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Determining the Attractiveness of the Norwegian Health Tech Cluster

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Determining the Attractiveness of the Norwegian Health Tech Cluster

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This Master thesis is written in fulfillment of the requirements for the Master of Science degree in Business with a major in Strategy at BI Norwegian Business School.

For the past two years we have been through an incredible academic and social journey, with the adaptation of new knowledge and new acquaintances. In particular, working with this thesis has been both interesting and has provided us with the needed experience to get a *good* start in the field of consulting. Further, the process has been highly influenced by Covid-19 and has pushed us to find innovative ways of working together as a team.

We are most grateful for all the guidance and support provided by our supervisor, Torger Reve, throughout this thesis process. We appreciate his contributions and constructive feedback, and his enthusiastic engagement both on and off topic. Also, without Reve as our supervisor, we would not have had the chance to write about this topic, and to this extent.

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Thank you!

Sincerely,

Laura Laukeland Kleiven

Khorist Kustani

Abstract

With the rising societal challenges we are facing, health tech is getting an increasingly central role in *battling* them. Yet, the industry remains as unknown for many. The strengthened centrality has led to an establishment of several national and international health tech clusters, among them in Norway.

The purpose of the following study has been to investigate how the Norwegian health tech cluster scores on the various dimensions presented in *The Emerald Model*. The findings have been derived with the intention to compare them to the 2011 study by Amir Sasson, to determine *whether*, and *how*, the cluster has evolved in relation to the state presented by Sasson.

Through the use of in-depth quantitative data, the analysis revealed that the Norwegian health tech cluster has positively developed on several dimensions of *The Emerald Model*. In particular, the findings revealed that the cluster has improved significantly on cluster attractiveness and knowledge dynamics. The development in cluster attractiveness is mainly due to the strengthened value creation of the firms in the cluster, as well as the regional proximity of their location. Knowledge dynamics has been positively affected by the activities and initiatives that the cluster organization, Norway Health Tech has initiated over the last decade. However, the cluster is yet to transition from emerged to developed, mainly as a result of two strong challenges: The structural barriers connected to the lack of a national market for health tech products and services, and the absence of competent owners and private capital. Specific recommendations directed towards the cluster firms and the public institutions have been presented to somewhat *help* overcome the challenges.

The related strengths and limitations of the study are thoroughly discussed, in addition to presenting possible areas to further investigate in potential future studies.

Keywords: *Cluster, cluster attractiveness, diagnostic, global knowledge hubs, health tech, health ICT, medtech, specialized subcontractors, The Emerald Model*

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Abbreviations and Definitions

BEUR	Billion Euros
BNOK	Billion Norwegian krone
ed.	Edition
e.g.	Exempli gratia
et al.	Et alia
GDP	Gross domestic product
Health tech	Health technology
ICT	Information and communications technology
i.e.	Id est
Medtech	Medical technology
MEUR	Million Euros
MNOK	Million Norwegian krone
NOK	Norwegian krone
OECD	Organization for Economic Co-operation and Development
Productivity	Value creation per employee
SME	Small and medium enterprises
Value creation	EBITDA + salary costs

1. Introduction

1.1 Background and Context

Health tech as an industry and concept is still young, yet among the world's fastest growing. The fast growth is partially a result of the demographic change the OECD countries, including Norway, are experiencing, characterized by an aging population and an exponential increase in the expectations towards healthcare (Jakobsen, Lind, Engebretsen & Skogli, 2019). The increased demand in healthcare has led to a boom in employment in the industry, as well as in the public healthcare expenditures.

Figure 1 describes the health expenditures as percentage of Norway's GDP (mainland, right axis), as well as the health expenditure per capita (NOK, left axis). From 2008 to 2018 health expenditure per capita increased with more than 55% from NOK 43 527 to 67 770. This trend is likely to continue with an increasing importance of the industry. The Norwegian Government highlights the health industry, with health tech as a key area, for increased revenues and a higher value creation in Norway for the coming years (Regjeringen, 2019a).

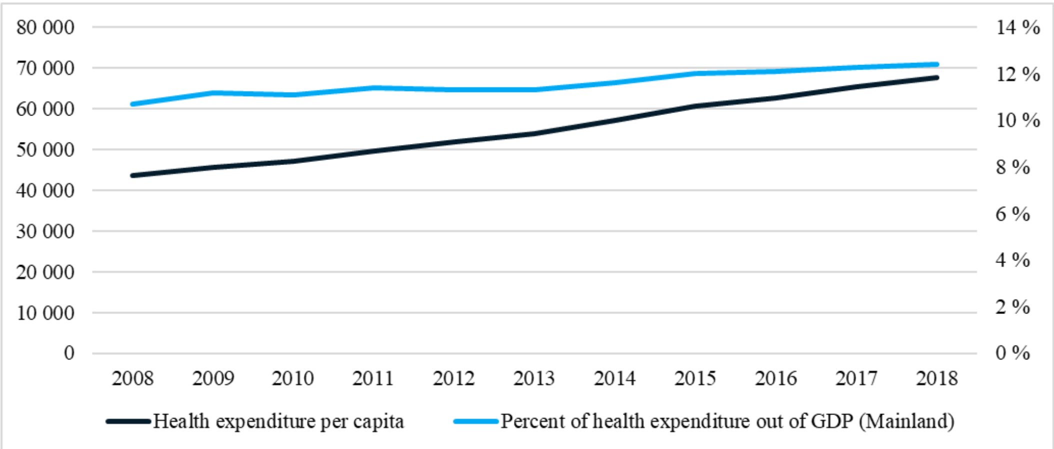

Figure 1 Health expenditure (2008-2018)

Source: SSB

The rapid growth has led to a high degree of competition and innovation within the field of health tech. This is supported by data presented by The European Patent Office, showing that the health tech industry was on top at filing patents in 2016 (Lehesranta, 2017). Further, The World Health Organization is stressing the importance of health tech firms by calling for innovative technologies to address global health concerns and improve the quality of life (WHO, 2010).

In turn, there has been a global emergence of health tech/medtech clusters, where several *world-class* clusters are located in European countries, primarily France, Germany, Ireland, Italy, Switzerland and the UK (Klein, Banga & Martelli, 2017). Further, the Norwegian market has its own health tech cluster with the cluster organization, Norway Health Tech.

With the establishment of IKT Grenland, MedITNor and the Oslo Cancer Cluster in the early 2000s, followed by Oslo Medtech and Trondheim Helseklynge in 2009, the Norwegian health sector experienced its first great advancements regarding cluster formation (Grünfield & Iversen, 2012). In recent years, Oslo Medtech became the most influential driver of this industry in Norway, later renamed to Norway Health Tech. Today, the cluster organization assists health tech firms through expansion of their network both nationally and internationally and has more than 280 firms in their member base that cover the entire health ecosystem (Norway Health Tech, n.d.a). The cluster organization is growing at a great pace, with a 91% growth rate in value creation over the past 10 years, and with 54 new cluster members in 2018 alone (Norway Health Tech, 2018a). Furthermore, over the period of 2008 to 2018 there has been a strong growth in web and physical paper-publications on topics related to health tech, more specifically a growth of more than 77% (See *Exhibit 1 – Media Analysis* in Appendix for exhaustive list of health tech-related words and topics).

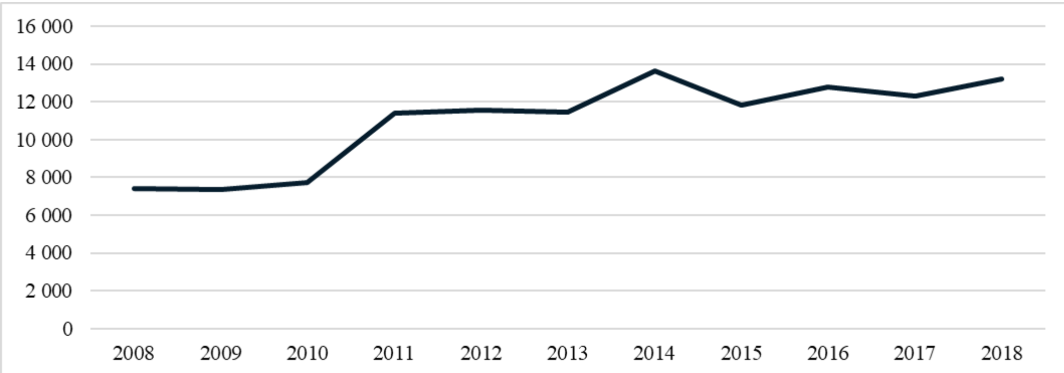

Figure 2 Web and paper publications with health tech-related words (2008-2018)

Source: Atekst and thesis analysis[1]

Since 2016, Menon Economics (hereafter Menon) has annually published a report with an intensive analysis on the Norwegian health industry. The 2019 report

[1] Figures and tables with "thesis analysis" in the source, represent models that are a result of analysis conducted by the authors of this study, in order to reduce potential confusions.

indicates that the industry is growing at a pace greater than the average industry growth in Norway, and this trend is claimed to persist (Jakobsen et al., 2019). Further, the report suggests that the Norwegian health industry can grow to become a key industry in Norway, as the global opportunities for health industries are expanding. Menon aims to provide a consistent message on how to achieve the profit realization and suggests that the value lies in adopting new products and solutions (Myhre, 2018). Yet, Norway is struggling to achieve these gains. Kathrine Myhre, the CEO of Norway Health Tech, highlights the public procurement policies as one of the most important challenges hampering profit realization and in turn the overall growth in the health industry. Myhre claims that the structure in these policies prevents the introduction of new products, services, and most importantly, technologies (Myhre, 2018). Menon supports this claim and suggests that the government should professionalize and modernize the health sector by allowing for more innovation in its procurement. They further claim that by professionalizing the public procurement process, the health sector can obtain savings amounting to 10-15% (Jakobsen et al., 2019).

1.2 Why Study the Norwegian Health Tech Cluster?

There are primarily two reasons for why the Norwegian health tech cluster is chosen as research area for this thesis:

First, as highlighted in Chapter 1.1, the health industry and its importance has boosted over the years and the importance is expected to grow further in the coming. Additionally, the interest towards the industry, and the products and services it offers, has increased in accordance to the societal challenges we are facing, with the Covid-19 pandemic being the most recent. This would in turn indicate the possibilities for a health cluster, as the Norwegian health tech cluster, to get a stronger foothold parallel to the industry growth.

Secondly, in 2011, Amir Sasson, a Provost at the Department of Strategy and Entrepreneurship at BI Norwegian Business School, conducted a comprehensive analysis of the Norwegian health industry. The findings were published in the research report, *Knowledge Based Health*, where the aim of the study was to assess the properties of a *global knowledge hub* and to determine whether the Norwegian health industry constitutes such a hub. The study was further published as a part of a larger study on several Norwegian industries, by Torger Reve and Amir Sasson in *Et Kunnskapsbasert Norge* (2012).

The report indicated that the Norwegian health industry and the health tech cluster had a great potential in a *demanding* and *challenging market.* Yet, it had not reached its full potential, resulting in a set of strategic recommendations directed towards firms in the industry, as well as specific public policy recommendations (Sasson, 2011).

Since the study of Sasson (2011), *major* industry changes have occurred. For instance, the cluster organization changed its name from Oslo MedTech to Norway Health Tech in 2017, marking a transition from a regional to a national cluster (Otmani, 2017). In that manner, we find it interesting to conduct a similar study to the one of Sasson (2011), and to examine the current state of the Norwegian health tech cluster. How did the cluster react to an empirical study? How far has the cluster developed since the 2011 study, and what challenges is it currently facing?

1.3 Contribution, Purpose and Research Question

In this study we seek to examine the attractiveness of the Norwegian health tech cluster based on its developments over the last eight years. By analyzing several aspects of the health tech industry itself, in addition to market characteristics in education, R&D and other relevant areas, we aim to determine the clusters current state compared to the state presented by Sasson (2011). Thus, we have derived the following research question that this study aims to investigate:

RQ: "*Has the Norwegian health tech cluster improved over the period of 2010-2018?"*

To address the presented research question, we draw on theory related to the determinants of a nations competitiveness as developed by the pioneer Michael E. Porter (1990). Further, we seek to ensure that this study is comparative to the one presented in *Knowledge Based Health* (Sasson, 2011), as the theoretical framework, as well as the analysis, will be based on the theory on cluster attractiveness and competitiveness as presented by Reve and Sasson (2012). The theory, and this research paper, have their base on three simple premises: For industries to be sustainable and competitive in a high-cost region like Norway, the industries have to compete globally, be knowledge-based and environmentally robust (Sasson, 2011).

