughly 10 % of all exports in the high technology industry in 2006, the medical device industry exports currently account for over 40 % of the exports. This time period is extremely interesting, since during this period the world economy was hit by the latest financial crisis that affected the high technology industry in general with major deficits in exports and imports globally. The trend illustrated in Figure 12 is clearly at an increasing pace compared to the other fields of high technology exports as shown earlier, in Figure 2.

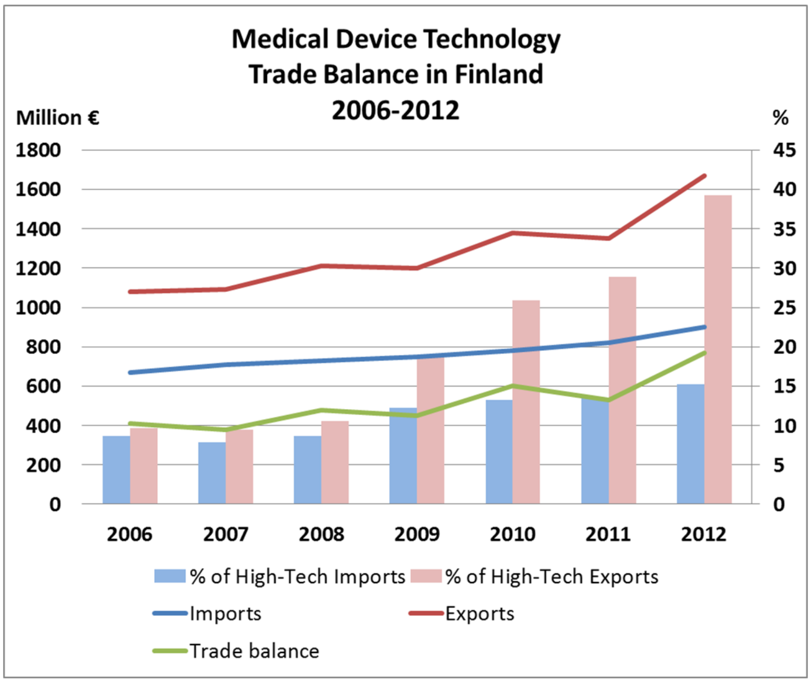

Figure 12. Medical device technology exports, imports and trade balance in Finland 2006-2012.

When compared to the total exports of Finland in the medical device technology industry, a clear similarity can also be found. The USA and EU region both account for 35 % of the exports. This totals to 70 % of the total market. Again, a relatively similar distribution to that of the location of the major medical device companies can be seen. The exports by nations and regions with those of Finland are illustrated in Figure 13. Clearly, this figure shows the effect of the geographical location of Finland. While USA has the largest share of the total trade as a single nation, the EU as whole accounts for approximately the same amount of exports. Also a notable 5 % share of Finland's trade balance comes from Russia, which has less than 4 % share in the medical device industry globally.

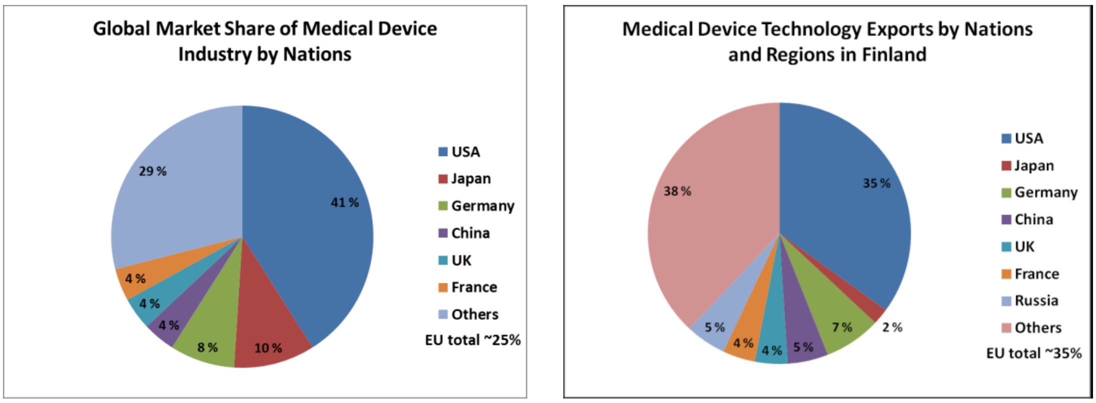

Figure 13. Global market share of the medical device industry by nations (left, Novotek) and Finland's exports by nations and regions in the medical device industry (right, after FiHTA 2013).

4.4 Medical device industry key initiatives

The key figures of the medical technology industry of the analyzed countries are shown in Table 2. This Table clearly shows that currently the market growth is nearly double in the BRIC countries compared with that of the developed countries. Another interesting statistic is that the trade balance of the developed countries is relatively high in comparison to the sales, while the trade balance in the BRIC countries is notably negative. This is a phenomenon that indicates the growing utilization in the developing countries of medical devices that are manufactured in the developed countries.

Table 2. Medical technology industry key figures.

	Eu-27	USA	BR	IN	CN	RUS	FIN	GER	UK
Employees (1000s)	575	520	N/A	N/A	N/A	N/A	10	175	71
Companies	>25000	>25000	N/A	N/A	N/A	N/A	160	N/A	N/A
Sales (Billion €)	95	127 Bn USD	N/A	N/A	N/A	N/A	0,95	7,5	3
Market share	28%	39%	2%	<1%	5%	2%	<1%	~8%	~3%
Market Growth	>5%	>5%	~10%	~10%	~10%	~10%	>5%	>5%	~1
Trade Balance (Billion€)	15.5	5.3	-1.24	-0.83	-1.29	-3.39	0.80	6.40	-2.0

Eu-27 = the nations of EU, USA = the United States of America, BR = Brazil, IN = India, CN = China, RUS = Russia, FIN = Finland, GER = Germany, UK = United Kingdom, N/A = Data not available.

Even though the global market is controlled by the 10 major companies, an interesting statistic is that nearly 95 % of the EU based and approximately 90 % of the USA based companies are considered as small and medium enterprises (SMEs) (Eucomed 2012). By definition, a company with less than 250 employees is considered as an SME in the European Union. The fact that so many companies are privately owned and relatively small in size makes the industry more flexible in decision making.

The medical technology has also other innovation management related, unique details. According to the EUCOMED (2012) presentation containing statistics of the EU based medical device companies, there is an innovation cycle of 18 – 24 months for a new method after the initial product has been launched. Also, the activity of patenting these innovations is ranked #1 among all fields of technology in the EU. The industry files a patent every 50 minutes, totaling over 10,000 patents annually. As a comparison to other fields of technology that are experiencing growth, Figure 14 has the numbers of patents filed between 2002 and 2012.

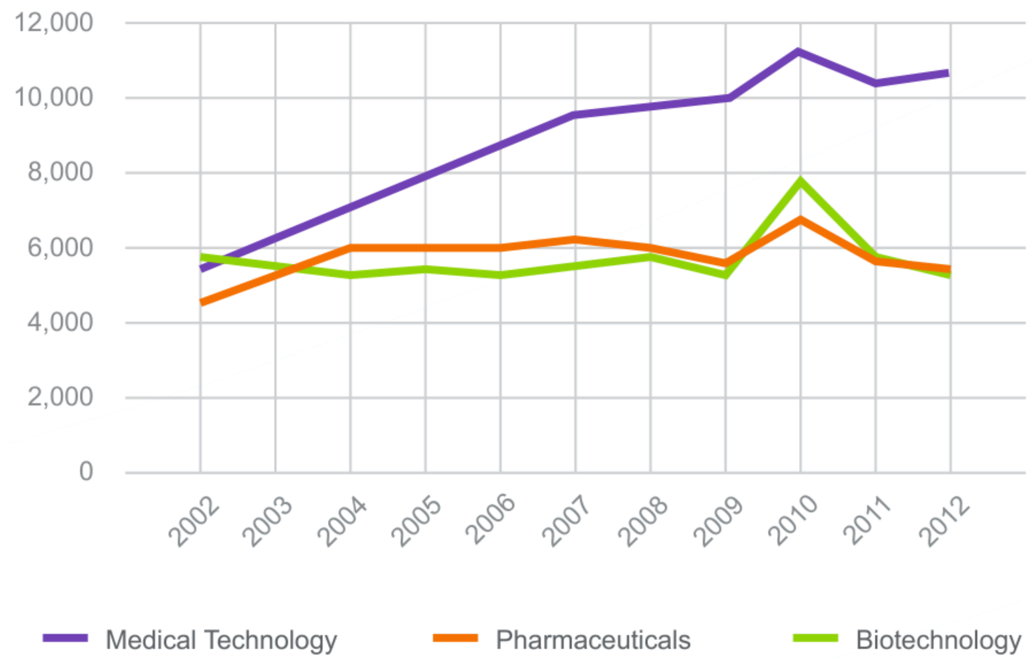

Figure 14. Patents filed by selected technologies in Europe (Eucomed 2013).

5 INNOVATION MANAGEMENT

"The best way to predict the future is to invent it."
(Alan Kay)

Innovations of technology and natural sciences have positively affected global economies dramatically (Dosi 1988). Often a technological innovation is a result of profound scientific research or, vice versa, a scientific innovation has been discovered through enabling technology. In the last centuries, it has been seen that major technological innovations have been directly linked with scientific revolutions (Dosi 1988). These enabling discoveries include innovations such as the origin of synthetic chemistry (Freeman 1982) in the field of natural sciences, the transistor (Nelson 1962) in the field of technology, and combined in the field of bioengineering (Orsenigo 1988). Trott (2011) remarked on the innovation process of different fields of the sciences: "Most of the significant inventions of the past two decades have not come from flashes of inspiration but from collaborative endeavors."

This chapter introduces the main aspects of innovation processes of the medical device technology industry. First, the linear models of innovation are presented with the special modifications that relate to the medical device design processes. The second section introduces a common medical device innovation lifecycle. Finally, specific innovation processes of four main types of medical devices are introduced.

5.1 Linear models of innovation

One method for estimating the future of medical device technologies is based on the innovation science push / demand pull model (Cantwell and Fai 1999, Trott 2011). In the broad context, the model is defined as a linear model of innovation. In its basic form, a new product is marketed to consumers / users through two different processes, i.e., science push and demand pull. These models have been used in product development processes already after World War II (Trott 2011). During that era, scientists and economists began to enhance product development processes by creating economic and technological models and innovation processes.

The conceptual framework of the linear models in general is a three category combination (Trott 2011). First, the concept introduces the science and technology base. This category includes the creation and enhancement of new knowledge. It is highly dominated and affected by universities and large research organizations. Then, in the technological development category, the process is dominated by industry and product development organizations. Finally, the conceptual framework introduces the needs of the market. This is driven by consumer needs and consumption of goods creating demand.

As this framework contains all the aspects of new product creation and as two main ways of product development paths arose, the linear model was divided into two sub-categories: science push and demand pull (Trott 2011). The science push model was dominant during and immediately after WW II. New products that were highly affected by the innovations of war machinery were brought to the market. Thus, it was left to marketing to find the right customers and the markets in general were passive recipients of the R&D work. This model has been highly functional in the pharmaceutical industry, while most of the other fields are now controlled by the consumer needs. The shift in consumer behavior development led to the second linear model. The change in the consumer behavior dates back to the 1970's and since then the second linear model, demand pull, was introduced (Trott 2011, von Hippel 1978). The major difference between the two models is the input for new product creation. While the science push model indicates that new innovations for products arise from innovations made by manufacturers and researchers, the demand pull model is driven by the customer needs. The linear models of the processes are illustrated in Figure 15.

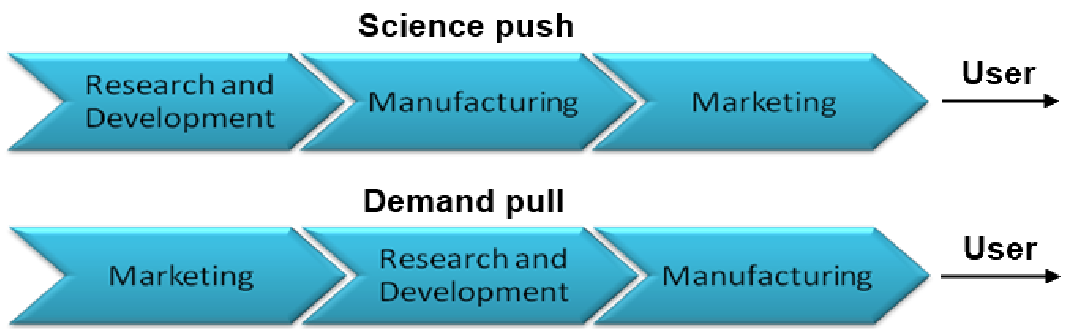

Figure 15. Linear models of innovation (Trott 2011).

As the medical device industry has mostly been evolved through demand based innovations, the organization of the model in this study is also such that the demand pull is introduced first followed by the science push model. The derived model is illustrated in the Figure 16.

In the Figure, the top flow chart illustrates a common demand pull model where the indication for new product comes from the market. Such indicators can be a growing diabetes population or the need for more controllable surgeries and shorter recovery times after the operations. The demand pull based market eventually leads to a new innovation through research and development. This then opens the market for the new product.

The bottom flow chart shows a common science push model, where a new innovation is the driver for the markets. The goal is to create the demand through an entirely new product or through a new method utilizing an existing one. Such products that have clearly become methods and devices in the surgical field are for example surgical navigators and other surgical guidance devices (Koivukangas 2012).

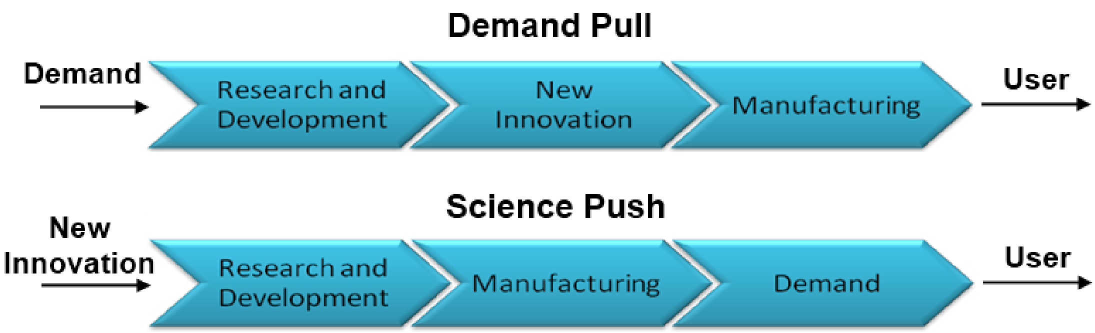

Figure 16. The demand pull / science push flow chart model.

5.2 Medical device innovation lifecycles

This thesis covers three main categories of lifecycles of medical devices from the innovation management point of view. In all these product types, a new innovation is based on an existing method. In these product categories, the methods do not change, but the technologies enabling them have been re-invented. A common life cycle of technologies is presented in Figure 17 (Karbhari *et al.* 1994). As with all products, in phase I the most time and costs consuming process is the fundamental science enabling a possible new product development. In this phase the maturity of the product is low with new prototypes tested and ideas iterated. During this phase the technology is experiencing a rapid growth while the need for base scientific research is decreasing. During phase II, the technology is experiencing the highest use rate and relevance, while the maturity is constantly increasing and the efforts in fundamental science decreasing. This is the phase during which the technology experiences the highest return on investment. When entering phase III, either the technology comes to the end of its life, or a new innovation lifts the use to a new level. Before the new innovation, or use, the maturity is at its highest capability. Depending on the forthcoming valley of death, the technology is re-invented or it is not continued.

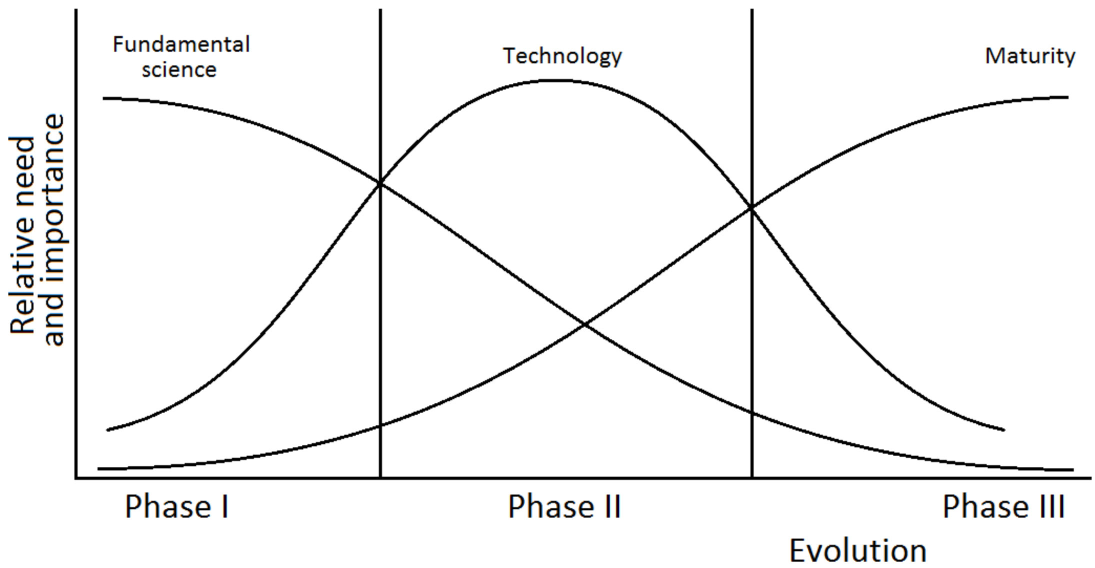

Figure 17. Innovation life cycle of technologies (Karbhari *et al.* 2006).

5.3 Fundamental medical device technologies

This section covers four main categories of medical device technologies that are considered as fundamental technologies of enabling different use cases. The medical imaging technologies are the basis for most of the more demanding operations and the first detectors of most of hospitalization demanding diseases. Image guided surgical devices form the basis of minimally invasive surgeries (Grunert *et al.* 2003) that have dramatically affected the decrease of hospital stay from 2 weeks to a few days (Davis *et al.* 2013, Grunert *et al.* 2003, Koivukangas 2012). As the main burden of global diseases is based on non-communicable diseases (WHO 2012) with cardiovascular diseases as the highest costing illness, the evolution of cardiac pacemakers is also introduced in this chapter. Finally, the predictive medicine and remote healthcare technologies are also covered.

5.3.1 Medical imaging technologies

The invention of medical imaging began after Wilhelm Röntgen unintentionally imaged his wife’s hand during experiments with new ray sources in 1895. Since then, new imaging modalities have experienced rapid growth among doctors. The main modalities in use are ultrasound, endoscopy and as more complex methods, computed tomography (CT) and magnetic resonance imaging (MRI). Being the basis of most image guided surgeries, the innovation life cycle of the CT and MRI are covered in more detail. The diffusion of these imagers is also used in the evaluation of the national situation of technological progress (He *et al*. 2009).

In terms of technology evolution, CT and MRI technologies have further been developed into specific sub-modalities. Economically the transition follows the common innovation life cycle process with the base method being unchanged, and new imaging modalities serving as positive shocks in the expansion of the market of the base device.

These imaging modalities have further been enhanced to cover the following more common modalities:

- Computed tomography
  CTA (computed tomography angiography)
  SPECT (single photon emission computed tomography)
- Magnetic resonance imaging
  MRA (magnetic resonance angiography)
  fMRI (functional magnetic resonance imaging)

The following Figure shows the evolution of CT and MRI.

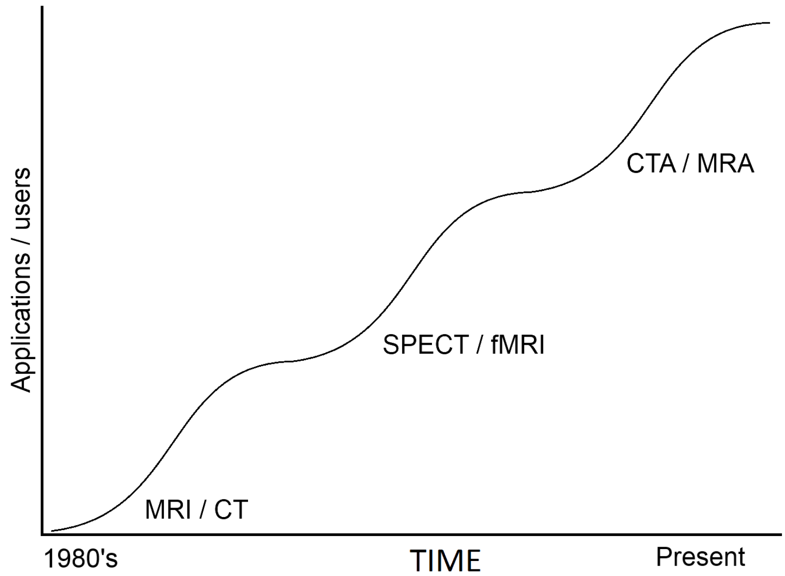

Figure 18. Technological evolution of medical imaging.

5.3.2 Computer assisted surgery technologies

Computer assisted surgery (CAS) navigation technologies have been developed rapidly since the late 1980's. The first navigators, namely neuronavigators, were invented for guiding the instruments deep in the human brain for safer and more rapid operations. Prior to these systems and devices, the disorder in the brain was located by approximation of the target with respect to the pre-operative images. The use of the navigators has enabled real time tracking of the instruments inside the human brain, thus guiding safe routes to the target. The first navigators were based on mechanical arms with optical encoders at each joint of the links. Through kinematics, the tip of the instrument could be measured with sub-millimetric accuracy (Koivukangas 2012). The main use of the first generation navigators was in operation of the brain.

As other fields of technologies evolved, also the navigational technology experienced rapid growth both in users and in applications. Especially the evolution of computers and camera technologies had a major impact in innovating new methods of instrument tracking. Thus, in the mid 1990's, the infra-red camera based optical navigation was introduced.

Finally, in the late 1990's, electromagnetic systems and field generators came to the maturity of enabling stable position tracking of instruments in their close proximity. This had a major impact in the invention of electromagnetic tracking based surgical navigation.

With the evolution of the surgical navigators and industrial robotics, the newest technology in computer assisted surgery was introduced in the market. In the late 1990's and early 2000's the first surgical robotic assisted operations were successfully accomplished.

The introduction of surgical navigation and, most recently, surgical robotics has had major impact on safer operations and quicker patient recovery. Navigator assisted brain surgeries have shortened the length of hospital stay from an average of two weeks down to two days with clearly less complications (Grunert *et al.* 2003). A recent research paper (Davis *et al.* 2013) indicates that also robotic assisted surgeries dramatically shorten the length of hospital stay (LOS) and reduce complication rates.

From the viewpoint of innovation management and evolution the CAS technologies differ somewhat from that of medical imaging. CAS technologies often experience a normal innovation life cycle, during which a current method or device is totally replaced by a new method of technology. This life cycle and evolution in users and applications is illustrated in Figure 19.

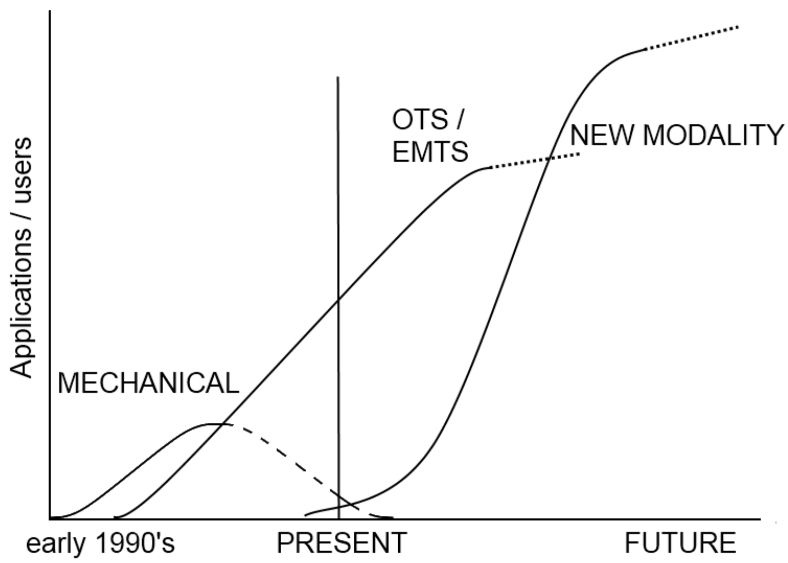

Figure 19. Technological evolution of surgical navigation.

5.3.3 Cardiac pacemaker technology

Cardiovascular diseases (CVDs) are a major concern globally (WHO 2012). The number of CVD patients is growing all over the world, dramatically affecting the rise of healthcare costs. Especially costs due to hospital treatment of CVDs have a major impact on total healthcare costs. There is a growing demand for methods and devices of treatment of this disease.

An innovation that has positively affected the life of millions of patients with CVD was introduced in hospitals in the 1950's. One of the pioneers was electronics engineer, Dr. Earl Bakken, the founder of Medtronic Inc. (Minneapolis, MN, USA). The invention came from a need of cardiologists at the University of Minnesota, who asked Dr. Bakken for a portable, battery operated cardiac pacemaker for a young patient. The first version was a 5 kilogram system on a cart with two leads attached to the heart of a patient.

Since then, as the technologies of ICT and sensors improved, the device is currently approximately the size of an egg with 6 mm in thickness. The device is also fully implanted and can be controlled wirelessly either at the hospital or at home. Figure 20 presents the evolution of the cardiac pacemaker with the first version of the 1950's and the latest version at present. An idea of the growing number of users can be seen in the evolution of the global leader in this field, Medtronic Inc. In 2010 their slogan was: "*Every 6 seconds*, *a life is improved by a Medtronic product or therapy."* The slogan today is: *"Every 3 seconds, a life is improved by a Medtronic product or therapy."* (*www.medtronic.com*).

Figure 20. The evolution of cardiac pacemakers (NRCC 2014).

5.3.4 Connected health technologies

The consumer products based IC technologies have enabled the widespread use of mobile, wireless devices for many purposes. It has also enabled these methods to be used in medical devices and furthermore opened the way for medical devices to be used in home healthcare. The basic infrastructure for wireless connections is currently available in major cities and regions globally. This has made it possible to transfer the collected data of a person's wellness monitoring and vital signs detection quickly and remotely.

The evolution of these technologies has dramatically affected the current stage of medical device technology which enables a number of vital signs monitoring methods and surgical guidance technologies for the broad fields of medicine.

Figure 21 illustrates the trend from traditional healthcare toward the future. In the past, healthcare was mainly informative between the doctor and the patient. Typically, a person went to see the doctor for their examination. Now the patient care is at a stage where there is more interaction between the parties, as the patient may find some indications regarding the illness before entering the hospital. At the same time the technology is enabling the shift toward integrated methods, as many healthcare devices have found their way into homes. Home healthcare is a current technology topic. All these prior steps are the basis for innovative healthcare. The megatrend of today is connected health with personalized medicine.

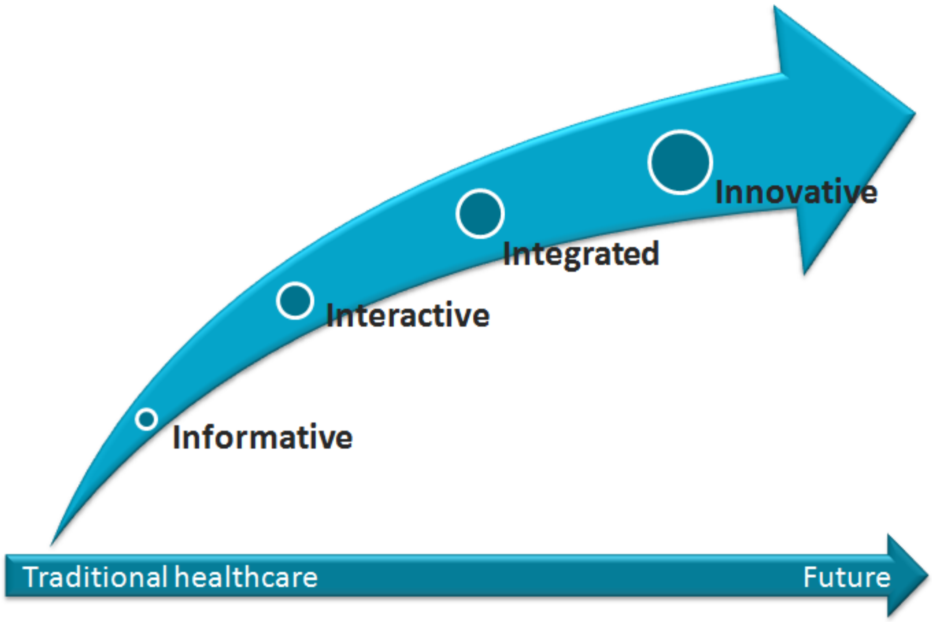

Figure 21. The technological evolution in healthcare.

6 RESEARCH DATA AND ESTIMATION METHODS

The analyses of this research are based on several data banks that are available online. The data has been obtained from the WHO, the OECD, The UN Comtrade, the World Bank and Finnish Customs. The data has been reported by each country and are thus official indicators of each analyzed nation.

Due to non-comprehensive data production and registration of each country, there are certain limitations that need to be discussed. Firstly, there was evident lack of data from the BRIC countries especially regarding the technology status. Thus, most of the analysis containing the effect of medical technology with respect to length of hospital stay was done only for the OECD countries. Secondly, the data in the OECD countries was also limited to cover registered data mostly consisting of public hospitals. The analysis has thus some weaknesses because of the lack of data, but a clear trend of medical device technology and its effect could, however, be identified.

6.1 Statistical analysis

The statistical analyses used in this thesis are based on the linear regression model as specified in Equation (1). As the nations are notably different in size both population-wise and economically, it was decided to utilize the panel data followed by analysis of each nation independently.

$$Y_{i,t} = \alpha_i + \beta_0 X_{i,t}^0 + \beta_1 X_{i,t}^1 + ... + \beta_k X_{i,t}^k + \varepsilon_{i,t} \qquad (1)$$

where:

- Y = Dependent variable
- α_i = Constant
- β_j , j = 0, …, k
- $X_{i,t}$ = Independent variables
- $\varepsilon_{i,t}$ = Error term
- i = Analyzed country, i = 1, …, n
- t = Analyzed year, t = 1, …, 20
- t = Analyzed year

6.2 Statistical data sources

Table 3 contains the variables and locations of the obtained data.

Table 3. Used variables and selected filters for the analysis.

Data source	Variables / Data sets
OECD http://www.oecd.org/els/health-systems/oecdhealthdata2013-frequentlyrequesteddata.htm	*Selected variables:* - Health at a glance: OECD indicators - OECD Health Statistics, 2013 Frequently Requested data *Used variables:* - Total expenditure on health, % of gross domestic product - MRI units per million population - CT scanners per million population - Average length of stay, Acute myocardial infarction, days
WHO/ GHO http://www.who.int/healthinfo/global_burden_disease/projections/en/	*Selected variables:* - Population proportion of over 60-year-olds - Mortality 2015 and 2030 – Baseline scenario - WHO regions and World Bank income categories *Used variables:* - II. Non-communicable diseases - C. Diabetes mellitus - G. Cardiovascular diseases - H. Respiratory diseases - Years: 2005, 2015 and 2030
World Bank http://databank.worldbank.org/	*Selected variables:* - GDP per capita (current USD) - Health expenditure, total (% of GDP) - Population ages 65 and above (% of total) - Years: 1990-2012
UN Comtrade http://comtrade.un.org	*Imports and exports of medical devices with following variables:* - Classification = HS as reported - Commodities = 9018 (CT and X-ray machines as the largest commodities) and 902214 (MRI machines as the largest commodity) - Reporters = Brazil, China, EU-27, Finland, Germany, India, Japan, Russian Federation, USA - Years = 1990 – 2012 - Trade partners included all countries in the world - Trade flow = Exports and Imports

Some data has also been obtained from national and international medical device technology organizations such as FiHTA (Finnish Health Technology Association) and Eucomed (European medical technology industry association). Most of this data was obtained from each organization's published reports and through specific questions from analysis specialists.

6.3 Statistics on global burden of diseases

6.3.1 Ageing and distribution of world population

Global statistics

According to the United Nations (UN) estimates, the fastest growing age group is over 60-year-olds also globally (UN 2013). The statistics furthermore indicate that the percentage distribution of the world population clearly shifts toward the less developed and especially the least developed regions. This is highly due to the annual fertility rate of 0.42 % in the developed countries in comparison to the three times higher, 1.37 % rate in the less developed countries. The statistics are illustrated in Figure 22, where the total world population is shown as the shaded background area and the percentage share of the developed and less developed countries as the solid lines.