Our current hypothesis is that the Norwegian health tech cluster has improved and strengthened considerably since 2010. This is drawn from the fact that the cluster organization, Norway Health Tech, has expanded and consolidated its innovation ecosystem to become a better facilitator for its members. We further believe that the cluster scores higher on *some* attractiveness dimensions, as presented in *The Emerald Model* (Reve & Sasson, 2012). Yet, the cluster is facing serious structural barriers in its Norwegian market, that may pose a great negative impact on its opportunities both on a national- and international level.

2. Theoretical Framework

2.1 The Determinants of a Nations Competitiveness

Why do some nations achieve global, cross-national success in specific industries? Why do some nations triumph internationally while some don't? What differentiates the competitiveness of one nation relative to another? Competitiveness has become one of the greatest areas of concern and interest for firms, industries and nations in general. Hence, the listed questions have been among the most frequently asked questions and investigated areas for several scholars. Among the scholars with the greatest influence on literature and theory on the competitiveness of nations, we find Michael E. Porter. Porter is known to have influenced several aspects of economic theories, notably on the topic of competitive advantages. Of special interest is his historic book from 1990, *The Competitive Advantages of Nations.*

Porter claims that the answer to why some nations succeed internationally lies in four characteristics of the nation that frames the competitive landscape for the firms, in which they aspire to create competitive advantages (Porter, 1990). The four attributes Porter introduces are:

1. *Factor conditions.* The presence of resources within the nation. E.g. Natural resources (such as oil) or human-made resources (such as infrastructure).
2. *Demand conditions.* The domestic demand for the products and services.
3. *Related and supporting industries.* The domestic presence of supplementary industries with international presence.
4. *Competitive conditions.* Related to *Porter's Five Forces*. The factors in which firms are created and managed. The use of factors that lead to a competitive advantage.

This model is often referred to as *Porter's Diamond*, or *The Diamond Model* due to its visualization (Figure 3).

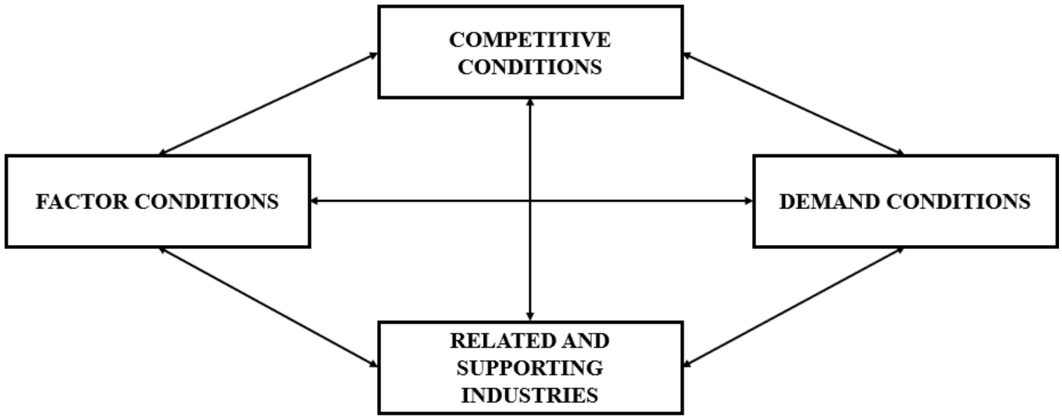

Figure 3 The Diamond Model: The Determinants of National Advantage
Source: The Competitive Advantages of Nations, 1990

To finalize the model presented by Porter (1990), two additional variables can be added to completely assess the national system, namely government and chance. The role of the government is visual through the policies' influence on each of the four characteristics of the model. Governments stimulate the competitive landscape of regions and nations through actions such as public purchase, regulations and policies. Chance events are incidents that create discontinuities and somewhat affect the industry structure and provide opportunities for a nation's firms. This can for example be shifts in foreign market demand, wars, and breakthrough in technologies (Porter, 1990).

Today, *The Diamond Model* works as a fundamental tool for strategic analysis of nations and regions, in addition to specific industries within it (Reve & Sasson, 2012). The essence lies in the interdependence between the four factors of the model, as well as the individual influence of each factor on the ability of firms within a given nation to attain advantages in a specific industry. The density and strength in the interconnections between the factors define a strong industry.

The industry works as the unit of analysis when examining and understanding the national advantage. However, the *success* of nations does not lie in the isolation of industries, but rather through the horizontal and vertical connections between them in *clusters* (Porter, 1990).

2.2 Understanding Industry Clusters

The traditional way of understanding industries has historically been to examine each firm individually. Firms, who are the micro unit of an economy, are often perceived as product producing units, converting raw materials to specific products through input-output-models (Reve & Sasson, 2012). A new industry perspective emerged with Thompson (1967) and Pfeffer and Salancik (1978), two of the most influential books on organizations, analyzing firms from the perspective of their environment, and their interdependence with it. Further, Scott (1981) analyzed firms as open systems, contradicting the previous definitions of seeing firms as closed systems separated from their environment. According to Scott, firms must be defined as open as they are dependent on flows of information, resources and personnel.

Previously, scholars begun analyzing firms' external stakeholders as some sort of coalition, and thus understanding the interaction between organizations, suppliers, customers, R&D institutions and governments in a new way (Reve & Sasson, 2012). This is further analyzed through the business analysis model, *Porter's Five Forces*, that was first introduced in the famous book, *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. This model introduces five non-neglectable forces that are present and shape *every* industry and market, and that are frequently used to assess the attractiveness, profitability and competition intensity of an industry (Porter, 1980).

The breakthrough from a business development perspective came with the introduction of *industry clusters* (Porter, 1990). Clusters are groups of firms, organizations and institutions that are somehow similar and interconnected through buyer-seller relationships, common technologies, markets and workforce needs in a defined geographic area. The firms within the clusters attain competitive advantages through the proximity to the competing firms, the suppliers, the skilled workforce and the shared basis of industry specific knowledge (Harvard Business School, n.d.). Clusters, also known as entrepreneurial ecosystems, combine social, cultural, economic and political attributes within a given region that encourage and enable the development of innovation startups and entrepreneurship (Spigel, 2015).

The theoretical breakthrough on the understanding of clusters came with the Nobel-Prize winning economist, Paul Krugman (1991). The theory highlights the positive knowledge externalities within a cluster which are creating benefits through the proximity of competing firms. Still, Michael Porter remains as the scholar with the greatest impact and importance on the concept. His studies have led to a substantial number of studies and initiatives globally within the field.

The clusters underline that a firm's competitiveness is a function of more than just the specific characteristics of the firm itself. The environment of the firm is a central aspect within the theory, which strengthens the importance of localization. Firms wish to be located in areas that are promoting R&D and innovation and gives access to capital and knowledge. This is particularly visible within knowledge-intensive industries as bio- and medtech (Reve & Sasson, 2012).

Within advanced economies, the *most* attractive clusters continuously become more global and knowledge based. These clusters grow to become *superclusters* with such an attractiveness that most key firms within the industry wish and need to be localized there. These clusters work as global knowledge hubs that contain the most advanced knowledge firms, competent owners and best R&D environments (Reve & Sasson, 2012). In these clusters, the concentration of industry-specific competence and competent ownership is so great that there is a rapid emergence of sectors within the industry and global knowledge hubs. Sasson (2011) argues that knowledge-based industrial development occurs in these hubs, which are characterized by a great proximity of innovative actors with close interaction with advanced R&D institutions, venture capitalists and competent owners.

2.3 Determining the Attractiveness of a Cluster

To assess whether an industry can be defined as a global knowledge hub, Reve and Sasson (2012) introduce a model that determines whether the cluster satisfies the ownership- and knowledge-related attractiveness, and whether it has a sufficient *knowledge dynamics*. For industries to be competitive, the authors conceptualize cluster attractiveness along the following six dimensions:

1. *Cluster attractiveness:* Can the industry be defined as a cluster – does it have a *sufficient* number of firms in order to do so? The dimension can be measured on industry size (e.g. employment, value creation, number of firms), depth and width, as well as on the degree of internationalization.

2. *Educational attractiveness:* Is there a presence of *relevant* study programs and educational courses that can provide the cluster with a specialized work force?

3. *Talent attractiveness:* How *good* is the cluster at attracting and capturing the best and most qualified workforce in the region, nationally and globally. A growing and knowledge-attractive cluster is expected to capture an increasing share of the high-qualified workers.

4. *R&D&I attractiveness:* The degree of research, development and innovation within the cluster relative to its size. A common way to measure this is through the study of patents, introduction of new products and services, and expenditure on R&D and innovation.

5. *Ownership attractiveness:* Attractiveness of the cluster from an economic perspective. Value creation occurs when knowledge (R&D and education) is effectively connected to competent ownership. Constitutes of government and private investment/ownership.

6. *Environmental attractiveness:* Is connected to the clusters ability to meet future sustainable solutions and environmental demands. Measured on a span of dimensions, e.g. the use of renewable energy, green housing, investment in sustainable R&D and efficient production processes.

Reve and Sasson further introduce *knowledge dynamics*, also referred to as *cluster dynamics,* as a last dimension which can be measured by outlining the connections between nodes within the cluster, as well as with related clusters and industries. They claim that *the industry dynamics usually lies in the intersect between related clusters.* The effects of the six-dimensional surface of the model on economic performance is moderated by the degree of knowledge dynamics (Sasson, 2011).

Together, the six determinants and the knowledge dynamics represent an explanatory model of the attractiveness of localities, which a government can affect through industrial policies. Further, the model is used to determine the sources of competitiveness for a cluster (Akpinar, Can & Mermercioglu, 2017). Figure 4 shows a visualization of *The Emerald Model* as introduced by Reve and Sasson. The model is two-dimensional where the 6 determinants make up the ground dimension, while knowledge dynamics represents the second dimension which gives the model its characteristic height.

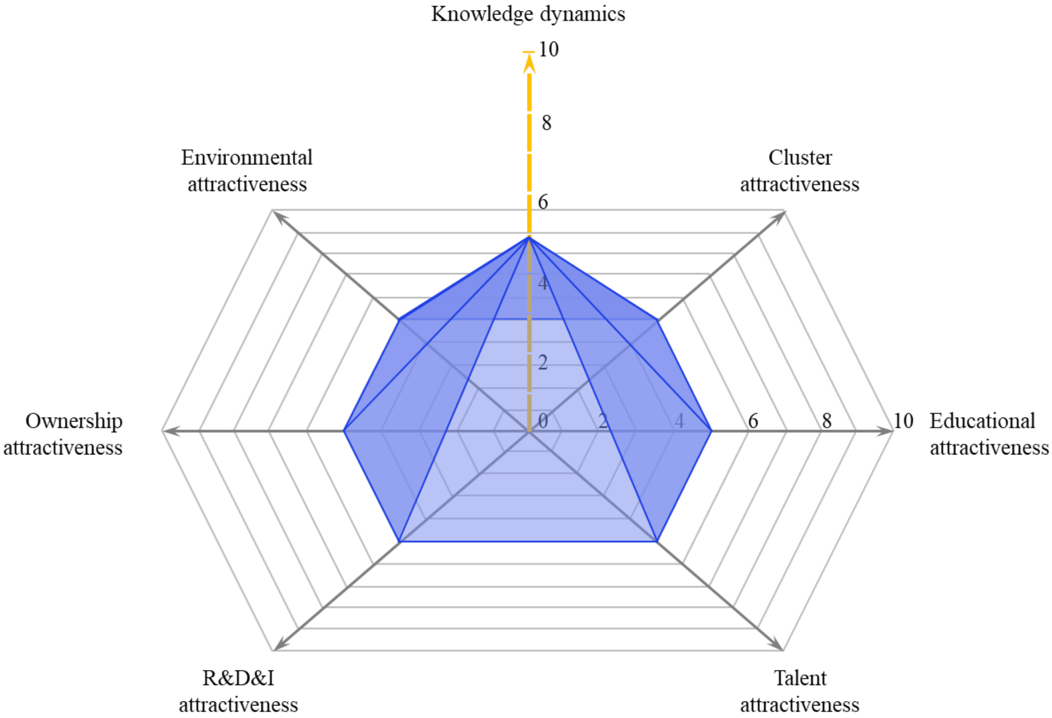

Figure 4 The Emerald Model

Source: Et Kunnskapsbasert Norge, 2012

3. Methodology

The aim of this chapter is to describe the method that has been applied in order to answer the research question of the thesis. The purpose of the study is to examine the development of the Norwegian health tech cluster from 2010-2018 and assess the industry's current attractiveness. As an important part of the analysis is to provide a reasonable comparison between this study`s findings and the findings of Sasson (2011), the chosen research design and data collection is inspired with that applied by Sasson.