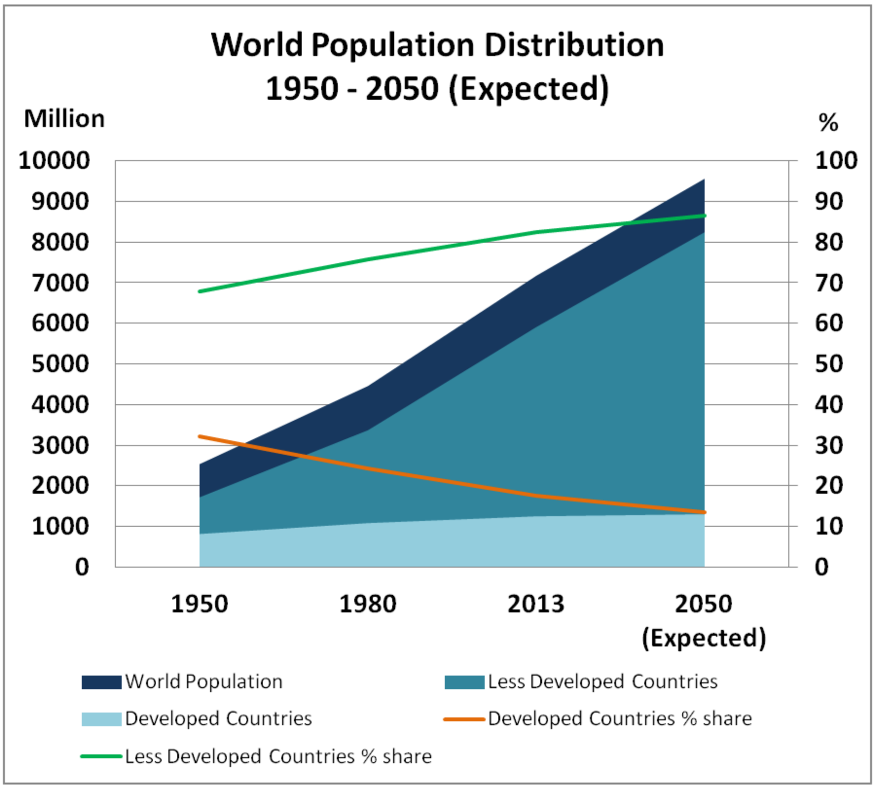

Figure 22. The world population by regions from the 1950's to the estimates of the 2050's.

Statistics in Finland

The statistics from the Statistics Finland (2013) reports indicate that the share of over 65-year-old people in the population of Finland is estimated to grow rapidly within the next few decades. An increase from 17,5 % in 2010 to 22,6 % is expected to happen already in 2020. Furthermore, the long period estimates show that the amount of over 65-year-olds will reach 28,2 % by 2060 as presented in Figure 23.

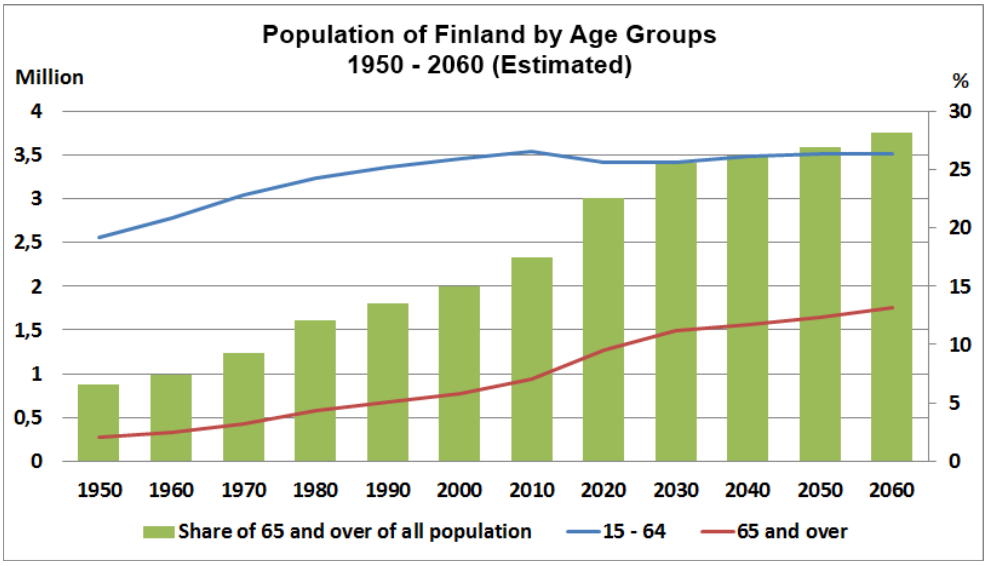

Figure 23. The population of Finland in age groups (scale on left) with the expected age group trends (scale on right).

6.3.2 Mortality caused by the non-communicable diseases

The WHO study (WHO 2013a) indicates that NCDs kill more than 36 million people annually, being a major concern globally. According to the findings, over 80 % of these deaths occur in low- and middle income countries. The NCD related deaths are further categorized into CVDs, respiratory diseases and diabetes. By far, the CVDs are the number one cause of the NCD deaths (WHO 2011, Mathers & Loncar 2006). In 2008, an estimated 17.3 million, or a total of 30 % of all deaths globally, were caused by the CVDs. The studies furthermore indicate that over 80 % of these deaths occurred in the low- and middle income countries. It is also estimated that the overall deaths will reach 23.3 million by 2030 with the ratio of developed and developing countries to remain nearly constant.

Figure 24 illustrates the resent history and estimated growth of the deaths caused by the NCDs by the World Bank income groups. In the Figure, the following nations are used in further analysis of this thesis.

HI = High income countries

- Brazil, Canada, Czech Republic, Finland, Germany, Japan, The Netherlands, New Zealand, Russian Federation, United Kingdom and the USA

MID = Upper middle income countries (Hungary, P.R. China)

LOW = Lower middle income countries (India)

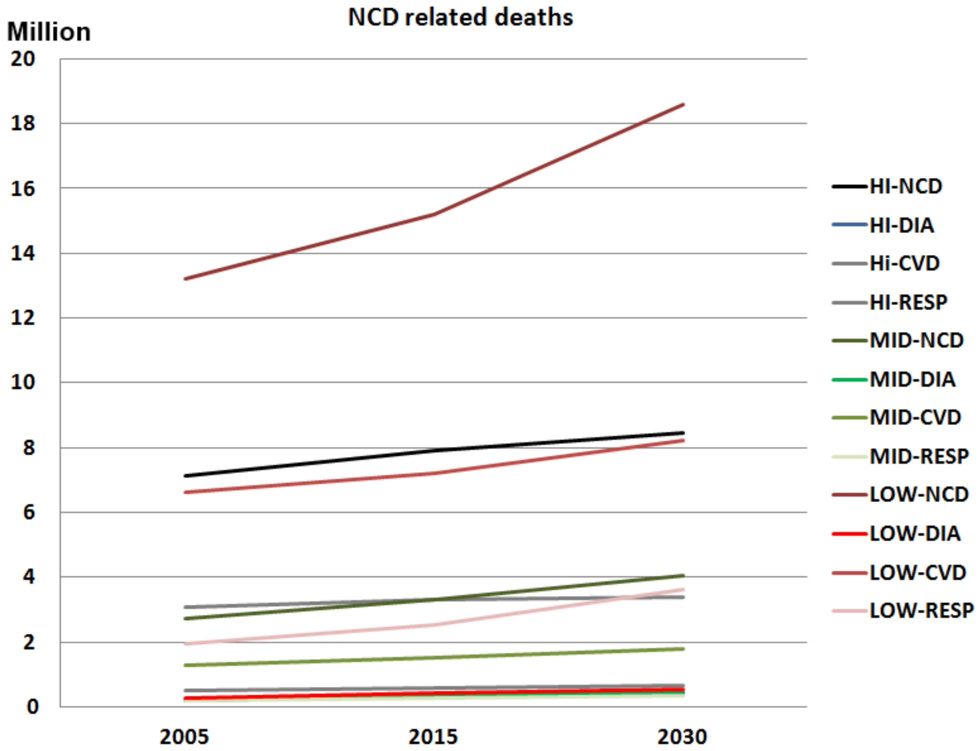

Figure 24. NCD related deaths by the World Bank income groups. NCD = non-communicable diseases, DIA = diabetes, CVD = cardiovascular diseases, RESP = respiratory diseases.

Figure 25 is a strongly illustrative representation of the current status of NCD related deaths by regions. The Figure indicates where the probability for deaths caused by them is highest. Clearly, it is seen that the regions with highest mortality rates are currently in the developing regions of the world.

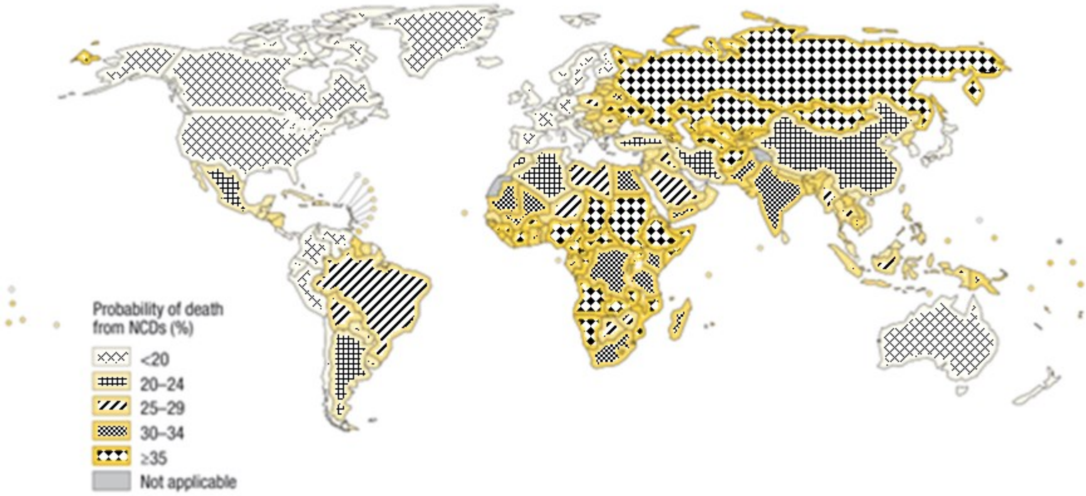

Figure 25. Probability of death from an NCD between ages 30 and 70 (%), 2008. (WHO 2012b).

Figures 26 and 27 indicate the growth rate of the NCD related mortalities and the ageing of population in the BRIC countries and in the OECD countries, respectively. In the Figures, the NCDs indicate the number of deaths caused by the NCDs and POP indicates the share of over 60-year-olds. These data are the average of each variable within these regions of interest.

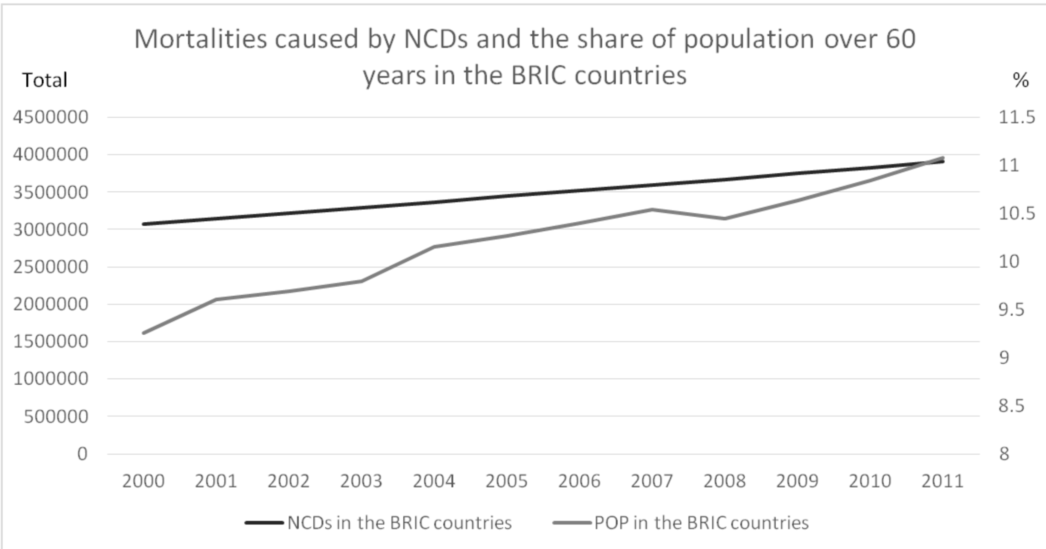

Figure 26. The growth of NCDs and ageing of population in the BRIC countries.

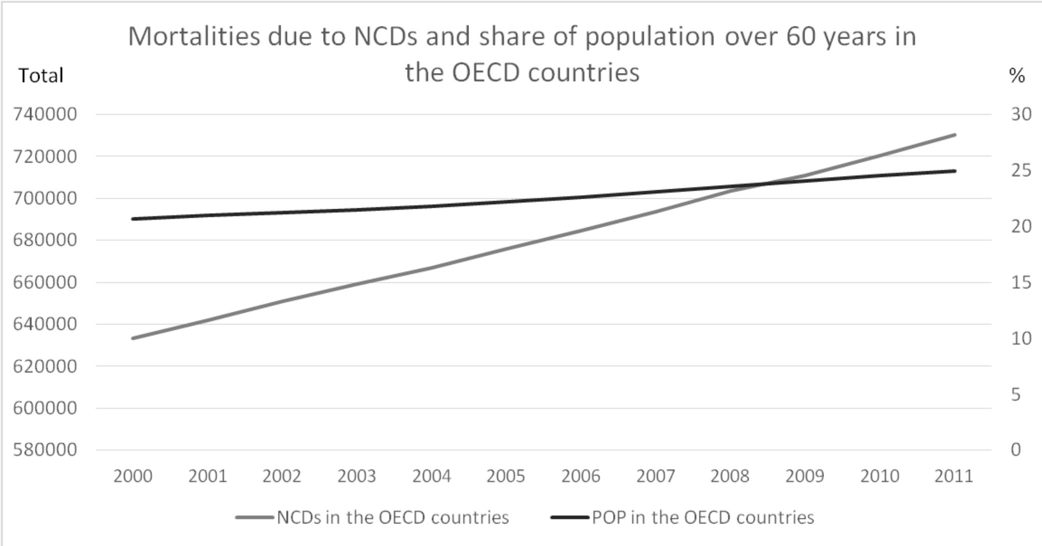

Figure 27. The growth of NCDs and ageing of population in the OECD countries.

6.4 Technological advancement data sources

The technological achievements and positive shocks in the innovations are covered in the results and discussion. These data was obtained from several company and publication sources. The major contribution of this analysis is in presenting the effect of the overall technological advancement which clearly also serves the field of medical device industry.

6.4.1 Diffusion of magnetic resonance imagers and computed tomography scanners

As covered by earlier studies (He *et al.* 2013), the diffusion of MRI and CT scanners can be used as estimators for the technological status of the hospitals in each nation. The following graphs (Figs. 28 and 29) contain the diffusion of the scanners in the chosen OECD countries in time series analyses from 1990 – 2012. It is seen that the number of devices in these countries has increased, thus indicating that the technological status has also improved in them.

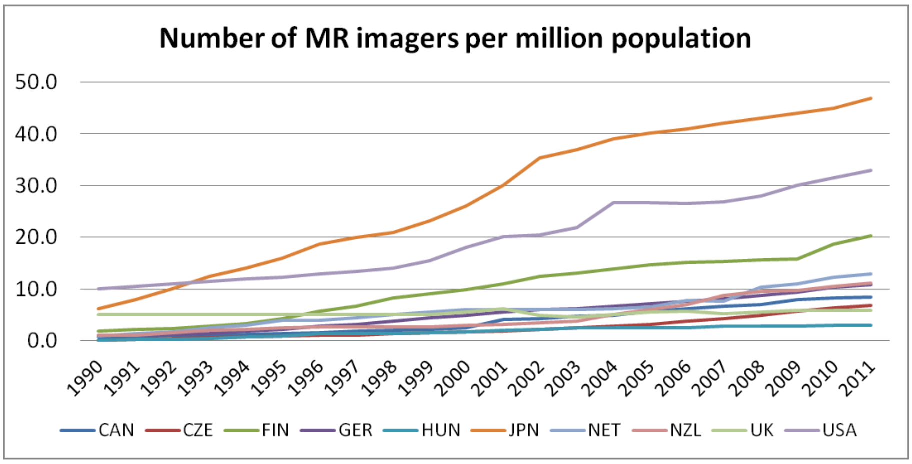

Figure 28. Diffusion of MRI scanners per million population.

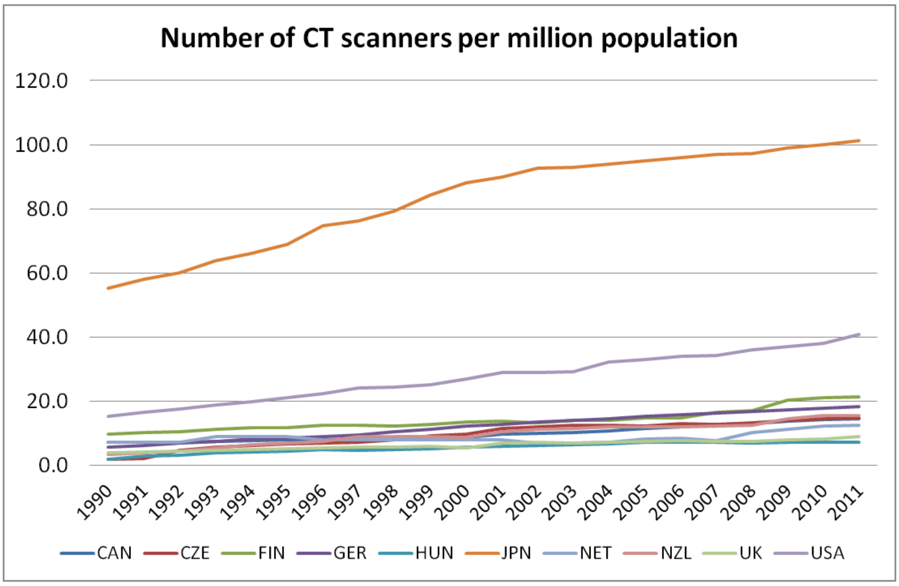

Figure 29. Diffusion of CT scanners per million population.

6.4.2 Statistics on the length of hospital stay in the OECD countries

The length of hospital stay (LOS) has a notable effect on the overall costs of patient treatment (Blume 1992). This is especially evident in the developed countries with high income level by the fact that the longer the patient is treated in the hospital, the longer the medical experts are needed in the treatment process. Also, the longer the patient needs hospital attention, the longer the person is away from daily work. The following graph (Fig. 30) indicates the trend in the average hospital stay in the developed countries. The dramatic decrease of the LOS is evident within the time frame of 1990 – 2011. The overall quality of healthcare has been improving, but also the technology has evolved.

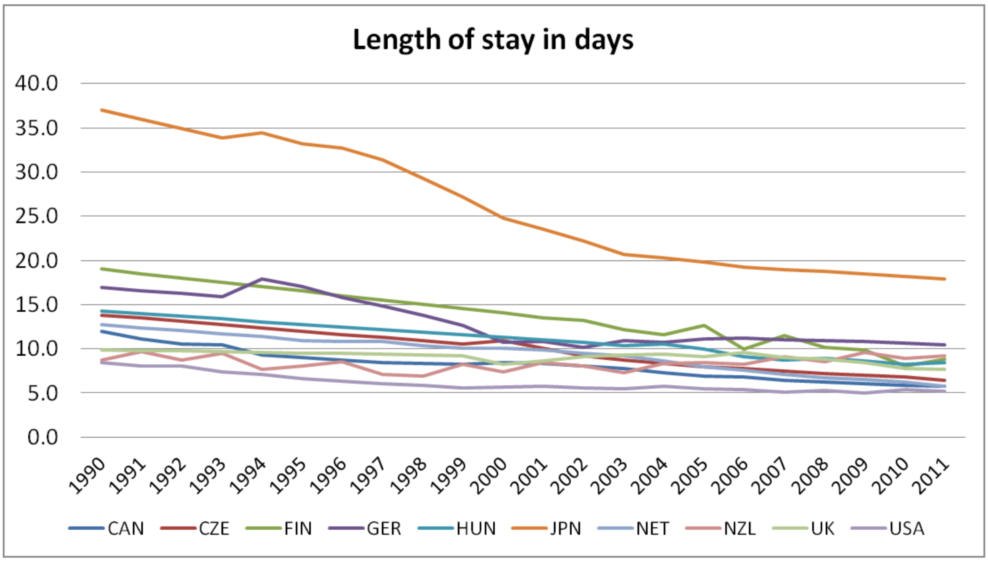

Figure 30. Average length of hospital stay in days.

The next data sets contain statistics of the diffusion of MRIs and CTs with respect to the LOS. The light gray line represents the average LOS in days in the OECD countries, while the black line indicates the diffusion of medical imagers during this time period. The medical imagers are an averaged total of both the CTs and the MRIs. As the graphs indicate, there is evident correlation between the length of hospital stay decrease and the increase on the number of medical imagers. These results are illustrated in Figure 31.

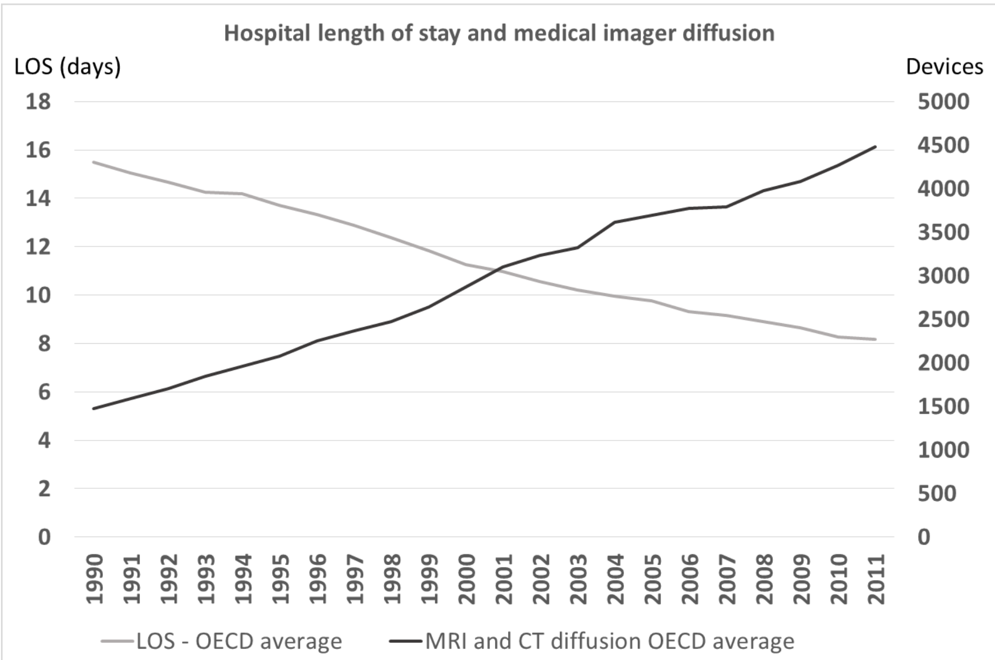

Figure 31. Average LOS and medical device diffusion in the OECD countries.

6.4.3 Total health expenditure of gross domestic product

In assessing the purchasing power and thus potentiality for purchasing new medical devices of the analyzed nations, the total health expenditure (THE) in current USD was used as the indicator. This was obtained using the THE as % of GDP multiplied by the GDP in current USD for each nation. The results are shown in Fig. 32. It is seen that even though the THE % share of GDP has been relatively constant during the time period, the amount in current USD has been growing relatively steadily. The background columns represent the total health expenditure as percent share of GDP and, respectively, the solid lines with common color the GDP of each nation.

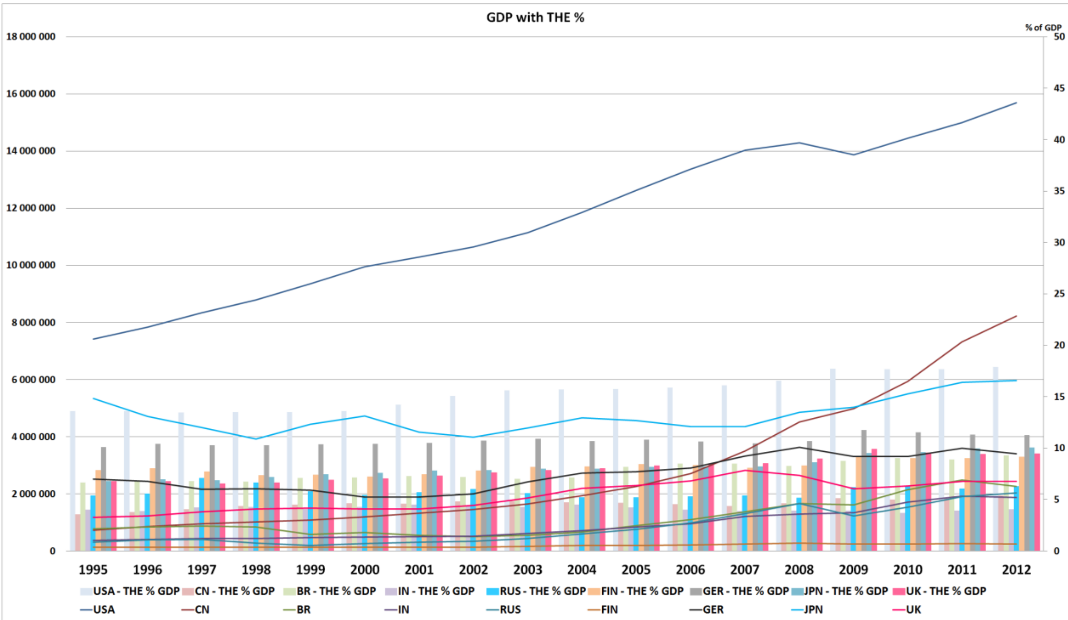

Figure 32. Time series analysis on the total health expenditure (scale on left) and percentage of the GDP (scale on right).

7 RESULTS AND MEDICAL DEVICE MARKET GROWTH ANALYSES

7.1 Demand pull based industry growth

7.1.1 The global burden of diseases

There are several key factors supporting the economic stability of the industry and especially the expected growth of the market, that are based on increasing demand for new medical devices. The following two future trends clearly indicate that the medical device market is at a stage of demand pull based market growth: First, the ageing of the population and a corresponding increase in wealth (*i.e.* higher purchasing power) and, second, the increasing incidences of diseases, such as non-communicable diseases (NCDs) (WHO 2013a, Mathers & Loncar 2006) including cardiovascular diseases (CVDs) (WHO 2013b), and diabetes (George *et al.* 2013, Zimmet *et al.* 2001). The second indicator also deals with the growing demand for high technology medical devices in the developing countries.

7.1.2 The effect of the ageing of the population on the global burden of diseases

In the analysis of the global burden of diseases, the rate of NCD related deaths per million population was chosen as the dependent variable. The variable was calculated for each assessed country by obtaining the total number of NCD related mortalities in each region which was then multiplied by the share of population per million of each country. The total health expenditure in current USD, the share of population over 60 years of age and the trade balance of each nation were chosen as the independent variables. The analysis is done for the BRIC countries and five selected OECD countries. In these analyses, the share of over 60-year-old population was chosen as the variable indicating the ageing of population, because of insufficient data relating to the over 65-year-old population in the BRIC countries.

BRIC country analyses

The regression analysis of the mortality due to NCDs in the BRIC countries is presented in Table 4. The four different models are based on the selected independent variables that describe the effect of each in predicting the future of NCD related deaths.

Table 4. Regression analyses results on non-communicable disease related deaths in the BRIC countries.

Independent variable	Model 1	Model 2	Model 3	Model 4
	Dependent variable: Mortality due to NCDs			
Constant	-405,832	-148,274	3189,091	-480,704
	<0,001	*0,021*	*<0,001*	*<0,001*
THE	-45,501	-47,660	142,370	
	<0,001	*<0,001*	*0,007*	
POP	58,703	57,036		54,524
	<0,001	*<0,001*		*<0,001*
TB	-0,313		1,811	-0,128
	<0,001		*0,008*	*0,244*
SER	184,099	249,483	2642,744	412,486
R^2	0,996	0,993	0,249	0,982

*N = 5*60 = 300. P-values in Italic. THE = Total health expenditure in current USD, POP = Population share of over 60-year-olds, TB = Trade balance.*

The statistics indicate that the deaths caused by NCDs have grown approximately 10 % within the last ten years. The statistics further indicate that the growth will continue at an annual rate of 4 %.

Models 1 and 2 support these predictions. The independent values in most of the models are statistically significant with minor standardized error present. Thus, the models are strong indicators in the analyses. First, the total health expenditure (THE) has a significant ($p<0,001$) decreasing effect on the growth of NCDs. Second, the ageing of the population (POP) strongly correlates ($p<0,001$) with the increase in the NCDs. Also the trade balance (TB) seems to have a significant ($p<0,001$) effect on the growth in the NCDs.

Due to different sized economies and populations in the BRIC countries, the analyses are shown for each nation separately in Table 5. These analyses indicate the differences of the nations. Out of these nations, Brazil and India have similar results related to the growth of NCDs with the panel analysis models 1 and 2. The ageing of the population in Russia and the trade balance of China have mixed correlations in the models. Further analyses are presented in Table 6, where the least significant independent variables are removed from the analyses.

Table 5. Regression results of deaths caused by NCDs in the BRIC countries.

	Assessed countries							
	BRA		RUS		IND		CHN	
Independent variables								
	Dependent variable: Deaths caused by non-communicable diseases (NCD)							
		Std		Std		Std		Std
Constant	35,706		83,495		-243,220		154,994	
	<0,001		*<0,001*		*<0,001*		*<0,001*	
THE	-0,059	-0,05	0,679	1,444	-11,760	-0,348	-2,329	-8,118
	0,769		*<0,001*		*<0,001*		*<0,001*	
POP	4,598	1,29	-0,016	-0,008	8,773	1,228	4,218	20,512
	<0,001		*0,845*		*<0,001*		*<0,001*	
TB	0,006	0,269	0,001	0,489	-0,038	-0,119	0,002	1,106
	<0,001		*0,005*		*0,003*		*0,301*	
SER	0,462		0,213		1,757		2,017	
R^2	0,997		0,987		0,999		0,998	

*N = 4*4*12=192. P-values in Italic. Std = Standardized result. THE = Total health expenditure in current USD, POP = Population share of over 60-year-olds, TB = Trade balance. BRA = Brazil, RUS = Russia, IND = India, CHN = China.*

The independent variables that were excluded in the analysis were: Total health expenditure (THE) for Brazil, the share of over 60-year-olds (POP) for Russia and the effect of trade balance (TB) for India and China. The results are collected in Table 7.

Table 6. Regression results on deaths caused by NCDs in the BRIC countries excluding least significant indicators.

	Assessed countries							
	BRA		RUS		IND		CHN	
Independent variables								
	Dependent variable: Deaths caused by non-communicable diseases (NCD)							
		Std		Std		Std		Std
Constant	36,698		83,188		-268,728		141,115	
	<0,001		*<0,001*		*<0,001*		*<0,001*	
THE			0,680	1,446	-9,794	-0,290	-2,455	-0,642
			<0,001		*0,012*		*<0,001*	
POP	4,525	1,268			9,168	1,284	4,320	1,615
	<0,001				*<0,001*		*<0,001*	
TB	0,007	0,298	0,001	0,490				
	<0,001		*0,002*					
SER	0,468		0,201		2,943		2,042	
R^2	0,997		0,987		0,998		0,998	

*N = 4*4*12=300. P-values in Italic. Std = Standardized result. THE = Total health expenditure in current USD, POP = Population share of over 60-year-olds, TB = Trade balance. BRA = Brazil, RUS = Russia, IND = India, CHN = China.*

The independent variable that has the highest effect on this growth is the ageing of the population. The effect of the share of over 60-year-olds in each nation is also statistically significant ($p<0.001$). Only in Russia, this variable had no statistical significance and it was thus excluded from the analyses. It can be seen that in Russia, the total health expenditure has the strongest correlation with the mortality due to NCDs.

In India and China the highest effect in lowering mortalities due to NCDs is seen to be the increase of total health expenditures. These results are strong ($p<0,001$) indicators that the more the government spends on healthcare, the less NCD caused mortalities occur.

The trade balance of each nation has a mixed response having a significant effect causing a decrease both in Brazil (*$p<0.001$*) and Russia (*$p=0.002$*). However, the trade balance statistics and published results indicate that the trade balance of medical device technologies being negative in the BRIC countries points to an increasing market for the manufacturers of these devices in the regions with the largest populations.

OECD country analyses

The analysis of the OECD countries was done similarly to that of the BRIC countries, but the effect of the medical devices was also included in the first regression model. In these analyses (Table 7), the strong correlation of each independent variable is seen with statistically significant (*$p<0,001$*) response.