3.1 Introduction

The health tech industry is a complex industry in which many variables affect its competitiveness and current value creation. A study on the attractiveness and competitiveness of this industry therefore requires an assessment of a multitude of variables which can be assessed using various research designs. Initial workshops have been conducted with Myhre and Reve in order to obtain knowledge regarding the industry, the cluster and for framing the chosen research question. These have proved invaluable for being able to define and derive an approach for the chosen methodology of the study. As made clear from the research question, the current attractiveness of this industry will be analyzed in the context of the developments the industry has faced over time. The availability of data measuring the industry's attractiveness and competitiveness over the time period of 2010-2018 enables an empirical study which provides the opportunity to analyze this development. This has led the study towards a quantitative approach in which quantifiable and measurable data have been collected and analyzed in order to provide valid conclusions.

3.2 Data Collection

Quantitative data collection

In this study, the Norwegian health tech cluster is defined as all private and public firms, in all steps of the value chain, including the support functions. These firms work with development and production of all health products, services and technologies. As this study is evaluating the health tech industry, the population does not include data on the treatment-, service- and pharmaceutical side of health. Further, we have in alignment with Menon broken the industry into four subgroups that cover the industry, namely Medtech, Health ICT, Diagnostic and Specialized subcontractors. The data is provided by Menon and includes firm-specific data for 922 firms. Table 1 presents a description of the population that represents the industry by illustrating the number of firms and employees in the respective subgroups, with firm examples.

Subgroup	Description	# Firms	# Employees	Examples
Medtech	All medical-technical products used to prevent and treat injuries and diseases	515	3 172	Meditronic Norge, Mediq Norge
Health ICT	All ICT-products and services that are deployed to prevent and treat diseases, as well as for administrative systems and processes in the health industry	167	13 526	IBM Norway, CSAM Health
Diagnostic	All biological, chemical and technological products used to diagnose in the health industry	105	3 419	GE Vingmed Ultrasound, Laerdal Medical
Specialized subcontractors	Providers of raw materials, equipment and services	135	5 694	Nemko, Link Medical Research

Table 1 Industry and subgroup definition

Source: Menon Economics and thesis analysis

With the industry defined, the assessment of it by applying the framework of *The Emerald Model* allows for an empirical analysis on the cluster's strength on the respective dimensions. The assessment is finalized with a score from 1-10, and as this score to some extent is subject to the authors judgement, it poses a potential weakness for the validity of the study. Thus, an important focus for the applied data collection has been on strengthening the overall validity. As a result, the main emphasis is spent on collecting *similar* quantitative data to the data collected by Sasson (2011) where this has proven possible. In addition, similar industry specific data has been collected over time, which has provided the opportunity to create time series and visualize trends in the datasets. These measures have not only proved important for strengthening the validity of the findings, but also for the *outcome* of the data analysis (Bell et al., 2019).

As the various dimensions of *The Emerald Model* require different data to be collected, the 7 dimensions serve as a guide for the chosen data collection. The dimensions are all analyzed in the context of the industry (Table 1), but for the dimensions in which there is limited access to quantifiable and measurable data per subgroup, other data sources, such as data from academia, industrial reports and news reports, have been applied. To assess the cluster's attractiveness on the different dimensions of *The Emerald Model,* we provide an overview of the data that has been collected and that is further analyzed in Chapter 4. In parentheses follows the main sources of data for each dimension, while Table 2 contains an in-depth description of the databases.

Cluster attractiveness: To determine whether the Norwegian health tech cluster is attractive, the cluster's value creation properties, its geographical distribution and to which extent the firms are internationalized is examined. For this, data on the firm's total revenues, value creation, salary costs and export revenues together with the regional distribution of the firms in the population, is collected (**Menon Economics**).

Educational attractiveness: The dimension of educational attractiveness assesses whether relevant educational programs can attract human capital that provides the essential knowledge which firms in the cluster can build further upon. Here, data on the total number of students in health tech-related fields, in addition to the total number of students in Norway distributed by educational level, i.e. Bachelor, Master and PhD, is collected (**Norwegian Centre for Research Data**).

Talent attractiveness: This dimension measures the degree to which the industry is successful in recruiting and retaining highly developed human capital. Data is collected on the firm's average salary costs and the average annual wage in comparable industries such as health- and social services, financial services and IT-, information- and communication services. For employment characteristics, data on the education level of employees in the Norwegian healthcare- and the ICT industry is collected, in addition to characteristics of the foreign labor force in Norway (**Menon Economics, OECD.Stat, SSB).**

R&D and Innovation attractiveness: Measures how research intensive and innovative the industry is. For the R&D side of this dimension, data on the number of academic publications in health tech-related topics, the distribution of these publications by institutions and the number of publications provided by different funding agencies is collected. In addition, the amount of private and public funds granted to the firms in the population is included. For the innovation side of the dimension, data on the number of new products/services introduced by the firms, in addition to the revenue that has been generated from these new offerings, is collected (**Innovation Norway, Menon Economics, Web of Science**).

Ownership attractiveness: The industry's ability to attract competent capital to finance its activities is assessed in this dimension. As an important aspect of this is to analyze the profitability of the firms in the industry, firm revenue data is examined. Furthermore, the number of shareholders and the size of the corporate groups the firms are a part of is collected (**Menon Economics, Odin Bureau van Dijk**).

Environmental attractiveness: Measures the extent to which the industry can meet future sustainable solutions and environmental demands. Firm specific data on the metrics that make out this dimension is strictly limited, and thus secondary data from online research that assesses the environmental impact of health tech is collected.

Knowledge dynamics: The existence of knowledge-related linkages and the dynamism of the environment proves difficult to assess with quantitative data. Thus, assessing this dimension is to a great extent based on secondary data from annual- and other official reports published by Norway Health Tech. The dimension is measured by examining the role of the cluster organization in strengthening knowledge sharing in the cluster through the implementation of different initiatives. Thus, data on initiatives that are implemented with the ambition of strengthening the collaboration between central cluster actors as firms, investors, universities and research institutions is collected (**Norway Health Tech**).

Database	Description
Menon Economics	Database covering accounting and activity information for all firms in Norway and Sweden. The database covers almost half a million firms and contains detailed information on profitability, growth, debt, exports, employment and ownership.
Odin Bureau van Dijk	Database containing comprehensive information on firms in the Nordic and Baltic countries. Includes information on: Firm financials, financial strength indicators, information on directors, stock data for listed firms, detailed corporate structure and the corporate family, shareholders and subsidiaries, market research, adverse filings, business and firm-related news, and M&A deals.
Web of Science	Database containing citation indexes representing the citation connections between scholar research articles found in the most significant journals globally, books and proceedings in the sciences, social sciences and art & humanities.
SSB	Database containing official statistics related to the economy, population and society at national, regional and local level in Norway.
OECD.Stat	Database including comprehensive data and metadata for OECD countries and selected non-member economies. Includes data by theme on demography and population, development, economic projections, education and training, environment, finance, globalization, health, industry and service, ICT, international trade and balance of payments, productivity with more.

Table 2 Database/Source description
Source: Menon Economics, Odin Bureau van Dijk, OECD, SSB, Web of Science and thesis analysis

4. Empirical Findings and Analysis

Sasson based his research report on *The Emerald Model* as presented in Chapter 2.3 and examined the Norwegian health industry based on the 7 metrics of the model. By examining each dimension individually, *The Emerald Model* allows for an empirical analysis on the cluster's strength on a given dimension which is finalized with a score from 1-10. At completion, the scores combined will give the model its characteristic look.

This chapter will systematically examine each of the dimensions of *The Emerald Model* in individual sections. Each section will contain a conclusion that summarizes the main findings from the analysis and provides a score to each of the model's dimensions. Further, the score and conclusion will be compared to the findings of Sasson (2011), in order to see a potential development, either positive or negative, for the health tech cluster on the respective dimensions.

To introduce this chapter, we present the four subgroups and their development in size over time, measured in number of employees (Figure 5). We see that Health ICT represents the largest subgroup when measured in number of employees. Despite accounting for 56% of the firms in the population, Medtech remains the smallest subgroup. All subgroups vary in terms of size and growth, and the largest difference is seen between Medtech and Health ICT, where Medtech grew by 1.4% compared to Health ICT which grew by 13% over the period of 2010-2018.

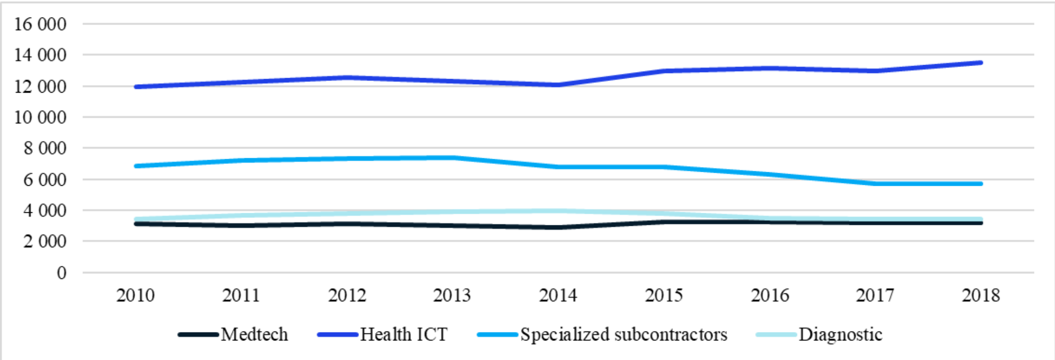

Figure 5 Employment by subgroup (2010-2018)[2]

Source: Menon Economics and thesis analysis

[2] As the population of health tech firms has developed, the graph may not include firms that no longer exist due to bankruptcies, acquisitions or mergers.

4.1 Cluster Attractiveness

Cluster completeness

Figure 6 shows the composition of firm revenue in the population by its respective subgroup for 2018. The cluster contains all relevant activities, and there is an existence of a critical mass of firms in all parts of the industry's value chain, however this varies depending on which subgroup the firms are part of. In 2018, there were 637 *active* firms in the population, where Medtech was the largest subgroup with 56% of the firms. On the contrary, Diagnostic *only* accounted for 6% of the population in 2018 with its 40 firms. The cluster is further characterized by a large number of small firms as 65% of the firms in the population had revenues of less than MNOK 10, showing a similar pattern to the findings in Sasson (2011). In 2008 Sasson found that the industry was characterized by many small firms, where 86% of the firms had revenues less than MNOK 10. This indicates that there has been a positive development over the period of 2008-2018, as a lower share of the firms are small when measured in total revenues.

In Medtech, 75% of firms have annual revenues of less than MNOK 10, 17% have annual revenues in the range MNOK 10 and 100, while *only* 7% have annual revenues between MNOK 100 and BNOK 1. In Health ICT 10 firms had annual revenues of more than BNOK 1, however these firms *only* make up 7% of the firms in the subgroup. Further, 57% of the Health ICT firms have annual revenues of less than MNOK 10. The Diagnostic subgroup contains the highest percentage of high revenue firms with 20% of its firms generating revenues in the range MNOK 100 and BNOK 1, and 10% generating revenues of more than BNOK 1. Diagnostic in Norway is generally characterized by large and more export-oriented firms compared to the other firms in this cluster (Jakobsen et al., 2019).