The models indicate that the diffusion of MRIs and CTs have strong correlation ($p<0,$001) with the decreasing number of NCD related mortalities in each nation. Also the ageing of the population has a clear effect on the increase in NCDs. However, there seems to be a possibility for multicollinearity with the results regarding the effect of the distribution of MRIs and CTs (devices) and the total health expenditure (THE). Thus, the analyses were extended to five models with different data excluded. These five models are chosen to see the real effects of each chosen variable by excluding some of the variables from the regression model.

Model 1 contains all the variables for the chosen OECD countries. The possible multicollinearity is eliminated in model 2 by excluding the ‘Devices’ variable. In model 3 also the trade balance (TB) was excluded for assessing purely the effect of general government and population related indicators. Model 4 contains the data that excludes the effect of government based indicators so that the analysis does not contain the money put into healthcare, which deviates strongly between the nations. Finally, model 5 excludes the effect of international trade of the medical devices.

Interestingly, the correlation remains constant with only minor change in the effect, when the analyses are done by excluding different independent variables. This is also seen in Table 7.

Table 7. Regression analyses results on the non-communicable diseases related deaths in the OECD countries.

Independent variable	Model 1	Model 2	Model 3	Model 4	Model 5
	Dependent variable: Mortality due to NCDs				
Constant	0,029	0,028	0,023	-0,038	0,020
	0,079	*0,152*	*0,243*	*0,158*	*0,260*
Devices	-0,002			-0,004	-0,001
	<0,001			*<0,001*	*<0,001*
THE	0,033	0,041	0,039		0,032
	<0,001	*<0,001*	*<0,001*		*<0,001*
POP	0,023	0,017	0,018	0,038	0,022
	<0,001	*<0,001*	*<0,001*	*<0,001*	*<0,001*
TB	-0,016	-0,008		-0,011	
	<0,001	*0,089*		*0,166*	
SER	0,065	0,0775	0,0788	0,1155	0,0716
R^2	0,989	0,984	0,983	0,965	0,986

*N = 5*5*12=300. P-values in Italic. Devices = Number of devices, THE = Total health expenditure in current USD, POP = Population share of over 60-year-olds, TB = Trade balance.*

Similarly to the BRIC countries, there are significant differences in the statistics of each nation of the selected OECD countries as each nation is different in the sizes of populations and economies, so the analysis was deepened with an analysis of each nation separately. These regression analysis results are presented in the following Table (8).

Table 8. Regression results of deaths caused by NCDs in the selected OECD countries.

	Assessed countries									
	USA		FIN		GER		UK		JPN	
Independent variables										
	Dependent variable: Deaths caused by non-communicable diseases (NCD)									
		Std		Std		Std		Std		Std
Constant	1,010		0,236		0,414		0,133		0,374	
	<0,001		*<0,001*		*0,006*		*<0,001*		*<0,001*	
Devices	0,000	0,023	0,000	0,204	0,003	0,801	0,000	-0,02	0,003	0,963
	0,662		*0,249*		*0,077*		*0,837*		*0,062*	
THE	0,015	0,636	0,064	0,269	0,000	0,014	0,013	0,417	-0,004	-0,15
	<0,001		*0,002*		*0,978*		*0,045*		*0,251*	
POP	0,008	0,358	0,040	0,371	0,000	0,024	0,016	0,749	0,001	0,123
	0,007		*0,05*		*0,948*		*<0,001*		*0,797*	
TB	-0,001	-0,02	0,020	0,176	0,001	0,145	0,005	0,198	-0,004	-0,07
	0,617		*0,041*		*0,723*		*0,132*		*0,373*	
SER	0,0032		0,0008		0,0033		0,0028		0,0031	
R^2	0,999		0,998		0,956		0,981		0,988	

*N = 5*5*12=300. P-values in Italic. Std = Standardized result. THE = Total health expenditure in current USD, POP = Population share of over 60-year-olds, TB = Trade balance, Devices = Total number of CT and MRI scanners. USA = United States of America, FIN = Finland, GER = Germany, UK = United Kingdom, JPN = Japan.*

This analysis presents the different driving factors of NCD related deaths in the selected OECD nations. The results have high deviation and with clearly less statistically significant indicators. This is mostly due to the different statistical data. Even though for example the trade balance is positive in most of the OECD countries, it is in fact negative in the UK and Japan for the last few years. Also, the diffusion of MRIs and CTs has been relatively stable especially in the USA, while in Japan there is dramatic increase in the numbers of devices within the last decade.

Thus, the following results of further analysis are collected by excluding the least significant independent variables for obtaining the strongest indicator for each nation. These results are collected in Table 9.

Table 9. Regression results on deaths caused by NCDs in the selected OECD countries, excluding least significant indicators.

	Assessed countries									
	USA		FIN		GER		UK		JPN	
Independent variables										
	Dependent variable: Deaths caused by non-communicable diseases (NCD)									
		Std		Std		Std		Std		Std
Constant	1,040		0,226		0,422		0,108		0,526	
	<0,001		*<0,001*		*<0,001*		*<0,001*		*<0,001*	
Devices					0,003	0,822				
					0,007					
THE	0,016	0,677	0,059	0,249			0,005	0,158	-0,003	-0,13
	<0,001		*0,002*				*0,106*		*0,209*	
POP	0,008	0,328	0,059	0,550			0,019	0,858	0,007	1,101
	<0,001		*<0,001*				*<0,001*		*<0,001*	
TB			0,025	0,220	0,001	0,162				
			0,009		*0,507*					
SER	0,002		0,0001		0,001		0,001		0,001	
R^2	1,000		0,995		0,997		0,995		0,998	

*N = 5*5*12=300. P-values in Italic. Std = Standardized result. THE = Total health expenditure in current USD, POP = Population share of over 60-year-olds, TB = Trade balance, Devices = Total number of CT and MRI scanners. USA = United States of America, FIN = Finland, GER = Germany, UK = United Kingdom, JPN = Japan.*

Similarly to the BRIC countries, the analyses for the OECD countries indicate a strong correlation between increases in deaths caused by the NCDs and the ageing of the populations in nearly all assessed nations (*p<0,001)*.

7.2 Science push based industry growth

As introduced in Chapter 5, the current megatrends in healthcare are personalized medicine and connected health. The evolution of technologies enabling the growing user and application base began in the early 1990's with image transfer between the doctors and patients.

As the healthcare follows this megatrend, patient care is also shifting from hospital treatment toward the use of remote information. As these systems are fully functioning, the next step will be remote diagnostics, meaning that a patient can perform a self-diagnosis and the device provides the result immediately. All these steps are the building blocks for predictive healthcare as illustrated by Fig. 33.

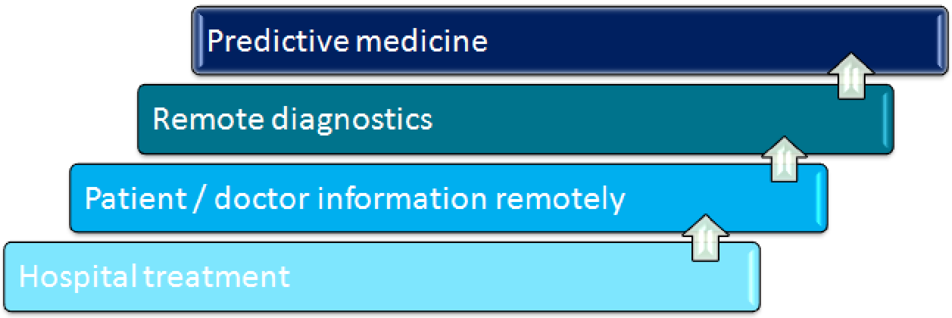

Figure 33. The path from traditional hospital treatment toward predictive medicine.

At present, surgeons and other medical personnel are the other expanding group of users that medical device manufacturers have found for their new products especially in the field of wireless data transfer. A survey made by AT&T (2010) indicated that in the USA alone in 2010, 22 % of operating surgeons used for example an iPad in their routine work daily. The survey also indicated that 4 out of 5 surgeons used smart phones or other mobile devices with a variety of medical device applications routinely. Finally, the AT&T research found that tablet sales are estimated to increase by 600% between 2010 and 2017 in hospitals alone.

The willingness to promote new methods of surgery and home healthcare is a key factor in creating growth in the medical device industry. Also, one key factor enabling the development and utilization of medical devices that is becoming more and more evident is the individual's willingness to pay, and clearly also their ability to pay for improved healthcare. There are great opportunities for medical device companies and manufacturers to satisfy these demands and future initiatives.

Meanwhile, as personal health monitoring systems become more commonplace, also the traditional open operations are shifting towards minimally invasive surgery (MIS). MIS has a high impact on patient recovery as the methods allow the surgeons to operate the patient using clearly smaller incisions, closer to the point of interest than traditionally (Davis *et al.* 2013, Grunert *et al.* 2003, Koivukangas 2012).

7.3 Technology effect on the length of hospital stay (LOS)

As covered earlier, a common indicator for the stage of technological maturity of national hospital resources is the distribution per million people of computed tomography (CT) scanners and magnetic resonance imagers (MRIs) (He *et al.* 2013, Oh *et al.* 2005). These indicators also define the performance of the healthcare systems in these nations. He (2013) and his co-workers studied the distribution of these imaging systems in China and found a strong correlation with these devices and the real GDP of each studied region. More interestingly, they also found that nearly 90 % of the imaging systems were imported from Western countries with the richest regions importing all of them. The study also indicates that the studied regions are among the 20 most well-off in China and that the current density of these systems per million people is still at roughly 30 % that of the OECD countries.

Length of hospital stay dependence on MRI and CT diffusion

A number of variables that would have been of interest for the regression analysis, had to be excluded due to insufficient data. Also, the number of countries had to be lowered from the 27 OECD countries to 10 due to the same reason. The length of stay in the hospitals was chosen as the dependent variable with the number of devices, the total health expenditure in current USD and the share of population over 65 years as the independent variables.

Table 10. Regression analyses results on the length of hospital stay.

Independent variable	Model 1	Model 2	Model 3	Model 4
	Dependent variable: Length of hospital stay (LOS)			
Constant	8,959	9,271	9,477	9,678
	<0,001	*<0,001*	*<0,001*	*<0,001*
Devices	0,109	0,131	0,143	
	<0,001	*<0,001*	*<0,001*	
THE	-0,008	-0,005		-0,012
	<0,001	*<0,001*		*<0,001*
POP	0,176		-0,205	0,534
	0,013		*<0,001*	*<0,001*
SER	4,560	4,615	4,951	5,178
R^2	0,444	0,422	0,341	0,279

*N = 4*10*22=880. P-values in Italic. Devices = Total number of CT and MRI scanners, THE = Total health expenditure in current USD, POP = Population share of over 65-year-olds.*

The constant for the LOS has a significant response (*p<0,001)* for each country. Since each nation has significant differences in the size of population and economy, further analysis was done for each selected OECD country to find the variables that best describe the effect on the LOS. These results are collected in Tables 11 and 12.

The effect of the technological status is also clearly significant in all countries except for UK and the USA. This can be explained by two main facts: Firstly, the LOS in the USA has been at a low and steady state (4 days) with the highest diffusion of medical devices since the early 1990's, explaining the little change over the analyzed time period. Secondly, the technological status of UK has had very little change within this same time period, thus explaining this insignificant change in the LOS.

Apart from these two nations, there is clearly a strong correlation between the decrease in the LOS and the increase in the number of devices (*p<0,001)* in the evaluated countries. Especially the standardized results show that the increasing use of medical technologies lowers the LOS by an average of 0.75 days annually.

Table 12 indicates the variables that have the highest significant response on the length of hospital stay. The interesting finding is that when the number of devices or the ageing of the population are found to be significant, both of these variables are both strong (*p<0,001*) and also causes for decrease (Devices) and increase (POP) in the length of stay.

Table 11. Regression results on length of hospital stay (LOS) dependence in the OECD countries.

	Assessed countries																			
	CAN		CZE		FIN		GER		HUN		JPN		NTL		NZL		UK		USA	
Independent variables																				
	Dependent variable: Length of hospital stay (LOS)																			
		Std		Std		Std		Std		Std		Std		Std		Std		Std		Std
Constant	26,469		5,340		29,084		11,814		35,71		53,914		29,636		13,168		24,379		15,039	
	0,377		*0,097*		*0,016*		*0,020*		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*0,019*	
Devices	0,117	0,35	-0,405	-0,99	-0,294	-0,81	-0,727	-1,88	-0,16	-0,22	-0,202	-0,833	0,092	0,203	-0,260	-1,01	0,238	-0,67	-0,141	-2,08
	0,077		*<0,001*		*0,087*		*<0,001*		*0,016*		*<0,001*		*0,085*		*0,012*		*0,035*		*0,040*	
THE	0,014	0,37	-0,134	-0,28	0,071	0,116	0,027	0,76	0,030	-0,19	0,013	0,167	-0,023	-0,30	0,066	0,160	0,009	0,96	0,003	1,733
	<0,001		*0,005*		*0,214*		*<0,001*		*0,002*		*0,013*		*0,009*		*0,197*		*0,005*		*0,122*	
POP	-5,374	-1,7	7,305	0,28	-11,58	-0,61	0,486	0,32	-14,74	-0,62	-0,44	-0,299	-9,222	-0,89	-3,802	-0,13	-1,446	-1,08	-0,189	-0,51
	<0,001		*0,006*		*0,552*		*0,342*		*<0,001*		*0,119*		*<0,001*		*0,709*		*0,003*		*0,363*	
SER	0,417		0,286		0,599		0,632		0,203		0,813		0,328		0,275		0,315		0,554	
R^2	0,950		0,988		0,971		0,955		0,991		0,988		0,980		0,978		0,780		0,754	

*N = 4*10*22=880. P-values in Italic. Std = Standardized result. Devices = Total number of CT and MRI scanners, THE = Total health expenditure in current USD, POP = Population share of over 65-year-olds. CAN = Canada, CZE = Czech Republic, FIN = Finland, GER = Germany, HUN = Hungary, JPN = Japan, NTL = The Netherlands, NZL = New Zealand, USA = United States of America, UK = United Kingdom.*

Table 12. Regression results on length of hospital stay (LOS) dependence in the OECD countries, excluding the least significant variables.

	Assessed countries																			
	CAN		CZE		FIN		GER		HUN		JPN		NTL		NZL		UK		USA	
Independent variables																				
	Dependent variable: Length of hospital stay (LOS)																			
		Std		Std		Std		Std		Std		Std		Std		Std		Std		Std
Constant	24,717		11,957		22,445		16,299		41,446		52,430		26,403		11,873		26,501		9,630	
	<0,001		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*<0,001*		*<0,001*	
Devices			-0,438	-1,07	-0,390	-1,07	-0,636	-1,65			-0,260	-1,07			-0,294	-1,14			-0,142	-2,10
			<0,001		*<0,001*		*<0,001*				*<0,001*				*<0,001*				*0,037*	
THE	0,018	0,50			0,059	0,097	0,030	0,852	-0,123	-0,21	0,007	0,09	-0,024	-0,31	0,065	0,157	0,007	0,689	0,002	1,26
	0,003				*0,257*		*<0,001*		*0,002*		*0,045*		*0,010*		*0,192*		*0,033*		*0,194*	
POP	-4,623	-1,4	2,321	0,088					-19,155	-0,80			-7,129	-0,70			-1,922	-1,43		
	<0,001		*0,295*						*<0,001*				*<0,001*				*<0,001*			
SER	0,415		0,347		0,589		0,631		0,233		0,848		0,348		0,269		0,348		0,553	
R^2	0,948		0,981		0,970		0,953		0,987		0,987		0,976		0,978		0,717		0,742	

*N = 4*10*22=880. P-values in Italic. Std = Standardized result. Devices = Total number of CT and MRI scanners, THE = Total health expenditure in current USD, POP = Population share of over 65-year-olds. CAN = Canada, CZE = Czech Republic, FIN = Finland, GER = Germany, HUN = Hungary, JPN = Japan, NTL = The Netherlands, NZL = New Zealand, USA = United States of America, UK = United Kingdom.*

7.4 The growing demand for medical devices

In assessing the effect of the increase of medical devices in different healthcare related initiatives, a panel analysis was performed utilizing data from the OECD countries. In the analysis, the diffusion of MRI and CT scanners was selected as the dependent variable with total health expenditure (THE), the share of 65-year-old population (POP), the trade balance (TB), the length of hospital stay (LOS) and the number of non-communicable diseases (NCD) as the independent variables. The results are presented in Table 13.

Table 13. Regression analyses results on the medical device technologies.

Independent variable	Model 1	Model 2	Model 3	Model 4	Model 5
	Dependent variable: Number of MRIs and CTs				
Constant	-27,007	5,562	-23,998	-29,455	36,648
	<0,001	0,298	<0,001	<0,001	<0,001
THE	0,064	-0,025			0,029
	<0,001	0,005			<0,001
POP	8,501	3,462		6,512	
	<0,001	<0,001		<0,001	
TB	-5,962	-6,957			-6,993
	<0,001	<0,001			0,002
LOS	2,614		3,118	2,282	
	<0,001		<0,001	<0,001	
NCD	-203,317		37,468	-103,918	
	<0,001		<0,001	<0,001	
SER	16,587	29,659	28,972	21,910	37,0659
R^2	0,834	0,458	0,478	0,704	0,145

*N = 6*10*22=1320. P-values in Italic. THE = Total health expenditure in current USD, POP = Population share of over 65-year-olds, TB = Trade balance, LOS = Length of hospital stay, NCD = Mortality due to non-communicable diseases.*

There is a strong, statistically significant (*p<0,001*) response on practically all variables and all models with the number of medical devices.

Model 1, which includes all independent variables, shows that the increase in THE, the ageing of the population (POP) and the length of hospital stay (LOS) all have a significant effect on the demand for medical devices. As expected, since the trade balance of most of the nations is relatively high and positive, this seen as a slightly reduced demand for medical devices in the assessed OECD countries. However, as discussed earlier, the demand for the devices is growing rapidly in the developing countries. Interestingly, though, the number of NCD related deaths has a negative correlation with the numbers of these devices. Thus, four more models are generated for further analysis.

Model 2 contains the indicators used in the demand pull based analysis. While being slightly less significant statistically, the results indicate that the ageing of population and trade balance are the key drivers behind the growth in the numbers of medical devices.

Model 3 uses the science push based independent variables of the length of hospital stay and mortality caused by the NCDs as the predictors for the growth of the medical device market. Evidently the growth of the medical device market correlates with the increase in both of these variables.

Model 4 contains the data that is dependent the population structure (share of over 65-year-olds, length of hospital stay and NCD based mortality) that is not directly dependent on the economy

Model 5 contains the data (total health expenditure and trade balance of medical devices) that, on the other hand, is directly related to economic indicators.

These results indicate that the increase in length of hospital stay (LOS) and the ageing of population (POP) have strong, statistically significant ($p<0,001$) effect on the demand for medical devices.

7.5 Summary of the analyses and research contribution

The regression analyses in this thesis were done for three main identified issues related to medical device technologies and their effect on the healthcare costs and on decreasing both the length of hospital stay and the number of NCD related deaths.

The first analyses dealt with deaths caused by the NCDs. The results indicate that the growing number of the over 60-year-old population has a strong correlation with the increase in the number of deaths caused by non-communicable diseases. This has also been identified by the WHO as one key initiative in the global burden of diseases.

The second set of analyses covered the effects of different independent variables on the length of hospital stay (LOS). These analyses show that the diffusion of medical devices has the highest, statistically significant effect on the LOS. The results thus indicate that as the length of hospital stay has a major impact in the overall healthcare costs, the higher diffusion of medical devices has an effect on decreasing the costs.

Finally, the third analyses were done by treating the number of medical devices as the dependent variable, against which the independent variables were tested. It was seen that an increase in the number medical devices shortened the LOS. Furthermore, these results together with those of the trade balance data analyses indicate that the demand for medical devices is in fact increasing in the developing countries.

As the regions of developing economies are experiencing high increases in GDP and populations, the increase in the distribution of the medical devices is also high, between 30 % to over 60 % annually. There is thus a strong correlation between the development of hospital treatment in the BRIC countries and the increase in exports of medical devices from the OECD countries.

Evidently these results indicate demand pull based economic growth in the field of medical device technology. The use of medical imaging is the basis for diagnosis of most of the injuries and other diseases that require hospitalization. Study of the diffusion of these imaging systems gives a basic understanding of the overall technological status of each nation and region. CT and MRI also form the basis for minimally invasive surgery and especially image guided surgery (Grunert *et al.* 2003). This demand has also been in studied by Clark *et al.* (2004) who reported that most of the costs in CVD treatment, which is a major part the NCDs, are based on the length of hospital stay (LOS).

8 DISCUSSION

Medical device technology has often been introduced as the largest cause for cost increases in healthcare. It has also often been suggested that new methods and devices are brought to the market before a real demand is in place, leading to accusations of technology determinism. However, the moment that a new method or device clearly improves the outcome of patient treatment compared to the previous method, these discussions lose their grounding. Many such treatments are common in today's hospitals, especially in the minimally invasive operations of neurosurgery, ENT and orthopedics. Furthermore, as CVDs and other NVDs are clearly increasing, and new devices and methods have been developed for treatment and remote control, there is an evident demand for continuing market growth.

8.1 Medical device technology market analysis methods

The estimation of the future growth of medical device technologies in this study is based on the comparison of the following selected indicators in the selected regions. First, an analysis of NCD related deaths indicates the demand for new technologies in preventing them and in the treatment process if such a disease has occurred. The second indicator estimates the current status of the technology in each country through diffusion of MRI and CT machines. The third indicator is the dependence of length of hospital stays with respect to MRI and CT scanners. In order to estimate the purchasing power of medical technologies, the fourth and fifth indicators contain the total health expenditures as a percent share of the GDP and the GDP data of the chosen countries.

Medical imaging technologies are considered a measure of technological advancement of hospitals and countries (He *et al.* 2013, Oh *et al.* 2005). Based on the common occurrence of emergency hospitalization, this is a justified conclusion. In any case of an impending serious situation, one of the first tasks at the hospital is to scan the patient for evidence of trauma or other disorder in the patient's anatomy. Most often the scanning is done utilizing a CT or an MR imager depending on the anatomical region of interest. These two imaging modalities are also the main methods of use in the more demanding minimally invasive surgery operations (Grunert *et al.* 2003, Koivukangas 2012).

8.2 Increasing demand for medical devices

As presented in Chapter 4, the medical device market is globally at a stage where the developed and mostly Western countries markets are becoming more and more saturated with medical devices and where the market for new devices and methods is rising relatively slowly. However, the market for new medical devices and technologies is experiencing the fastest growth in the BRIC countries, accounting for roughly 60 % of the global population.

Another driving factor in estimating the future demand of medical devices is the increase in the wealth of the population. As an example, in Finland the total savings of the ageing (61 to70-year-old) population has been increasing at a rapid pace from 15 000 € in the beginning of the 2000's to an estimated 40 000 € in 2020. When including all the other aspects (homes, stocks and other shares), the statistics show an even steeper increase in the total wealth of the ageing people (Tilastokeskus 2013). Clearly, people will have more to spend with well-being a key priority (Alkio 2012).

In the global context, the main methods for preventing and lowering the risks for CVD caused deaths include promoting healthier life styles and accessibility to better medication. However, regarding the increasing demand for medical devices, the WHO (2013b) also emphasizes the utilization of them in treating people with these diagnosed diseases. A recent report on utilizing medical technology (MTAA 2012) in Australia shows that approximately 300,000 Australians live with chronic heart failure (CHF). Furthermore, the study estimates that 30,000 people are diagnosed with CHF annually.

The statistics indicate that the treatment of CHF diagnosed people account for total costs of $5.94 billion for healthcare each year. Most of these costs are due to patient treatment in the hospitals (Clark *et al.* 2004). However, the statistics show that the most cost-effective way to treat people with pacemakers is to utilize new methods of remote monitoring technologies. These technologies enable treatment through wireless connections at home, thus lowering the hospital stay healthcare costs. Clearly, as the statistics indicate the growing trend of CVDs, the demand for cardiac pacemakers, prosthetic valves and other implantable medical devices is evident.

According to the WHO, nearly 10 % of the population globally suffers from diabetes. Furthermore, the statistics indicate that more than 80 % of the people live in the low- and middle-income countries, where diabetes related deaths are estimated to double between 2005 and 2030 (WHO 2013c). A number of diabetes related studies have been conducted globally (George *et al.* 2013, Zimmet *et al.* 2001) and also in Finland (Jarvala *et al.* 2010, Sund & Koski 2009) indicating the growth of the need for new methods for improving patient care. The willingness for healthier life styles and longer lives calls for new methods and devices for treating patients with diabetes and other illnesses.

8.3 Emerging opportunities for market growth

In this thesis, the economic growth study is based on the analysis of the trade balance of the industry. The time series for the analysis was collected from 1990 to the last fully submitted data of 2012. The analysis shows a clear difference between the exports and imports in the BRIC countries. This provides the basis for the expected demand for new medical devices in the developing countries.

The current domination of the developed countries with the USA and EU having been the driving forces of this growth is in a transition toward the new regions of evident demand. While the developed countries are mostly saturated with the high technology medical devices, the developing countries are largely in the phase of purchasing their first device especially in the rural areas (Haring 2013).

The statistics indicate an average annual growth of 5% in the developed countries while that of the developing countries is over 10 %. This transition both opens new markets for the existing manufacturers and also enables new companies to enter the highly competitive field of technology (Haring 2013). This has also caused the dominant players to open factories and development sites in the developed countries. Interesting facts about huge potential and remarkable revenue growth can be found for example in these two public companies' recent presentations for stakeholders: Siemens (2011) and GE (2012). Both of these global leaders in their specialties indicate notable increases of market especially in China over the last few years.

The second main finding in this thesis predicting medical technology market growth deals with a subject that has been noted as a challenge in the developed countries. Since the 1980's, it has been known that the ageing of population will become a challenge for healthcare in the near future. Quality of life has been a global topic since the 1970's. Reports such as the OECD report of Finland in February 2014, indicate that changes in the age structure of Finland will be a great challenge. The ageing of the population and the growth of the elderly segment however could cause a high potential for the medical device industry. As people live longer and value the possibility for home healthcare instead of elderly homes, new methods for patient follow-up are needed. As the statistics indicate, the population is ageing and also the numbers of medical device applications and home healthcare devices are increasing. The analyses in this thesis also indicate that this could be used as a positive indicator for the growth of the medical device industry.

Thirdly, the research and predictions of the WHO have triggered the discussions about global health challenges. Many of these demands can be answered by education and guidance. However, many of these challenges can also be handled by new treatment methods and medical devices. The major concerns globally are the NCDs with CVDs showing dramatic growth especially in the developing countries. Many devices that can be used in treatment and prevention of these diseases are already in the market, but with new innovations, their costs can be decreased. Also through innovation cycles new methods can also be developed. The analysis in Chapter 6 indicates that the NCDs are increasing, thus opening markets for new methods of treatment and prevention.

Finally, the expected market growth is based on the justification of the utilization of new and improved surgical devices. The average length of hospital stay brings two main causes of cost increases of healthcare. On the one hand, the longer a patient stays in the hospital, the more hospital beds and thus personnel are needed. On the other hand, the longer the patient is in the hospital, the longer the person is away from work. The presented analyses indicate that there is clear correlation between the decrease in the length of hospital stay and the technological status of the countries. Thus, the utilization by hospitals of new devices enhances each patient treatment process, reducing the healthcare costs of each individual especially through minimally invasive surgery.

Much debate has concerned especially surgeries utilizing the daVinci robot (Intuitve Surgical, Inc., Sunnyvale CA, USA). Many studies have estimated that the use of the device will increase both the length of hospital stay and the overall costs of the operations. However, the most recent study (Davis *et al.* 2013) containing over 3l 000 patients clearly shows that the costs have decreased and most importantly, the length of the hospital stay has decreased dramatically. These findings are significant since the operations were performed by the same doctors in the same clinic so the deviations of the results were minimized.

Furthermore, Donahoe and King (2012) have shown that in the USA, the medical device technology is in fact only a minor cause for the increase in healthcare costs. In the paper they report that the overall share caused by medical devices in healthcare costs is currently roughly 6 %. The Eucomed (2012) report also indicates that the overall spending on medical devices in the European Union is roughly 7,5 %.

A question raised by Martin Buxton in a conference in San Francisco in 1989: “Technology is the answer but what was the question,” can thus be answered by “The question is the demand for development of new methods and devices for improved patient treatment and healing.” As Schumpeter stated, “Scientific discovery (innovation) occurs when a physical / technological observation is made. That observation leads to an invention that applies the discovery to develop a product or service in a new and valuable way.”

The most remarkable innovations in the medical device industry have been achieved when doctors have been looking for new ways of patient treatment. The list of such innovations is long and admirable with products such as cardiac pacemakers, CT and MRI scanners, surgical navigators and most recently, remote vital signs monitoring systems. This has in turn created huge global markets.

The demand for new methods and devices is thus evident. The challenge in providing these devices to all patients in need deals with minimization of the costs. The new devices to be used in the developing countries must be of equal quality for half the price compared to that in the developed countries. However, the future initiatives also clearly call for new methods and devices, enabling the trend of medical device industry to keep up the steady economic growth. The statistics are also a great indication of the medical device industry experiencing demand pull and science push based market development.

9 CONCLUSIONS

9.1 Research contribution

The basis and interest for this thesis was the global economic situation of the high technology industry. In the traditional fields of high technology and the more recent field of ICT, there is a clear transition toward the continents with lower development costs and continents that are in the need of new technologies. This transition has hit the developed countries (i.e. Western Europe and the USA) the hardest. The most recent financial crisis fuelled the sparks for moving manufacturing and development of technologies to the less developed countries.

This report covers the current situation in the Western countries with Finland as the country of specific interest. The comparative trade balance analysis shows that while other fields of high technology industry show negative trade balances, that of the medical device industry is at a record high positive level. The statistics clearly show that Finland in particular is in need of new waves of technological growth companies. The overall trade balance, in fact, has been negative throughout recent years. Also, the most successful information and communication technology company of the first decade of the 2000's, Nokia, came to have a negative effect on the overall GDP of Finland.

Even though the other fields of technologies are clearly in transition, the statistics show that the medical device industry is in its highest growth in history. In 2012, the field grew at a pace of over 25 % in Finland and at double digits globally. At the same time new methods and technologies are entering the market both in the hospitals and in home healthcare.

In Finland, the medical device industry imports currently accounts for nearly 40 % of the total high technology markets. This is remarkable to note, as this industry is relatively compact in size and in work force in comparison to the other high technology industries.

Initial driving factors for this enormous economic growth can be explained by the science push and demand pull models. The time series analyses in this report indicate that the medical device industry could serve as a global market opening technology. The statistics show that this industry is highly affected by population growth and changes in age structure, with increasing demand for new technologies to prevent and treat illnesses, and the industry is not so greatly affected by global financial disruptions.

However, with the diverse field of medical devices, there are certain special aspects that differentiate the field from other technologies and that are the basis for continuous growth. One main differentiating factor of medical devices from other fields of technology is that often the use of these products is vital for patient survival. According to studies and research (MedTech Europe 2012), billions of patients are treated annually with medical devices. This is naturally a fact that is not dependent on the prevailing global economic situation.

9.2 Suggestions on future research

This research has concentrated on the analysis and estimations of the predicted growth of the global medical device industry with emphasis on Finland. The analyses of this research are based on available data from major public organizations and corporations of the world. Furthermore, the reporting of data of each country is the responsibility of the national correspondents. This was also noted in this research, as a number of variables and countries had to be excluded from the analyses, contributing to limitations in the available data. However, as presented in this research, clear indications that support the expectations for growth of the industry can be elucidated.

An interesting point for future research would be in evaluating country-specific differences in the medical device industry. As indicated in this research, each nation differs in the size of its economy, population and foreign trade. Thus, deeper country-specific analysis could reveal specific, more directed market dynamics.

Another point of interest could be to analyze how corporate collaboration enhances competition and even the opening of new markets for the major global companies. Recent press releases especially in the European Union show that for example BrainLab GmBH (Munich, Germany) and Royal Philips N.V. (Amsterdam, The Netherlands) have agreed to collaborate on development of intraoperative MRI, while Elekta AB (Stockholm, Sweden) has acquired the radiotherapy business unit of Royal Philips N.V. BrainLab GmBH and Karl Storz GmBH (Tuttlingen, Germany) also reported on a project in which both companies will jointly develop the worldwide market for Image Guided Surgery applications. Such massive joint ventures both strengthen the individual companies, bringing also new customers, and also assure possession of or access to key assets and technologies in the competitive global market of medical devices.