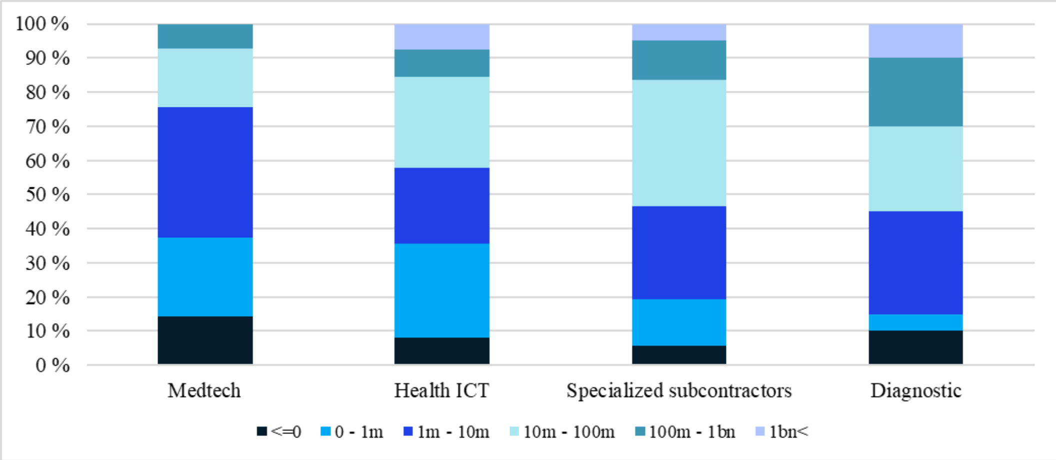

Figure 6 Industry composition by revenue and subgroup (2018)

Source: Menon Economics and thesis analysis

Economic characteristics

Table 3 and Figure 7 investigate the economic attractiveness of the subgroups by illustrating the development in value creation over an eight-year period. The development has varied across the different subgroups, but also internally within each of the groups. In Medtech there are still many small firms who over the eight-year period are yet to create value, while other Medtech firms have experienced a continuous growth in value creation in the same period. However, when reviewing the different subgroups in total, it appears that the cluster has experienced a strong growth over the period, with a total growth of 40%. Health ICT had the greatest contribution to the total value creation in both 2010 and 2018, while Diagnostic experienced the greatest growth, amounting to 59%. In Health ICT we see that the total value creation is mainly generated from a few large firms, which also applies for Diagnostic.

	2010	2018	Change	Change in %
Medtech	2 012	2 493	480	24 %
Health ICT	19 050	27 849	8 799	46 %
Specialized subcontractors	5 983	6 427	443	7 %
Diagnostic	4 984	7 949	2 965	59 %
Total	32 030	44 718	12 688	40 %

Table 3 Value creation by subgroup for 2008 and 2018, MNOK

Source: Menon Economics and thesis analysis

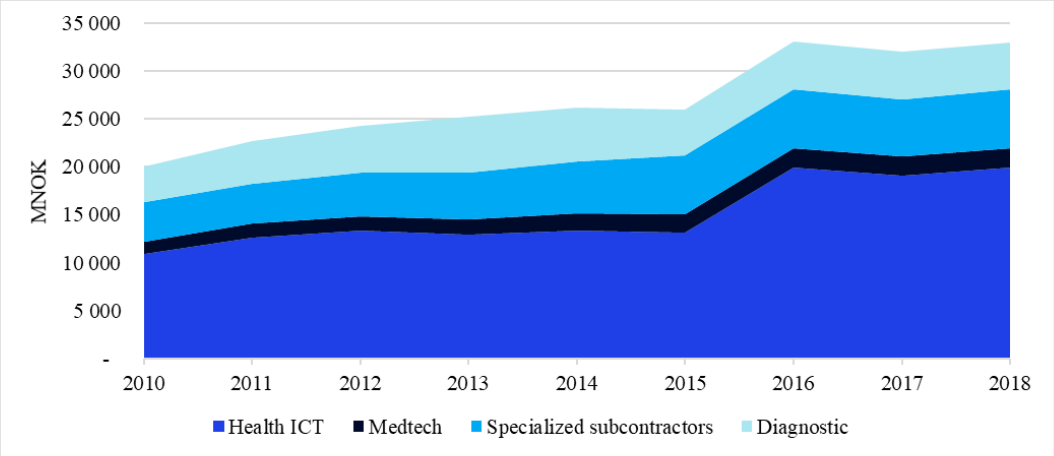

Figure 7 Development in value creation by subgroup, MNOK (2010-2018)
Source: Menon Economics and thesis analysis

Figure 8 illustrates the value creation and salary cost by subgroup in MNOK for 2018. Overall, 38% of the value creation in all four subgroups can be attributed to salary costs. Sasson (2011) found in his analysis that 82% of the value creation was attributed to salary costs in 2009. Health ICT stands out as the subgroup with the highest value creation per employee. Here, *only* 29% of the value creation is attributed to salary costs which is visible in the figure by the large gap between salary costs and value creation in bar three and four. Health ICT is closely followed by Diagnostic, in which 31% of the value creation is attributed to salary costs. Medtech is the subgroup where most of the value creation can be attributed to salary costs (47%) closely followed by Specialized subcontractors (46%).

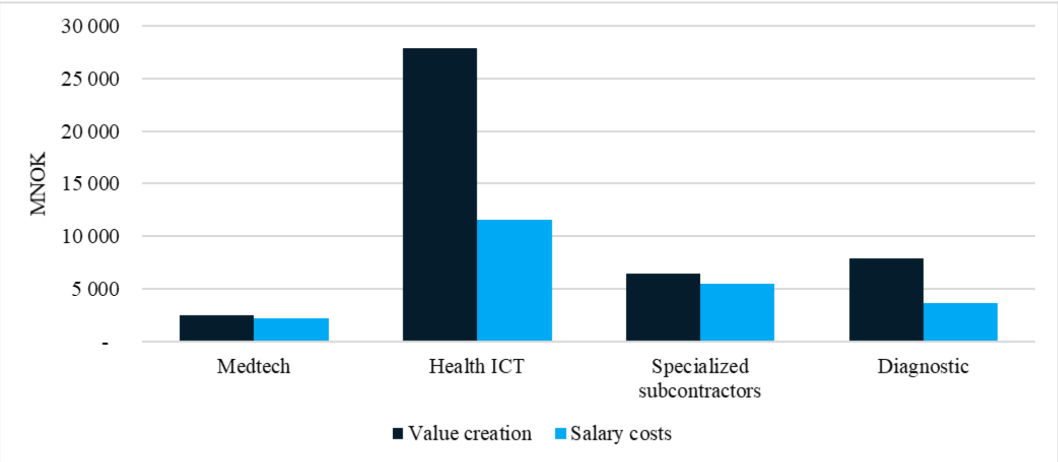

Figure 8 Value creation and salary costs by subgroup, MNOK (2018)
Source: Menon Economics and thesis analysis

Figure 9 shows value creation per employee in the different subgroups from 2016-2018 and illustrates the economic attractiveness across the different activities in the cluster. On average, value creation across the four subgroups was MNOK 1.576 in

2018. The average value creation in the health industry in 2009 was MNOK 0.6 per employee (Sasson, 2011), indicating a strong development over the period.

As illustrated by the figure, Diagnostic and Health ICT are the subgroups with the highest value creation per employee. Over the three-year period of 2016-2018, Diagnostic had an average value creation of MNOK 2.2, while Health ICT had an average value creation of MNOK 2.046. The value creation per employee in Medtech was moderate with an average of MNOK 0.76. Lastly, Specialized subcontractors had an average value creation of MNOK 1.069. All subgroups, except Health ICT, experienced a positive trend with consecutive growth in the three-year period. Health ICT, as illustrated in the figure, experienced a small decrease in value creation per employee from 2017 to 2018.

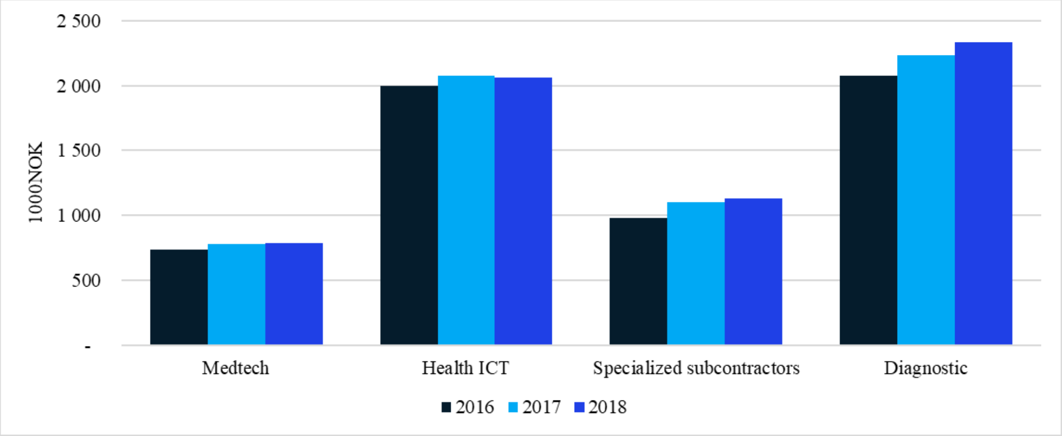

Figure 9 Productivity by subgroup, thousands NOK (2016-2018)

Source: Menon Economics and thesis analysis

Geographic concentration

It is important to analyze the geographic distribution of health-related economic activities to assess and understand the economic performance of the different firms in the industry. Clusters work best when related economic activities are co-located in the proximity of each other (Sasson, 2011). Figure 10 shows the regional distribution and proximity of firms in 2018. The distribution of the different health tech firms in the cluster are closely following the regional distribution pattern of the Norwegian population. 27% of the firms are located in Oslo, and 21% of the firms are located in Viken. Thus, 48% of all firms are located in the two regions that are also the most populated regions in Norway. Sasson (2011) also found that most of the firms in the health industry were located in Oslo and Akershus. On the 1st of January 2020, Akershus was consolidated with Buskerud and Østfold into a joint region named Viken. This consolidation was a result of the new regional reform in Norway (Regjeringen, 2019b). The largest hospitals in Norway are located in Oslo and Viken, and it is also in Oslo that several health tech-related clusters organizations, such as Norway Health Tech, Oslo Cancer Cluster and The Life Science Cluster, have their base.

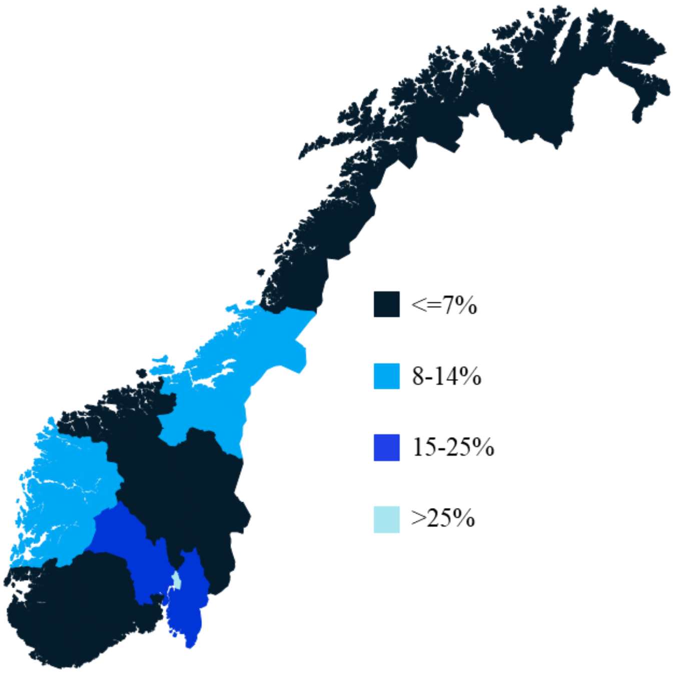

Figure 10 Regional distribution and proximity of firms (2018)
Source: Menon Economics and thesis analysis

Figure 11 shows the regional distribution of firms and their revenues in 2018. As presented in the figure, there is economic activity in every region in Norway, but with a strong variation across the regions. Viken and Oslo stand out as the regions generating the majority of the revenue in the cluster. The two regions together represent 89% of the revenues generated in 2018. Møre and Romsdal represents the region with the lowest contribution to the total revenues, with *only* 0.5%. Sasson (2011) analyzed the regional distribution of firms and revenue in 2008, but distinguished between Diagnosis, Service and Treatment. His findings from these three shares the similar patterns as the findings presented in this study, with Oslo/Akershus standing out as the areas generating the most revenue.

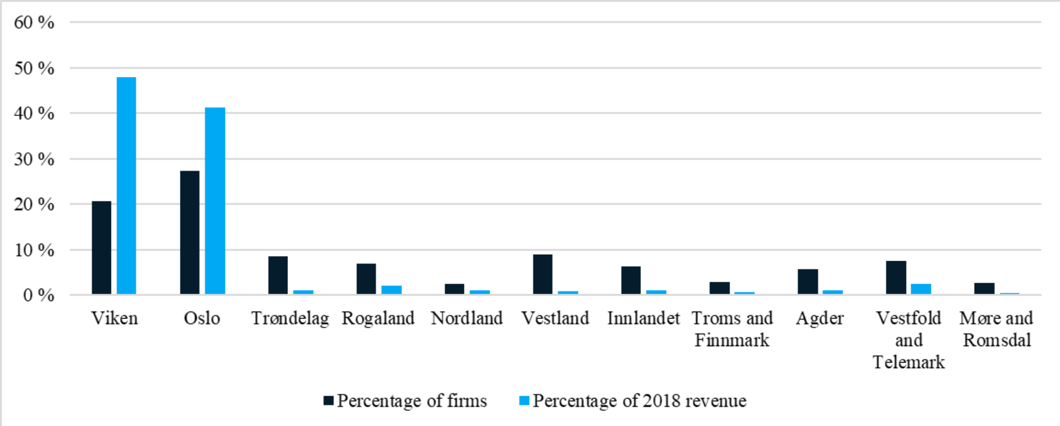

Figure 11 Regional distribution of firms and revenue (2018)

Source: Menon Economics and thesis analysis

Internationalization

Industry experts claim that health tech firms must look to the international market to succeed, but has the industry internationalized? Table 4 provides data on the share of firms in each subgroup that has export revenues, as well as the proportion of revenues generated from exports as a share of total. The data is collected by Menon through a survey that was conducted in 2019. The results indicate that around half of the firms in Medtech and Diagnostic have export revenues, and that export amounted to 52% and 89% respectively in the subgroups. Diagnostic was the subgroup with the largest share of export revenues in Sasson (2011), yet the subgroup has experienced a growth in foreign sales from 83% in 2010. Overall, the table indicates that the industry has a large number of firms that are present in international markets.

	Firms with export revenues	**Export as share of total revenues**
Medtech	56 %	52 %
Health ICT	30 %	6 %
Specialized subcontractors	33 %	61 %
Diagnostic	54 %	89 %

Table 4 Share of firms with export revenues and export as share of total revenues (2018)

Source: Helsenæringens Verdi 2019

While the firms in the cluster, especially in Medtech, are experiencing an increased share of export revenues, an interesting finding derived by MedTech Europe is that Norway is among the countries with a trade deficit of medtech products. In 2018 alone, the trade deficit amounted to as much as MEUR 684. In comparison, Finland and Denmark had a trade surplus of MEUR 891 and 576 respectively, while Sweden had a deficit of MEUR 259 (MedTech Europe, 2020). A *high* level of imports can indicate a lack of competitiveness of the domestic products compared to the international. This is further underlined by the *low* levels of export. It is also worth mentioning that the trade deficit in Norway has grown with MEUR 80 since 2016 (MedTech Europe, 2018).

Cluster attractiveness: Conclusions

Value creation in the health tech cluster has shown a strong development across all subgroups, with an average of MNOK 1.576 in 2018. Overall, the firms experienced a total increase of 40% in value creation in the period 2010-2018. This growth was mainly driven by Diagnostic and Health ICT which grew with 59% and 46% respectively over the period. Further, Health ICT remains as the subgroup with the largest contribution to the total value creation, while Diagnostic remains as the subgroup with the highest productivity.

Medtech, which is the largest subgroup measured in number of firms (56% of firms in population), is by far the subgroup with the lowest contribution to the total value creation, as well as the subgroup with the lowest productivity. Further, *only* around 25% of the Medtech firms have annual revenues greater than MNOK 10, compared to the Diagnostic firms where as many as 55% have revenues greater than MNOK 10. This is a reason of concern, as Medtech firms represent the core firms in this cluster and in the health tech industry in general.

A cluster is stronger when related economic activities are performed with a proximity to another. Economic activity, measured in number of firms and revenue, is highly concentrated in the Oslo and Viken region, who account for 48% of all firms and 89% of the revenue. Further, a strong cluster has a strong presence in all steps of the value chain. However, as highlighted earlier, the industry is strongly dominated by a large number of Medtech firms (56%), while the remaining subgroups individually make up a smaller share of total firms (Health ICT 18%, Diagnostic 11%, Specialized subcontractors 15%).

In total, the cluster scores a 6 on cluster attractiveness. Comparing this score to Sasson (2011), the one given to the cluster on cluster attractiveness was a 4. The score was based on the moderate average value creation of MNOK 0.6 per employee and the high salary costs which constituted for 82% of total value creation. The transition from 4 to 6 is mainly driven by the increase in value creation by the firms in the industry.

4.2 Educational Attractiveness

Important for all four subgroups in the industry is their dependency on investments in human capital, and thus having the ability to attract it to their fields. Analyzing the number of students in health tech-related fields is an important measure in assessing the educational attractiveness of the industry. The health tech-related fields that have been examined in this study, broadly include programs in medicine, health, biochemistry, health technology, medical technology, engineering, technology, and business (See *Exhibit 2 – Health Tech-Related Study Fields* in Appendix for exhaustive list of health tech-related topics).

Figure 12 illustrates an overview of the total number of students in health tech-related fields from 2010-2018. This figure includes students who are undertaking Bachelor, Master and PhD studies. The number of students has steadily increased over the period of 2010-2018, and in 2018, 21 838 students were enrolled in health tech-related studies. This was an increase of 27% from 2010 where the number of students was 17 142. In total, the study-levels experienced an annual average growth of 3.1% which puts the growth in health tech-related fields above the national average of 2.8%. This indicates that the health tech-related fields are attracting more students, in turn attracting a large degree of relevant human capital and talent.

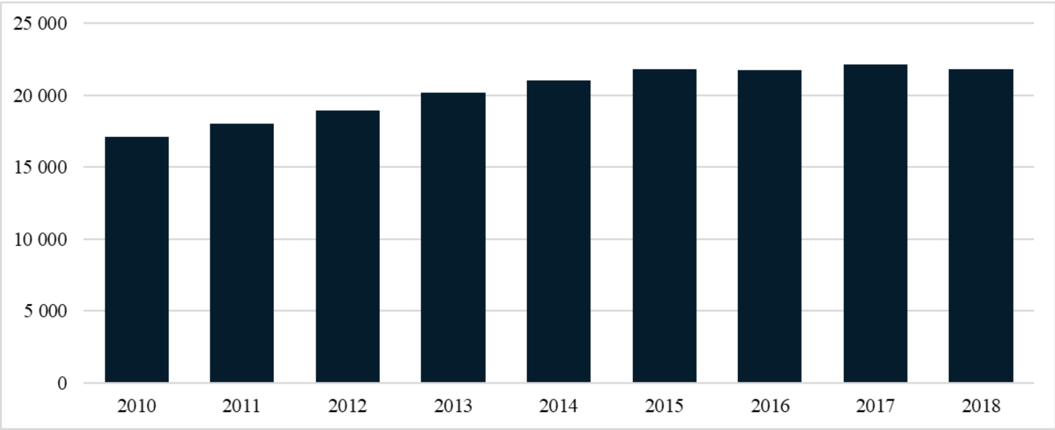

Figure 12 Total number of students in health tech-related fields (2010-2018)[3]

Source: NSD and thesis analysis

Figure 13 shows how the different levels of education are distributed from 2010-2018. When using the total number of students within all study fields in Norway as

[3] Rounding may occur due to privacy concerns.

a benchmark, we discover that the health tech-related fields deviate some from the average. For Master and PhD studies, the average annual growth of students within health tech-related fields is below the average growth rate for all Master and PhD study-levels in Norway. The average annual growth of Master students for all studies in total is 3.7 %, while it for health tech-related fields is 3.2%. Similarly, the average annual growth of PhD students for all studies in Norway is 3.7%, while it for the health tech-related fields is 3.0%. This indicates that the health tech-related fields are slightly less attractive on a Master and PhD-level than the average for these study-levels across all fields. When it comes to Bachelor students, the average annual growth within health tech-related studies is above the national average, with a 3.1% annual average growth in health tech-related fields, versus the national average of 2.5%. This indicates that health tech-related fields attract more Bachelor students than the average field of study. Sasson (2011) found the opposite for the period 2005-2009 in his study, regarding Bachelor students. This indicates a positive development for the talent attractiveness of Bachelor students to heath tech-related fields. Further, being able to attract more Bachelor students will in turn increase the chances of more students undertaking Master and PhD studies within the relevant fields.

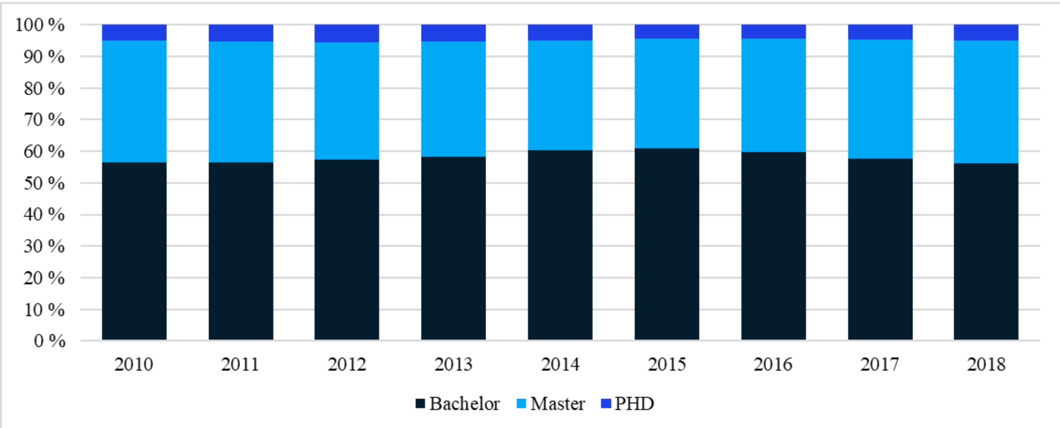

Figure 13 Students in health tech-related fields by education level (2010-2018)

Source: NSD and thesis analysis

Figure 14 shows the number of Bachelor students in health tech-related fields from 2010-2018. The share of Bachelor students has increased by an annual average of 6.6% from 2010 to 2015, before decreasing by 2.7% from 2016-2018. This is a source of negative concern as the decrease in number of Bachelor students in the period of 2016-2018 can potentially lead to a decrease in the number of Master and PhD students within health tech-related fields in the future.

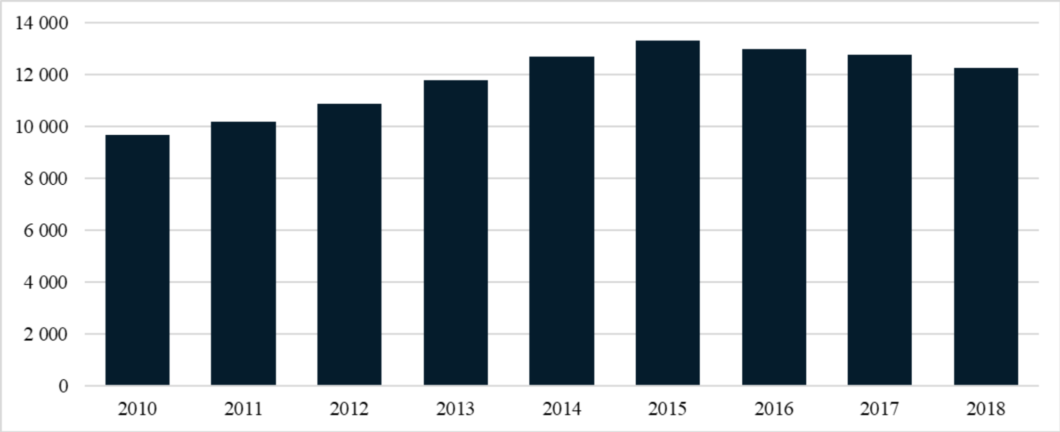

Figure 14 Number of Bachelor students in health tech-related fields (2010-2018)
Source: NSD and thesis analysis

Figure 15 shows the number of Master students in health tech-related fields from 2010-2018. The graph indicates a positive linear trend in the level of Master students in the study field of health tech. These findings expose a positive trend and deviates from the findings of Sasson (2011) who found a negative linear trend for the period of 2005-2009. The positive trend illustrated in the figure represents positive news for the industry as students with a Master's degree hold important positions in a knowledge intensive industry (Sasson, 2011). An increase in the number of Master students means that the firms will have a bigger talent pool to choose from when hiring, and that more students are able to undertake PhD studies.