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APPENDIX 1 STATISTICS ON MORTALITIES CAUSED BY NON-COMMUNICABLE DISEASES

BRIC countries

	BRAZIL						
	NCD	THE %	GDP	POP	POP > 60	Exports	Imports
2000	9,76E+05	7,16	6,45E+05	1,71E+08	8,13	4,47E+07	3,00E+08
2001	9,99E+05	7,27	5,54E+05	1,74E+08	8,27	4,73E+07	3,83E+08
2002	1,02E+06	7,19	5,06E+05	1,76E+08	8,41	6,09E+07	3,26E+08
2003	1,04E+06	7,03	5,52E+05	1,79E+08	8,55	6,82E+07	2,50E+08
2004	1,06E+06	7,13	6,64E+05	1,81E+08	8,72	8,48E+07	3,02E+08
2005	1,09E+06	8,17	8,82E+05	1,83E+08	8,90	1,09E+08	3,85E+08
2006	1,11E+06	8,48	1,09E+06	1,86E+08	9,11	1,28E+08	5,24E+08
2007	1,13E+06	8,47	1,37E+06	1,88E+08	9,34	1,49E+08	6,93E+08
2008	1,15E+06	8,28	1,65E+06	1,90E+08	9,59	1,59E+08	8,82E+08
2009	1,17E+06	8,75	1,62E+06	1,91E+08	9,87	1,45E+08	9,07E+08
2010	1,19E+06	9,01	2,14E+06	1,93E+08	10,17	1,50E+08	1,21E+09
2011	1,21E+06	8,90	2,48E+06	1,95E+08	10,48	1,82E+08	1,36E+09

NCD = Total number of non-communicable diseases, THE % = Total health expenditure as percentage share of GDP, POP = Total population, POP > 60 = Proportion of over 60-year-old population.

	RUSSIAN FEDERATION						
	NCD	THE %	GDP	POP	POP > 60	Exports	Imports
2000	8,36E+05	5,42	2,60E+05	1,47E+08	12,00	4,09E+07	3,46E+08
2001	8,39E+05	5,67	3,07E+05	1,46E+08	13,00	1,67E+07	6,27E+08
2002	8,41E+05	5,98	3,45E+05	1,45E+08	13,00	1,77E+07	5,27E+08
2003	8,44E+05	5,61	4,30E+05	1,45E+08	13,00	3,00E+07	6,97E+08
2004	8,47E+05	5,19	5,91E+05	1,44E+08	14,00	3,73E+07	7,17E+08
2005	8,50E+05	5,21	7,64E+05	1,44E+08	14,00	4,46E+07	8,26E+08
2006	8,54E+05	5,30	9,90E+05	1,43E+08	14,00	5,11E+07	1,30E+09
2007	8,59E+05	5,38	1,30E+06	1,43E+08	14,00	5,71E+07	2,05E+09
2008	8,65E+05	5,14	1,66E+06	1,43E+08	13,00	6,33E+07	2,70E+09
2009	8,71E+05	6,17	1,22E+06	1,43E+08	13,00	4,79E+07	1,67E+09
2010	8,78E+05	6,30	1,52E+06	1,43E+08	13,00	3,98E+07	2,00E+09
2011	8,85E+05	6,06	1,90E+06	1,43E+08	13,00	4,78E+07	2,51E+09

NCD = Total number of non-communicable diseases, THE % = Total health expenditure as percentage share of GDP, POP = Total population, POP > 60 = Proportion of over 60-year-old population.

	INDIA						
	NCD	THE %	GDP	POP	POP > 60	Exports	Imports
2000	3,75E+06	4,27	4,83E+05	1,05E+09	6,87	8,30E+07	2,85E+08
2001	3,90E+06	4,50	4,98E+05	1,07E+09	6,94	1,09E+08	3,44E+08
2002	4,06E+06	4,40	5,21E+05	1,09E+09	7,01	1,38E+08	3,53E+08
2003	4,21E+06	4,29	6,09E+05	1,11E+09	7,08	1,60E+08	3,70E+08
2004	4,37E+06	4,50	7,15E+05	1,12E+09	7,15	1,70E+08	4,34E+08
2005	4,53E+06	4,25	8,37E+05	1,14E+09	7,23	2,42E+08	6,11E+08
2006	4,69E+06	4,03	9,48E+05	1,16E+09	7,31	2,95E+08	7,19E+08
2007	4,86E+06	3,88	1,21E+06	1,17E+09	7,39	2,98E+08	8,66E+08
2008	5,03E+06	3,93	1,29E+06	1,19E+09	7,48	3,59E+08	9,88E+08
2009	5,20E+06	3,93	1,34E+06	1,21E+09	7,60	3,85E+08	9,36E+08
2010	5,37E+06	3,69	1,70E+06	1,22E+09	7,74	5,15E+08	1,12E+09
2011	5,55E+06	3,92	1,92E+06	1,24E+09	7,91	5,81E+08	1,26E+09

NCD = Total number of non-communicable diseases, THE % = Total health expenditure as percentage share of GDP, POP = Total population, POP > 60 = Proportion of over 60-year-old population.

	P. R. CHINA						
	NCD	THE %	GDP	POP	POP > 60	Exports	Imports
2000	6,74E+06	4,62	1,20E+06	1,26E+09	10,04	2,90E+08	6,95E+08
2001	6,86E+06	4,58	1,32E+06	1,27E+09	10,20	3,52E+08	1,05E+09
2002	6,97E+06	4,81	1,45E+06	1,28E+09	10,36	4,30E+08	9,82E+08
2003	7,09E+06	4,85	1,64E+06	1,29E+09	10,54	5,87E+08	1,29E+09
2004	7,20E+06	4,75	1,93E+06	1,30E+09	10,73	8,49E+08	1,60E+09
2005	7,31E+06	4,68	2,26E+06	1,30E+09	10,94	1,14E+09	1,80E+09
2006	7,42E+06	4,55	2,71E+06	1,31E+09	11,18	1,50E+09	1,68E+09
2007	7,53E+06	4,35	3,49E+06	1,32E+09	11,43	1,98E+09	1,98E+09
2008	7,64E+06	4,63	4,52E+06	1,32E+09	11,73	2,63E+09	2,39E+09
2009	7,75E+06	5,15	4,99E+06	1,33E+09	12,06	2,80E+09	2,95E+09
2010	7,86E+06	4,98	5,93E+06	1,34E+09	12,46	3,40E+09	3,75E+09
2011	7,97E+06	5,15	7,32E+06	1,34E+09	12,91	4,05E+09	4,82E+09

NCD = Total number of non-communicable diseases, THE % = Total health expenditure as percentage share of GDP, POP = Total population, POP > 60 = Proportion of over 60-year-old population.

OECD Countries (Selected)

	UNITED STATES OF AMERICA						
	NCD	MRI	CT	THE	Pop > 60	Exports	Imports
2000	1608525	20	28	212197,7	16,23	9,56E+09	6,07E+09
2001	1637239	20,11	28,88	235857,3	16,26	1,08E+10	6,89E+09
2002	1665332	21	29	261297,8	16,32	1,05E+10	8,31E+09
2003	1692650	21,97	29,26	281366,7	16,41	1,16E+10	9,75E+09
2004	1721452	26,67	32,29	302704,8	16,56	1,29E+10	1,19E+10
2005	1750576	26,6	33	317892,7	16,76	1,48E+10	1,32E+10
2006	1780850	26,58	34,02	343532,7	17,03	1,67E+10	1,39E+10
2007	1811308	25,93	34,31	357260,5	17,35	1,8E+10	1,47E+10
2008	1842089	28	36	373358,1	17,72	2,07E+10	1,55E+10
2009	1871995	30	37,5	383293	18,11	2,09E+10	1,43E+10
2010	1901385	31,52	39	380280,2	18,51	2,28E+10	1,61E+10
2011	1929414	32	40,89	389280,5	18,91	2,44E+10	1,78E+10

NCD = Total number of non-communicable diseases, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE = Total health expenditure in USD, POP = Total population, POP > 60 = Proportion of over 60-year-old population. POP = total population (can be found in Appendix 2).

	FINLAND						
	NCD	MRI	CT	THE	Pop > 60	Exports	Imports
2000	29506,86	9,85	13,52	9603,4696	19,91	300115696	1,44E+08
2001	29806,73	10,99	13,69	10232,546	20,12	391425818	1,73E+08
2002	30113,47	12,5	13,27	11179,169	20,33	391735512	1,8E+08
2003	30415,53	13,04	14	11741,729	20,58	500312272	2,18E+08
2004	30736,29	13,96	14,15	12811,491	20,92	546855599	2,52E+08
2005	31076,17	14,68	14,68	13579,657	21,38	656267202	3,19E+08
2006	31435,56	15,19	14,81	14576,738	21,97	717607333	3,48E+08
2007	31802,83	15,32	16,45	15363,87	22,66	728860440	3,94E+08
2008	32184,19	15,62	18	16807,708	23,41	835801393	4,23E+08
2009	32579,89	15,73	20,42	17563,111	24,14	838346084	4,1E+08
2010	32965,61	18,65	21,07	17638,223	24,81	931725806	4,12E+08
2011	33363,58	20,23	21,34	18731,505	25,39	918749956	4,45E+08

NCD = Total number of non-communicable diseases, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE = Total health expenditure in USD, POP = Total population, POP > 60 = Proportion of over 60-year-old population. POP = total population (can be found in Appendix 2).

	GERMANY						
	NCD	MRI	CT	THE	Pop > 60	Exports	Imports
2000	468370,1	4,93	12,15	220376,9	23,3	3,91E+09	2,46E+09
2001	472707,9	5,48	12,71	231282	23,75	4,75E+09	2,79E+09
2002	477415,1	5,98	13,6	242775,2	24,16	5,48E+09	3,18E+09
2003	481362,3	6,23	14,04	255633,8	24,51	6,34E+09	3,58E+09
2004	484978,5	6,6	14,6	261161,7	24,82	7,57E+09	4,18E+09
2005	488504,8	7,09	15,41	277356,1	25,08	8,63E+09	4,64E+09
2006	491611,1	7,71	15,83	294225,9	25,3	9,9E+09	5,4E+09
2007	494612,5	8,18	16,29	306061,3	25,47	1,16E+10	6,03E+09
2008	497543,4	8,72	16,73	326249,3	25,63	1,33E+10	6,93E+09
2009	499798,3	9,47	17,24	346114,7	25,81	1,21E+10	6,76E+09
2010	502290,7	10,3	17,73	361835,8	26,05	1,27E+10	7,05E+09
2011	506243,4	10,77	18,3	379869,9	26,35	1,43E+10	8,01E+09

NCD = Total number of non-communicable diseases, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE = Total health expenditure in USD, POP = Total population, POP > 60 = Proportion of over 60-year-old population. POP = total population (can be found in Appendix 2).

	UNITED KINGDOM						
	NCD	MRI	CT	THE	Pop > 60	Exports	Imports
2000	335691,8	5,62	5,35	41400,18	20,71	1137600829	1,49E+09
2001	339623,2	6,21	6,88	41057,04	20,75	1296840594	1,81E+09
2002	343476,5	4,99	7,3	43679,35	20,79	1600000000	2,00E+09
2003	347488,5	4,55	6,92	46049,88	20,86	1964004113	2,34E+09
2004	347053,2	5,08	7,13	55245,33	20,97	1964004113	3,14E+09
2005	351920,2	5,49	7,57	64583,83	21,16	2261121764	3,84E+09
2006	356617,8	5,72	7,67	75519,14	21,41	2333866821	3,91E+09
2007	361604,7	5,6	7,6	82901,77	21,73	2154184842	4,03E+09
2008	372009,3	5,62	7,42	95603,4	22,07	2321914597	4,51E+09
2009	371791,5	5,8	8	103842,3	22,4	2286520773	4,13E+09
2010	377073	5,95	8,31	111575,5	22,68	2453431790	3,63E+09
2011	391874,1	5,91	8,92	123842,2	22,89	2739742519	3,41E+09

NCD = Total number of non-communicable diseases, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE = Total health expenditure in USD, POP = Total population, POP > 60 = Proportion of over 60-year-old population. POP = total population (can be found in Appendix 2).

	JAPAN						
	NCD	MRI	CT	THE	Pop > 60	Exports	Imports
2000	723567,9	33	90	250137	23,29	2,64E+09	2,92E+09
2001	731327,8	34	91	263622,9	23,88	2,53E+09	3,12E+09
2002	737840,7	35,32	92,62	272792,2	24,49	2,6E+09	2,98E+09
2003	744599,8	37	93	285094,6	25,1	2,93E+09	3,09E+09
2004	750693,4	38,5	94	300072,3	25,76	3,43E+09	3,56E+09
2005	756870	40,14	95	318241,7	26,5	3,63E+09	3,96E+09
2006	762582,4	41	96	333265,6	27,33	3,76E+09	4,2E+09
2007	768288,9	42	97	350927,4	28,21	4,17E+09	4,01E+09
2008	773510,9	43,1	97,27	369110,9	29,09	4,4E+09	4,75E+09
2009	778097,3	44	99	388758,7	29,92	4,04E+09	4,65E+09
2010	787148,5	45,2	100	414500,8	30,68	4,62E+09	5,78E+09
2011	791357,2	46,87	101,28	421070,6	31,35	4,82E+09	5,99E+09

NCD = Total number of non-communicable diseases, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE = Total health expenditure in USD, POP = Total population, POP > 60 = Proportion of over 60-year-old population. POP = total population (can be found in Appendix 2).

APPENDIX 2 STATISTICS ON LENGTH OF STAY

OECD Countries

	CANADA							CZECH REPUBLIC						
	LOS	MRI	CT	THE %	GDP	POP	POP>65	LOS	MRI	CT	THE %	GDP	POP	POP>65
1990	12	0,7	7,2	8,9	5,83E+11	2,78E+07	11,2	13,8	0,1	2,0	4,4	3,91E+10	1,03E+07	12,7
1991	11,1	0,8	7,1	9,6	5,98E+11	2,82E+07	11,4	13,5	0,2	2,1	4,7	2,87E+10	1,03E+07	12,9
1992	10,5	1,0	7,3	9,8	5,80E+11	2,85E+07	11,5	13,1	0,4	4,7	4,8	3,34E+10	1,03E+07	13,0
1993	10,4	1,1	7,5	9,7	5,64E+11	2,88E+07	11,7	12,7	0,6	5,7	6,4	3,93E+10	1,03E+07	13,1
1994	9,3	1,2	7,7	9,4	5,64E+11	2,91E+07	11,8	12,4	0,7	6,2	6,5	4,60E+10	1,03E+07	13,1
1995 to 1998 removed due to insufficient space!														
1999	8,2	2,2	8,5	8,9	6,61E+11	3,05E+07	12,4	10,5	1,6	9,1	6,3	6,22E+10	1,03E+07	13,7
2000	8,4	2,5	8,7	8,8	7,25E+11	3,08E+07	12,5	10,9	1,7	9,6	6,3	5,88E+10	1,03E+07	13,8
2001	8,3	4,2	9,8	9,3	7,15E+11	3,11E+07	12,7	10,1	1,9	11,4	6,4	6,44E+10	1,02E+07	13,9
2002	8,1	4,3	10,0	9,6	7,35E+11	3,14E+07	12,8	9,2	2,2	12,1	6,8	7,84E+10	1,02E+07	13,9
2003	7,8	4,7	10,3	9,8	8,66E+11	3,17E+07	12,9	8,7	2,5	12,6	7,1	9,53E+10	1,02E+07	13,9
2004	7,3	4,9	10,7	9,8	9,92E+11	3,20E+07	13,0	8,3	2,8	12,6	6,9	1,14E+11	1,02E+07	14,0
2005	6,9	5,7	11,6	9,8	1,13E+12	3,23E+07	13,1	8,0	3,1	12,3	6,9	1,30E+11	1,02E+07	14,1
2006	6,8	6,2	12,0	10,0	1,28E+12	3,26E+07	13,3	7,8	3,8	13,1	6,7	1,48E+11	1,02E+07	14,3
2007	6,4	6,7	12,7	10,0	1,42E+12	3,29E+07	13,4	7,5	4,4	12,9	6,5	1,81E+11	1,03E+07	14,5
2008	6,2	7,0	13,0	10,3	1,50E+12	3,32E+07	13,6	7,2	5,0	13,3	6,8	2,25E+11	1,04E+07	14,7
2009	6	7,9	13,8	11,4	1,34E+12	3,36E+07	13,9	7,0	5,7	14,1	8,0	1,97E+11	1,04E+07	15,0
2010	5,9	8,2	14,2	11,4	1,58E+12	3,40E+07	14,2	6,8	6,3	14,5	7,4	1,98E+11	1,05E+07	15,4
2011	5,8	8,5	14,6	11,2	1,74E+12	3,43E+07	14,5	6,4	6,9	14,8	7,5	2,16E+11	1,05E+07	15,8

LOS = Length of stay, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE % = Total health expenditure as percentage share of GDP, GDP = Gross domestic product in current USD, POP = Total population, POP > 65 = Proportion of over 65-year-old population.