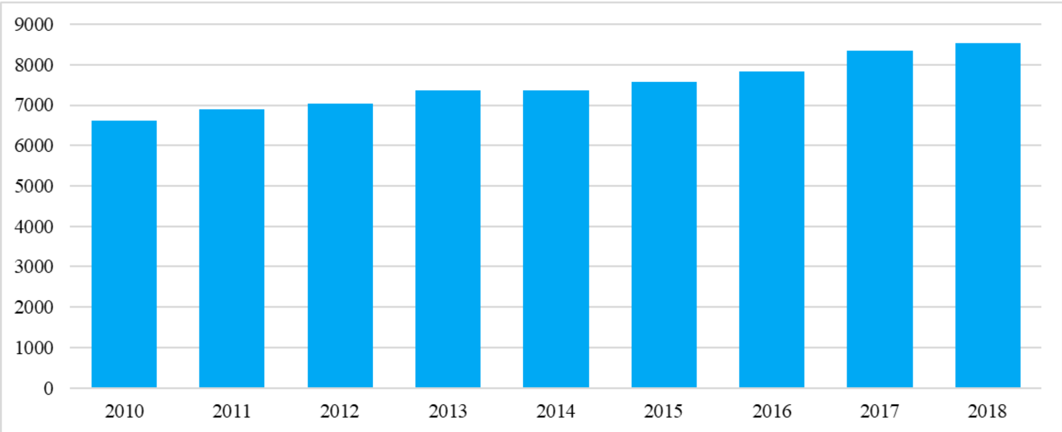

Figure 15 Number of Master students in health tech-related fields (2010-2018)
Source: NSD and thesis analysis

Figure 16 shows the number of PhD students in health tech-related fields from 2010-2018. Comparing the current state to the one in 2010, there has been a growth of 25% in the number of students who have undertaken PhD studies within health tech-related fields. This growth is in line with the growth of PhD students for all study fields in Norway.

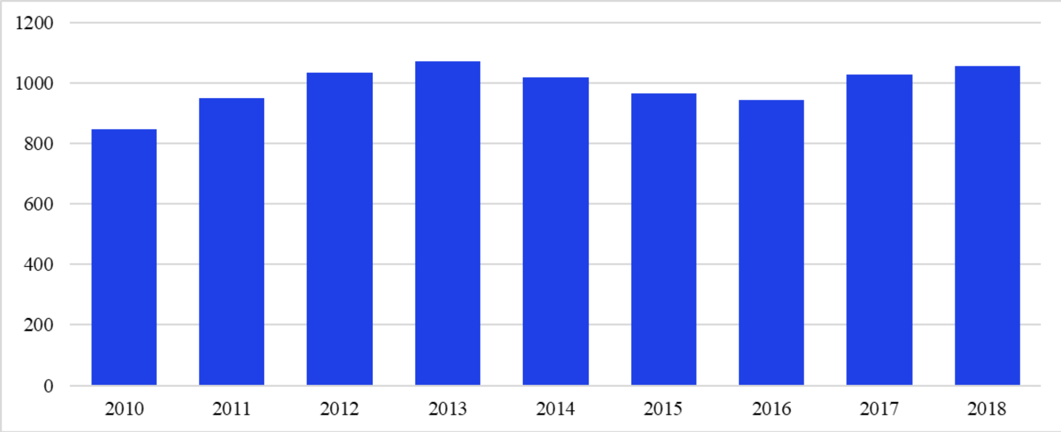

Figure 16 Number of PhD students in health tech-related fields (2010-2018)[4]

Source: NSD and thesis analysis

Figure 17 indicates how the development in health tech-related fields is relative to the national development in the total population of students at each level. The number of students in health tech-related fields should increase if these fields are gaining in popularity among the student population. The comparison of the development of the number of students in health tech-related fields relative to all subject areas in Norway shows that the shares for Bachelor students remain stable at around 10%, while for Master students it remains stable at around 20%. The share of PhD students is much higher, with a share that until 2014 was stable at around 70% but that has varied from 2014-2018, ending on just below a 70% share in 2018.

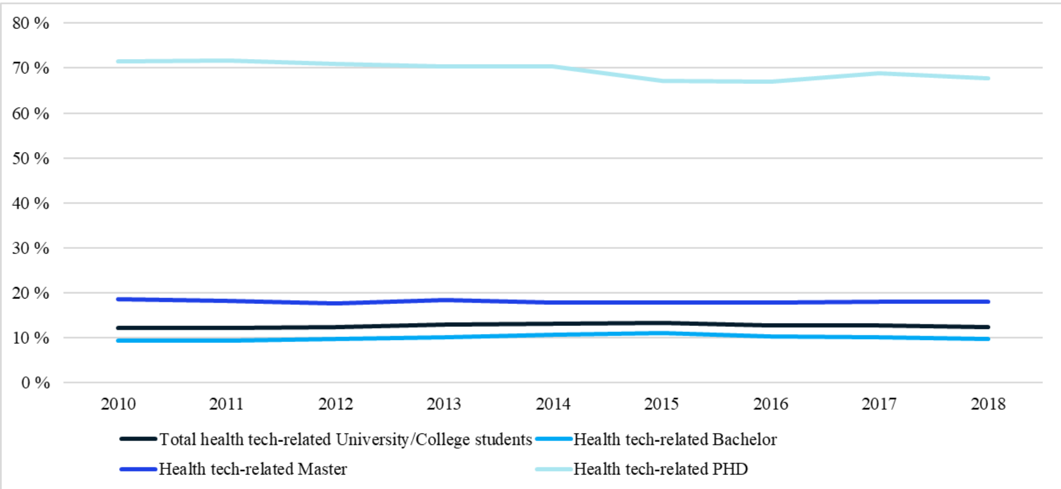

Figure 17 Students in health tech-related studies relative to total students (2010-2018)

Source: NSD and thesis analysis

We also note the emergence of additional studies that are health tech-oriented, and thus relevant for the cluster. The University of Oslo (hereafter UiO) launched the

[4] Candidates that have finished their doctoral degrees.

course *Medical technology* as an integrated part in the Master program in electronics and computer technology in 2011 (UiO, n.d.). Further, Oslo Metropolitan University (hereafter OsloMet) offers a study within medical technology that is integrated in their Bachelor program in engineering (Kompetansenorge, n.d.). As mentioned in Chapter 4.1, 48% of all firms in the cluster are located in Oslo and Viken, and the establishment of health tech-related study fields in this region has the potential to generate valuable talent for the firms located there.

The emergence of new study fields relevant to the health tech cluster is not *only* evident in Oslo and Viken. The Norwegian University of Science and Technology (hereafter NTNU) have been early in their effort to invest in health tech-related fields. In 2014, a new and broader thematic initiative in health, welfare and technology was established; *NTNU Health*. Medical technology remains an important part of NTNU's new thematic initiative and the activity continues with launching new studies that are related towards the industry (NTNU, n.d.). The University of Bergen (hereafter UiB) also launched medical technology as an integrated part of the university's Master program in engineering in 2017 (UiB, 2020). We also note that the University of Tromsø has launched a 5-year study within health tech. This study was launched in the fall of 2018 and is integrated in the engineering study in informatics (UiT, n.d.). In 2018, the University of South East Norway integrated the study of digitalization and innovation in health and welfare services to their Master study in clinical health work.

Despite the positive development in new health tech-related fields and subjects, there are still some concerns among major health players in Norway. With the Director of The Norwegian Public Health Institute in the forefront, central health actors have mobilized to ask politicians to organize a committee with the purpose of strengthening the focus on health tech in higher education. One of the proposals is to investigate how medical equipment and health technology can become a separate education program. Despite being partly integrated in the health and social education programs, it is not sufficiently represented in relation to the need the industry has today (Kalveland, 2020). The outbreak of Covid-19 can potentially *help* boost the focus on health tech in higher education. In light of Covid-19, a record number of 150 785 applicants applied for higher education in Norway. This record must be seen in the context of the increased uncertainty that the pandemic causes for those who currently hold positions in exposed industries. However, disregarding this effect and viewing the distribution of applicants per study field, studies within health and information technology experienced a record in number of applicants with a growth of 4.1% and 13.7% respectively. The largest applicant group per study field is within health with 39 254 applicants (Unit, 2020).

Educational attractiveness: Conclusions

Over the period 2010-2018, the total number of students in health tech-related studies experienced a growth of 27% ending at a total of 21 838 students in 2018. Also, the number of students enrolling in health tech-related fields is above the national average which is a positive sign for the industry. A reason for concern is the moderate negative trend that started in 2016 with regards to the number of Bachelor students. From 2015-2018 the number of Bachelor students decreased by 8% which reduces the pool of students that can potentially proceed to Masters- and doctoral studies. On the contrary, the number of Master students has been linearly increasing over the period, indicating that the attractiveness for these studies relevant for the industry has improved. The number of PhD students has been somewhat variable over the period but experienced a growth of 27%. Further, PhD students in health tech-related studies amounted to 68% of the total PhD students in Norway in 2018. However, this fraction is lower than in 2010, when it amounted to 71%.

In total, the cluster scores a 7 on educational attractiveness, compared to a 6 in 2010, indicating a positive trend on this dimension. Sasson based his score on the negative trend in number of Master students, a stagnated attractiveness for Bachelor and Master students, and a declining attractiveness for doctoral candidates. Further, he found that the proportion of students in relevant studies had remained constant over the period 2005-2009.

4.3 Talent Attractiveness

Talent, activity and salary attractiveness

The educational institutions have a central role in developing the unique human capital that the different sectors, industries and clusters compete in attracting. The ability of attracting talent is central in determining if an industry has a strong position relative to another (Reve & Sasson, 2012). For an industry to be competitive in the long run, it needs the ability of attracting the right talent.

A central aspect in attracting talent, and especially newly educated talent, is through competitive wages. Figure 18 shows the average annual salary cost per employee in each of the subgroups, compared to the average annual wage in relevant and comparable industries as health and social services, IT, information- and communication services and financial services for the period 2015-2018. The figure shows that the average annual salary cost per employee in Diagnostic was *way* above the other subgroups and industries, reaching MNOK 1 059 in 2018. Following Diagnostic are the subgroups Specialized subcontractors and Health ICT with MNOK 969 and 856 in 2018 respectively. When comparing the four health tech subgroups to the health and social services, we see that all subgroups have a higher average annual salary cost in the period. This could in turn lead to a shift and movement among talent from the health and social industry, and a wish to specialize and move into health tech.

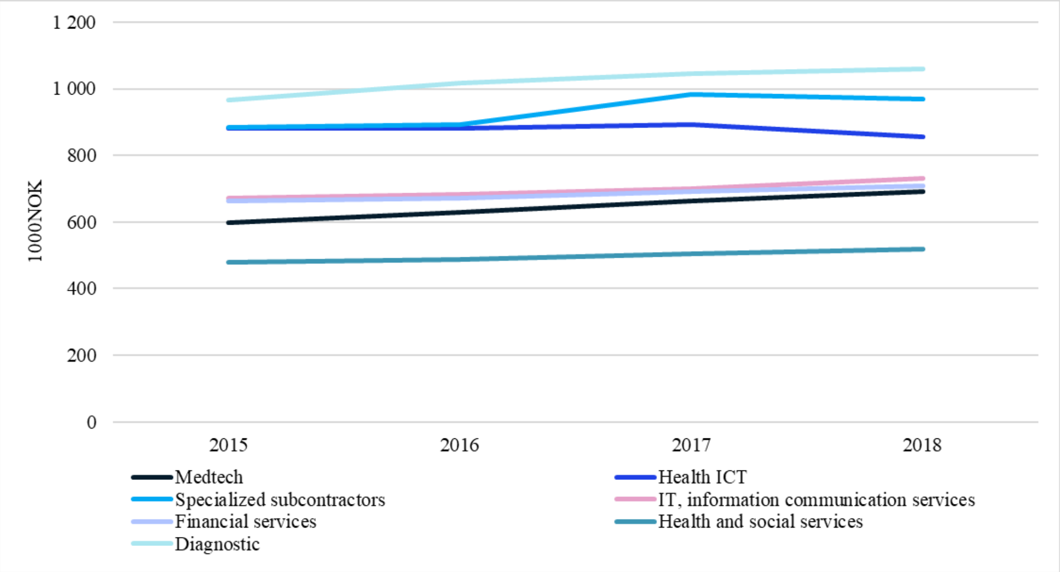

Figure 18 Avg. annual salary cost by subgroup / average annual wage per industry (2015-2018)
Source: Menon Economics, SSB and thesis analysis

Further, Figure 19 shows the development in average annual salary cost per employee in each of the subgroups in the population for the years 2016-2018. The trend in Medtech and Diagnostic has been strictly positive over the period, while Health ICT and Specialized subcontractors experienced a dip in 2018. Further, Diagnostic is the *only* subgroup with average annual salary costs of more than MNOK 1, which was the case for all three years. Medtech has remained as the subgroup with the lowest average annual salary costs, which is most likely due to the fact that the subgroup is mostly made up of startups and SMEs.

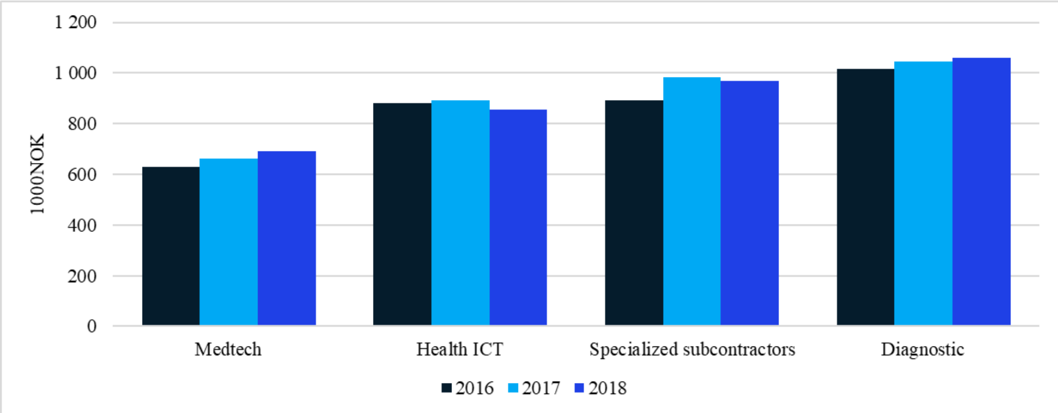

Figure 19 Average annual salary cost by subgroup (2016-2018)

Source: Menon Economics and thesis analysis

Employment characteristics

Statistics Norway has the overall responsibility for providing statistics regarding the Norwegian society. Among the statistics they provide is data on employee education and on salaries by sector and industry. However, this data is not available for health tech, as it is yet to be defined as a specific industry in Norway. To get a sense of how the health tech cluster scores on talent attractiveness, we examine the health industry and other relevant industries and fields of study/work, as health tech is in the intersection of several industries.

Figure 20 shows the trend in number of employees by type of education. In 2018 there were 459 642 employees in the health industry that had healthcare education, or other educations from college and university. Overall, the number of employees grew by 24% in the period. Employees with healthcare education make up the biggest fraction of the total number of employees in the industry (60%). Yet, healthcare was the education type with the smallest growth in the period, amounting to 23%, compared to 27% on the college level and 30% on the university level.

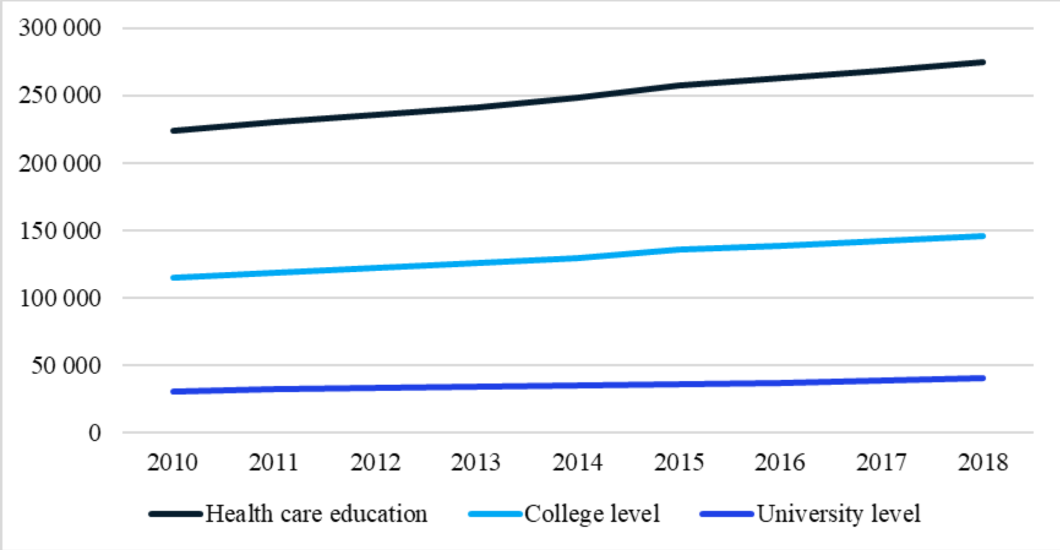

Figure 20 Employment in the health industry by level and type of education (2010-2018)
Source: SSB and thesis analysis

Foreign employment

An attractive industry needs not *only* to attract the right domestic talent, but also foreign. As of 2020 (April 24th), there were 2 113 823 foreign employees in Norway. Of these, 385 837 work in the health and social sector (18%). From Figure 21 we can see that most of the foreign workforce in the health and social sector are from European countries (96%).

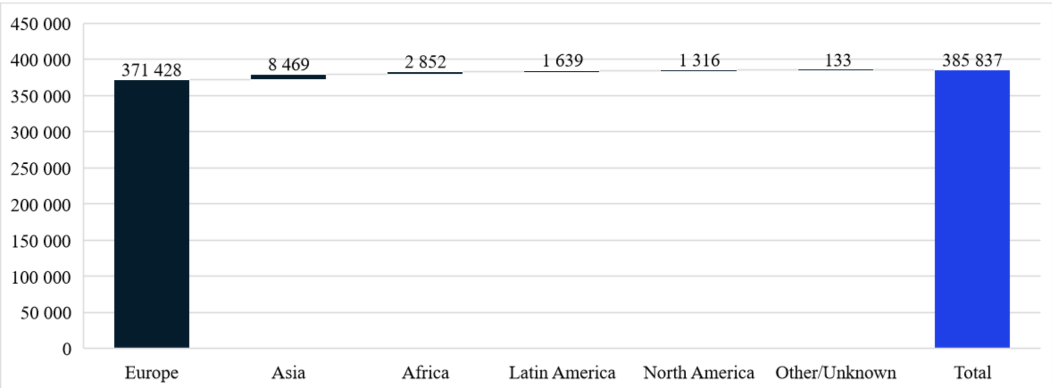

Figure 21 Foreign employees in the health and social sector by region of birth (2020)
Source: OECD and thesis analysis

Figure 22 illustrates a breakdown of foreign employees in the Norwegian health and social sector by their respective education level. From the figure we find some strong results, as 40.8% of the foreign employees hold a Bachelor, Master or PhD degree (ISCED 5 and 6 from ISCED 1997). This is a strong result for the health and social sector, as 30% of the total foreign labor force in Norway hold a Bachelor, Master or PhD degree, indicating that a larger share of employees in the health and social sector hold degrees from higher education. Further, almost half the foreign labor force hold a degree from high school, while *only* 7.4% have solely finished primary and middle school.

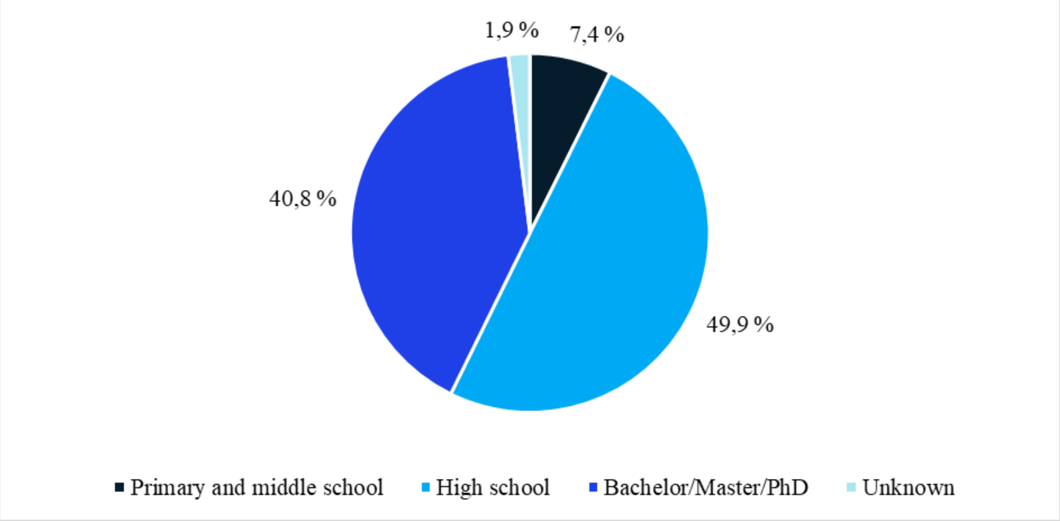

Figure 22 Foreign employees in the health and social sector by education level (2020)
Source: OECD and thesis analysis

Figure 23 shows the total number of foreign employees with a Bachelor, Master or PhD, by field of study. What we can see is that 61% of these employees have studied in fields that are highly relevant for the health tech industry, namely in health and welfare, science, social sciences, business and law, and engineering, manufacturing and construction. This indicates that there is a great amount of relevant talent in Norway that could eventually end up in health tech. It is worth mentioning that the high number of foreign employees in the industry is not strictly positive, as it can be a clear indication of a lack of domestic talent.

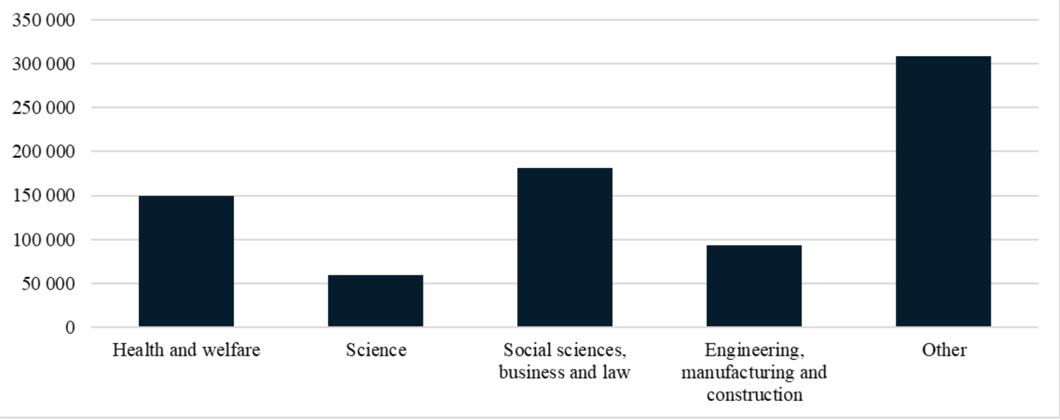

Figure 23 Foreign employees in Norway by field of study (2020)
Source: OECD and thesis analysis

Talent attractiveness: Conclusions

The average annual salary cost in each of the subgroups has had a positive trend over the years, which can indicate a positive development in the average annual wages in the respective subgroups. Further, we see that all subgroups have higher average annual salary costs per employee than the average annual wage in the health and social sector, which can potentially lead to a movement of talent from health and social services to health tech.

However, what is quite problematic is that the health tech cluster is highly characterized by a large number of SMEs, especially startups, who in general offer less attractive conditions than the large corporations. This is especially relevant for Medtech, which is not only the subgroup with the highest share of SMEs, but also the subgroup with the lowest average annual salary costs. Further, the large difference between the four subgroups' average annual salary indicates that Diagnostics and Specialized subcontractors are performing better than Health ICT and Medtech. It raises a concern that Medtech, which is not only the *core* of the industry but also the most knowledge-intensive subgroup, has the lowest average annual salary of the four subgroups.

Further, we question the high number of foreign employees, as it can indicate a lack of domestic talent. Nonetheless, the media coverage of the industry has been predominantly positive in Norway, due to the positive recent developments in research and the innovation-friendly attitude. These aspects strengthen the knowledge and interest of the industry, which are critical factors for attracting talent.

In total, the cluster scores a 5 on talent attractiveness. The score given by Sasson (2011) was a 4, indicating a positive trend on this dimension. Sasson based his score on the decline and moderate growth rates in number of employees in different subgroups of the industry that have an education in relevant fields. Further, Sasson claimed that the human capital of the foreign employees in the Norwegian health industry was lower than of the average employee.