	FINLAND							GERMANY						
	LOS	MRI	CT	THE %	GDP	POP	POP>65	LOS	MRI	CT	THE %	GDP	POP	POP>65
1990	19,0	1,8	9,8	7,7	1,39E+11	4,99E+06	13,4	17,0	1,0	5,7	8,3	1,71E+12	7,94E+07	15,0
1991	18,5	2,2	10,2	8,8	1,25E+11	5,01E+06	13,6	16,6	1,1	6,3	9,0	1,81E+12	8,00E+07	15,1
1992	18,0	2,4	10,5	9,0	1,10E+11	5,04E+06	13,7	16,2	1,2	6,9	9,6	2,06E+12	8,06E+07	15,2
1993	17,5	2,8	11,3	8,2	8,73E+10	5,07E+06	13,9	15,9	1,4	7,6	9,6	2,01E+12	8,12E+07	15,2
1994	17,0	3,3	11,8	7,7	1,01E+11	5,09E+06	14,1	17,9	1,8	8,2	9,8	2,15E+12	8,14E+07	15,3
1995	16,5	4,3	11,8	7,8	1,31E+11	5,11E+06	14,2	17,0	2,3	8,6	10,1	2,52E+12	8,17E+07	15,4
1996	16,0	5,7	12,5	8,0	1,28E+11	5,12E+06	14,4	15,8	2,8	9,1	10,4	2,44E+12	8,19E+07	15,5
1997	15,5	6,6	12,5	7,7	1,23E+11	5,14E+06	14,5	14,8	3,2	9,6	10,3	2,16E+12	8,20E+07	15,6
1998	15,0	8,3	12,2	7,4	1,30E+11	5,15E+06	14,6	13,8	3,7	10,6	10,3	2,18E+12	8,20E+07	15,8
1999	14,5	9,1	12,8	7,4	1,30E+11	5,17E+06	14,8	12,6	4,4	11,2	10,4	2,13E+12	8,21E+07	16,0
2000	14,0	9,9	13,5	7,2	1,22E+11	5,18E+06	14,9	10,7	4,9	12,2	10,4	1,89E+12	8,22E+07	16,3
2001	13,5	11,0	13,7	7,4	1,25E+11	5,19E+06	15,1	10,8	5,5	12,7	10,5	1,88E+12	8,23E+07	16,8
2002	13,2	12,5	13,3	7,8	1,35E+11	5,20E+06	15,3	10,2	6,0	13,6	10,7	2,01E+12	8,25E+07	17,3
2003	12,2	13,0	14,0	8,2	1,64E+11	5,21E+06	15,5	10,9	6,2	14,0	10,9	2,42E+12	8,25E+07	17,9
2004	11,6	14,0	14,2	8,2	1,89E+11	5,23E+06	15,7	10,7	6,6	14,6	10,7	2,73E+12	8,25E+07	18,4
2005	12,6	14,7	14,7	8,4	1,96E+11	5,25E+06	15,9	11,1	7,1	15,4	10,8	2,77E+12	8,25E+07	18,9
2006	10,0	15,2	14,8	8,3	2,08E+11	5,27E+06	16,1	11,2	7,7	15,8	10,6	2,90E+12	8,24E+07	19,4
2007	11,5	15,3	16,5	8,0	2,46E+11	5,29E+06	16,3	11,0	8,2	16,3	10,5	3,32E+12	8,23E+07	19,8
2008	10,2	15,6	18,0	8,3	2,72E+11	5,31E+06	16,5	10,9	8,7	16,7	10,7	3,62E+12	8,21E+07	20,2
2009	9,9	15,7	20,4	9,2	2,39E+11	5,34E+06	16,7	10,8	9,5	17,2	11,8	3,30E+12	8,19E+07	20,6
2010	8,1	18,7	21,1	9,0	2,37E+11	5,36E+06	17,1	10,6	10,3	17,7	11,5	3,30E+12	8,18E+07	20,8
2011	8,8	20,2	21,3	9,0	2,62E+11	5,39E+06	17,7	10,4	10,8	18,3	11,3	3,63E+12	8,18E+07	21,0

LOS = Length of stay, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE % = Total health expenditure as percentage share of GDP, GDP = Gross domestic product in current USD, POP = Total population, POP > 65 = Proportion of over 65-year-old population.

	HUNGARY							JAPAN						
	LOS	MRI	CT	THE %	GDP	POP	POP>65	LOS	MRI	CT	THE %	GDP	POP	POP>65
1990	14,3	0,1	1,9	7,0	3,31E+10	1,04E+07	13,5	37,0	6,1	55,2	5,8	3,10E+12	1,24E+08	11,9
1991	14,0	0,3	3,0	7,1	3,41E+10	1,04E+07	13,7	36,0	8,0	58,0	5,9	3,54E+12	1,24E+08	12,4
1992	13,7	0,3	3,1	7,6	3,80E+10	1,04E+07	13,9	34,9	10,0	60,0	6,1	3,85E+12	1,24E+08	12,9
1993	13,4	0,4	3,9	7,6	3,94E+10	1,04E+07	14,0	33,9	12,5	63,8	6,4	4,41E+12	1,25E+08	13,4
1994	13,1	0,8	4,2	8,2	4,24E+10	1,03E+07	14,2	34,4	14,0	66,2	6,7	4,85E+12	1,25E+08	13,9
1995	12,8	1,0	4,6	7,3	4,56E+10	1,03E+07	14,3	33,2	16,0	69,0	6,8	5,33E+12	1,25E+08	14,4
1996	12,5	1,4	5,0	7,1	4,59E+10	1,03E+07	14,5	32,7	18,8	74,7	7,0	4,71E+12	1,26E+08	14,9
1997	12,2	1,4	4,6	6,8	4,65E+10	1,03E+07	14,6	31,4	20,0	76,2	6,9	4,32E+12	1,26E+08	15,5
1998	11,9	1,5	5,0	7,2	4,80E+10	1,03E+07	14,8	29,3	21,0	79,3	7,2	3,91E+12	1,26E+08	16,1
1999	11,6	1,5	5,1	7,3	4,83E+10	1,02E+07	15,0	27,2	23,2	84,4	7,4	4,43E+12	1,27E+08	16,6
2000	11,3	1,8	5,7	7,2	4,64E+10	1,02E+07	15,1	24,8	26,0	88,0	7,6	4,73E+12	1,27E+08	17,2
2001	11,0	2,0	6,0	7,2	5,27E+10	1,02E+07	15,3	23,5	30,0	90,0	7,8	4,16E+12	1,27E+08	17,7
2002	10,7	2,3	6,3	7,6	6,64E+10	1,02E+07	15,4	22,2	35,3	92,6	7,9	3,98E+12	1,27E+08	18,2
2003	10,4	2,6	6,5	8,6	8,35E+10	1,01E+07	15,5	20,7	37,0	93,0	8,0	4,30E+12	1,28E+08	18,8
2004	10,5	2,6	6,8	8,2	1,02E+11	1,01E+07	15,6	20,3	39,0	94,0	8,0	4,66E+12	1,28E+08	19,3
2005	10,0	2,6	7,1	8,4	1,10E+11	1,01E+07	15,7	19,8	40,1	95,0	8,2	4,57E+12	1,28E+08	19,8
2006	9,1	2,6	7,3	8,3	1,13E+11	1,01E+07	15,9	19,2	41,0	96,0	8,2	4,36E+12	1,28E+08	20,4
2007	8,7	2,8	7,3	7,7	1,36E+11	1,01E+07	16,1	19,0	42,0	97,0	8,2	4,36E+12	1,28E+08	21,0
2008	8,9	2,8	7,1	7,5	1,54E+11	1,00E+07	16,3	18,8	43,1	97,3	8,6	4,85E+12	1,28E+08	21,6
2009	8,6	2,8	7,2	7,7	1,27E+11	1,00E+07	16,5	18,5	44,0	99,0	9,5	5,04E+12	1,28E+08	22,3
2010	8,2	3,0	7,3	8,0	1,28E+11	1,00E+07	16,7	18,2	45,0	100,0	9,6	5,50E+12	1,27E+08	23,0
2011	8,4	3,0	7,3	7,9	1,37E+11	9,97E+06	16,9	17,9	46,9	101,3	9,6	5,90E+12	1,28E+08	23,7

LOS = Length of stay, MRI = Distribution of MRIs per million population, CT = Distribution of MRIs per million population, THE % = Total health expenditure as percentage share of GDP, GDP = Gross domestic product in current USD, POP = Total population, POP > 65 = Proportion of over 65-year-old population.

	THE NETHERLANDS							NEW ZEALAND						
	LOS	MRI	CT	THE %	GDP	POP	POP>65	LOS	MRI	CT	THE %	GDP	POP	POP>65
1990	12,7	0,9	7,3	8,0	2,95E+11	1,50E+07	12,8	10,7	1,0	3,5	6,8	4,50E+10	3,33E+06	11,1
1991	12,4	1,3	7,3	8,2	3,03E+11	1,51E+07	12,9	10,5	1,1	4,0	7,3	4,23E+10	3,50E+06	11,2
1992	12,1	1,8	7,2	8,4	3,36E+11	1,52E+07	13,0	10,3	1,5	4,5	7,4	4,12E+10	3,53E+06	11,3
1993	11,7	2,5	9,0	8,5	3,27E+11	1,53E+07	13,0	10,0	2,0	5,5	7,1	4,63E+10	3,57E+06	11,4
1994	11,4	3,0	9,0	8,3	3,51E+11	1,54E+07	13,1	9,7	2,2	6,5	7,1	5,48E+10	3,62E+06	11,5
1995	10,9	3,9	9,0	8,3	4,19E+11	1,55E+07	13,2	9,5	2,5	7,0	7,1	6,33E+10	3,67E+06	11,5
1996	10,8	4,0	8,0	8,2	4,18E+11	1,55E+07	13,2	9,4	2,7	7,5	7,0	6,94E+10	3,73E+06	11,6
1997	10,8	4,5	8,0	7,9	3,87E+11	1,56E+07	13,3	9,2	2,6	9,0	7,2	6,54E+10	3,78E+06	11,6
1998	10,3	5,0	8,0	8,1	4,03E+11	1,57E+07	13,4	9,1	2,6	8,9	7,7	5,56E+10	3,82E+06	11,7
1999	10,1	5,5	8,0	8,1	4,11E+11	1,58E+07	13,5	8,7	2,7	8,9	7,5	5,81E+10	3,84E+06	11,7
2000	10,1	6,0	8,0	8,0	3,85E+11	1,59E+07	13,6	8,5	3,0	8,8	7,6	5,20E+10	3,86E+06	11,8
2001	9,9	6,0	8,0	8,3	4,01E+11	1,60E+07	13,6	8,2	3,2	10,6	7,7	5,33E+10	3,88E+06	11,8
2002	9,5	6,1	7,0	8,9	4,38E+11	1,61E+07	13,7	7,8	3,5	11,1	8,0	6,60E+10	3,95E+06	11,8
2003	9,2	6,1	7,0	9,8	5,38E+11	1,62E+07	13,8	7,5	3,7	11,4	7,9	8,74E+10	4,03E+06	11,9
2004	8,6	6,2	7,1	10,0	6,10E+11	1,63E+07	13,9	7,0	5,0	12,0	8,0	1,03E+11	4,09E+06	11,9
2005	8,0	6,6	8,2	10,9	6,38E+11	1,63E+07	14,0	6,8	6,0	12,0	8,4	1,14E+11	4,13E+06	12,0
2006	7,6	7,8	8,4	10,7	6,78E+11	1,63E+07	14,2	6,6	7,0	12,0	8,8	1,10E+11	4,18E+06	12,1
2007	7,1	7,6	7,8	10,8	7,83E+11	1,64E+07	14,4	6,3	8,8	12,3	8,5	1,35E+11	4,23E+06	12,3
2008	6,7	10,4	10,2	11,0	8,71E+11	1,64E+07	14,7	6,1	9,6	12,4	9,3	1,31E+11	4,27E+06	12,5
2009	6,5	11,0	11,3	11,9	7,96E+11	1,65E+07	15,0	5,8	9,7	14,6	10,0	1,19E+11	4,32E+06	12,7
2010	6,2	12,2	12,3	12,1	7,77E+11	1,66E+07	15,4	5,6	10,5	15,6	10,2	1,43E+11	4,37E+06	13,0
2011	5,8	12,9	12,5	11,9	8,33E+11	1,67E+07	15,9	5,3	11,1	15,4	10,3	1,63E+11	4,41E+06	13,3

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	UNITED KINGDOM							UNITED STATES OF AMERICA						
	LOS	MRI	CT	THE %	GDP	POP	POP>65	LOS	MRI	CT	THE %	GDP	POP	POP>65
1990	9,9	5,0	4,0	5,8	1,02E+12	5,72E+07	15,7	8,4	10,0	15,3	12,4	5,98E+12	2,50E+08	12,5
1991	9,8	5,0	4,3	6,3	1,07E+12	5,74E+07	15,8	8,1	10,5	16,5	13,1	6,17E+12	2,53E+08	12,5
1992	9,7	5,0	4,5	6,7	1,11E+12	5,76E+07	15,8	8,1	11,0	17,7	13,4	6,54E+12	2,57E+08	12,6
1993	9,7	5,0	4,7	6,7	9,97E+11	5,77E+07	15,8	7,4	11,5	18,8	13,7	6,88E+12	2,60E+08	12,6
1994	9,6	5,0	4,9	6,8	1,08E+12	5,79E+07	15,8	7,1	12,0	20,0	13,6	7,31E+12	2,63E+08	12,6
1995	9,5	5,0	5,1	6,8	1,18E+12	5,80E+07	15,8	6,6	12,3	21,1	13,7	7,66E+12	2,66E+08	12,6
1996	9,4	5,0	5,4	6,8	1,24E+12	5,82E+07	15,8	6,3	13,0	22,3	13,7	8,10E+12	2,69E+08	12,6
1997	9,4	5,0	5,6	6,6	1,38E+12	5,83E+07	15,8	6,0	13,5	24,1	13,6	8,61E+12	2,73E+08	12,5
1998	9,3	5,0	5,8	6,6	1,48E+12	5,85E+07	15,8	5,9	14,0	24,5	13,6	9,09E+12	2,76E+08	12,5
1999	9,2	5,0	6,0	6,9	1,52E+12	5,87E+07	15,8	5,6	15,4	25,1	13,6	9,67E+12	2,79E+08	12,4
2000	8,2	5,6	5,4	7,0	1,49E+12	5,89E+07	15,8	5,7	18,0	27,0	13,7	1,03E+13	2,82E+08	12,4
2001	8,6	6,2	6,9	7,3	1,49E+12	5,91E+07	15,8	5,8	20,1	28,9	14,3	1,06E+13	2,85E+08	12,3
2002	9,1	5,0	7,3	7,6	1,62E+12	5,94E+07	15,8	5,6	20,5	29,0	15,2	1,10E+13	2,88E+08	12,3
2003	9,3	4,6	6,9	7,8	1,88E+12	5,96E+07	15,9	5,5	22,0	29,3	15,7	1,15E+13	2,90E+08	12,3
2004	9,4	5,1	7,1	8,0	2,22E+12	6,00E+07	15,9	5,8	26,7	32,3	15,8	1,23E+13	2,93E+08	12,3
2005	9,1	5,5	7,6	8,3	2,32E+12	6,04E+07	16,0	5,5	26,7	33,0	15,8	1,31E+13	2,96E+08	12,3
2006	9,6	5,7	7,7	8,4	2,48E+12	6,08E+07	16,0	5,4	26,6	34,0	15,9	1,39E+13	2,98E+08	12,4
2007	9,0	5,2	7,5	8,5	2,86E+12	6,13E+07	16,1	5,1	26,9	34,3	16,2	1,45E+13	3,01E+08	12,5
2008	8,8	5,6	7,4	9,0	2,69E+12	6,18E+07	16,2	5,3	28,0	36,0	16,6	1,47E+13	3,04E+08	12,7
2009	8,4	5,8	8,0	9,9	2,21E+12	6,22E+07	16,4	5,0	30,0	37,0	17,7	1,44E+13	3,07E+08	12,8
2010	7,8	6,0	8,3	9,6	2,29E+12	6,27E+07	16,6	5,4	31,5	38,0	17,7	1,50E+13	3,09E+08	13,1
2011	7,7	5,9	8,9	9,4	2,48E+12	6,33E+07	16,9	5,2	33,0	40,9	17,7	1,55E+13	3,12E+08	13,3

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