4.4 R&D and Innovation Attractiveness

The Norwegian innovation landscape

Annually, The European Commission publishes the European Innovation Scoreboard, which provides a comparative analysis on the innovation performance of different EU countries and other European countries (European Commission, 2019). In 2018, Norway ranked as a *Strong Innovator* in the European Innovation Scoreboard with a score of 128, which was 11 points higher than the EU average that year. However, Norway is not an *Innovation Leader* like Sweden who scores 148 on the Innovation Scoreboard (European Commission, 2019). The performance in innovation in Norway has increased relative to that of the EU from 2011. The strongest innovation dimension of Norway is Innovators, Linkages and Innovation-friendly environment. Norway also scores high on International scientific co-publications, Public-private co-publications and Innovative SMEs collaborating with others. Norway's lowest indicator scores on innovation are on Medium and high-tech product exports, Design applications, Sale of new-to-market and new-to-firm product innovations (European Commission, 2019). The European Innovation Scoreboard is a scoreboard that considers the overall innovation within a nation, and not a specific industry.

The Organization for Economic Cooperation and Development (OECD) defines R&D as activities that "*Comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge (including knowledge of man, culture and society) and the use of this knowledge to devise new applications*" (OECD, n.d. a). The health tech industry is a knowledge intensive industry which is dependent on obtaining a skilled workforce, but also dependent on development, research and innovation. Thus, the importance of R&D spending is strong in this industry. Norway is still spending less on R&D than the average OECD country. However, from 2013-2017 there was a notable increase in R&D spending in Norway before a decrease again from 2017-2018. In 2018 Norway spent 2.073% of their GDP on R&D compared to the OECD average of 2.4%. For comparison, Israel, the OECD country that spent the most on R&D, spent 4.94 % of their GDP on R&D in 2018 (OECD, n.d. b). Although these numbers evidently reveal that Norway scores below average on R&D spending, it is important to stress that these numbers assess all Norwegian industries. In terms of R&D and innovation in the health and healthcare industry, Norway is among the OECD countries with the highest share of R&D spending (OECD, 2017). This entails that health and health-related industries are prioritized in Norway in relation to R&D spending. The following section seeks to assess this.

The Norwegian health innovation system

Research and innovation in health and healthcare has proven to be important and prioritized in Norway. The research that has been funded and conducted at universities has grown significantly in Norway and is expected to continue to grow due to the many governmental strategies and initiatives that put emphasis on the topic of health and healthcare (OECD, 2017). This is a positive trend for a knowledge intensive industry as health tech. As illustrated by Figure 24, the number of academic publications on health tech-related topics has been increasing over the period 2010-2018 with a tripling of academic publications over the period (See *Exhibit 3 – Criteria's for Health-Related Academic Publications* in Appendix for exhaustive list of health tech-related topics). Academic publications create a platform where commercialized innovation has the potential to occur, and thus the number of publications is important to assess in order to analyze how productive the resources available in the health tech industry are. The development of academic publications shows a positive trend in terms of R&D and innovation attractiveness.

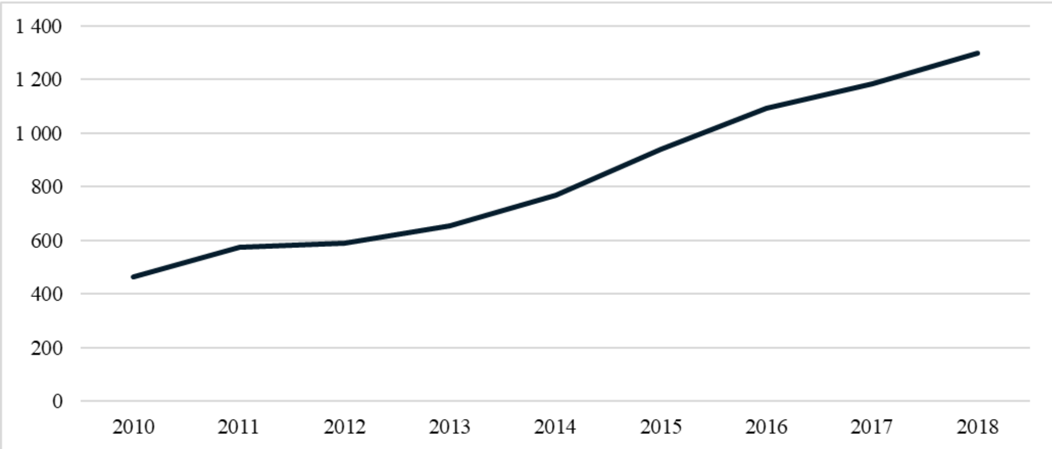

Figure 24 Academic publications in health tech-related topics (2010-2018)

Source: Web of Science and thesis analysis

Figure 25 illustrates the distribution of academic publications in health tech-related topics by institutions with most publications. UiO accounts for close to 30% of the publications followed by NTNU and UiB. UiO is not *only* closely located to Oslo University Hospital but is also the institution that has the closest cooperation with the hospital. Oslo University Hospital is Norway's leading research hospital (Oslo Universitetssykehus, n.d.), yet it is not among the top 7 institutions in regard to number of publications. Further, UiO has a proximity to- and a strong collaboration with Norway Health Tech.

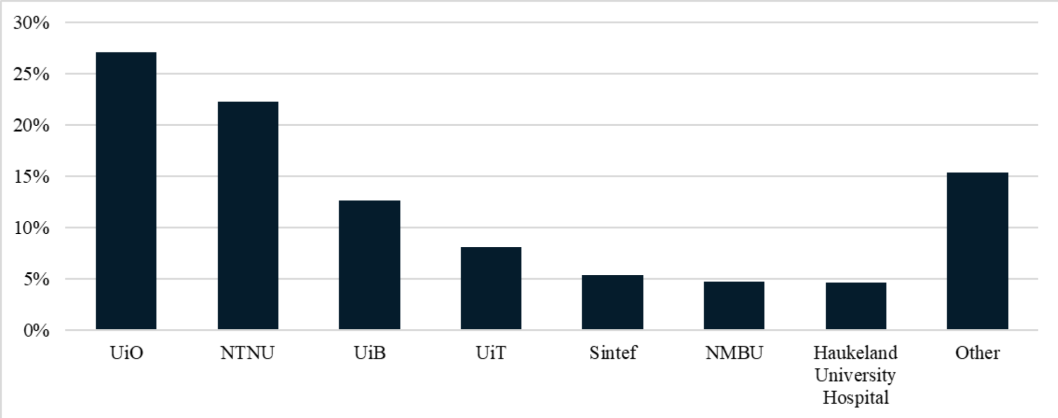

Figure 25 Academic publications in health tech-related topics by institutions (2010-2018)[5]
Source: Web of Science and thesis analysis

Figure 26 shows the number of academic publications in health tech-related topics by funding agencies from 2010-2018. *Other,* represents more than 6 275 funding agencies who each represent a small amount, but together funded more than 70% of the academic publications on health tech-related topics. Looking aside from this group, we see that the Research Council of Norway is the funding agency that alone stands for most of the academic publications and funded 14.1% of all publications in the period. Further we see that six out of the seven largest funding agencies were foreign, with the European Union (EU), U.S. Department of Health & Human Services (HHS), National Institutes of Health (NIH), European Commission Joint Research Centre, National Natural Science Foundation of China (NSFC) and The UK Medical Research Council (MRC). This can indicate that strong international institutions as the above listed, look to Norway for research on health tech-related topics. On the contrary, one could argue that the funding from domestic agencies should be stronger, in order to retain the knowledge derived from the research that has been conducted.

[5] Other includes 6 275 institutions.

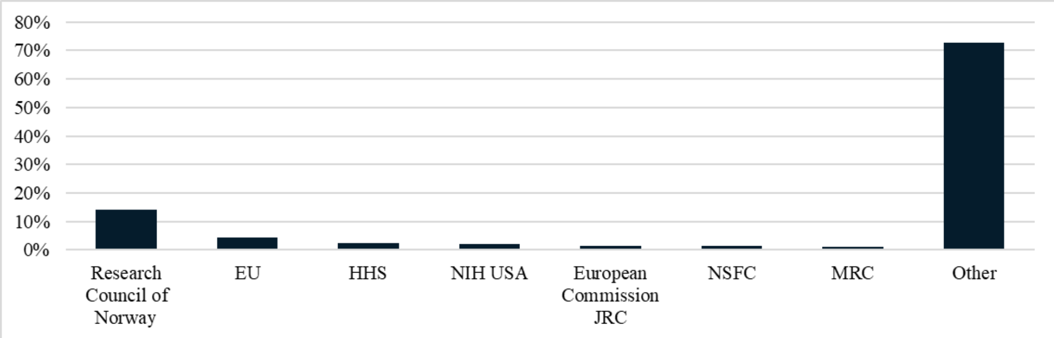

Figure 26 Academic publications in health tech-related topics by funding agencies (2010-2018)[6]
Source: Web of Science and thesis analysis

Current innovative capacity

To assess the degree of innovation in the health tech industry, Menon conducted a survey in 2019 asking the respondents whether they had introduced new products and/or services over the last three years, as well as the revenue generated from these new offerings. The results are presented in Figure 27. As we can see, 88% of the Health ICT firms responded that they had introduced new products and/or services in the period 2016-2018. Further, as much as 62% of their annual revenues was generated from these new offerings. A reason for this is the short timeline from introduction to revenue generation in Health ICT (Jakobsen et al., 2019). Diagnostic stands out as the subgroup with the lowest share of product innovation over the period. Further, *only* 24% of the revenues are generated from these products. A reason for this is that the group is characterized by a large amount of established international actors that have high revenues. Thus it is natural that new offerings would make up a smaller share of the total revenues.

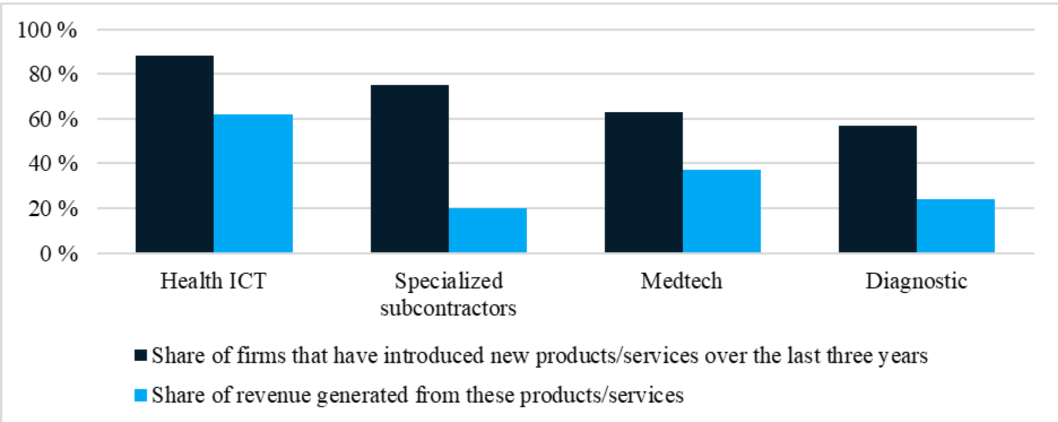

Figure 27 Share of firms that have introduced new products/services (2019)
Source: Helsenæringens Verdi 2018

[6] Other includes 6 275 funding agencies.

A success story – Hy5

- Worlds first hydraulic hand prosthesis
- Produced at Raufoss Industrial Park
- Launched onto the Norwegian market in 2017
- Got a distribution agreement with College Park Industries to introduce the product in the American market: *"Commercial breakthrough."* – **Christian Fredrik Stray, CEO & Co-Founder**

Source: NCE Raufoss (2018), Finansavisen (2019)

Financing R&D

Financing R&D is an important aspect of a firm's ability to innovate, and consists of both public and private funding.

On the public side, Innovation Norway is the nationwide actor that helps firms in all sectors and industries with innovation and development. By providing firms with funds in the form of grants, loans and guarantees they help develop competitive firms in all industries (Innovasjon Norge, n.d.). Figure 28 shows the development in total funds received by firms in the population (left axis), as well as the percentage share of the funds granted to these firms relative to the total funds granted by Innovation Norway in a respective year (right axis). From the figure we can see that in 2010 funds granted to firms in the population amounted to MNOK 76.9 while in 2018 it amounted to MNOK 116.5. This entails that the total funds granted to these firms increased by more than 50% over an eight-year period, which is a positive trend. On the contrary, the funds granted to firms in the population *only* amounted to 1.4% and 1.7% of the total Innovation Norway funds in 2010 and 2018 respectively.

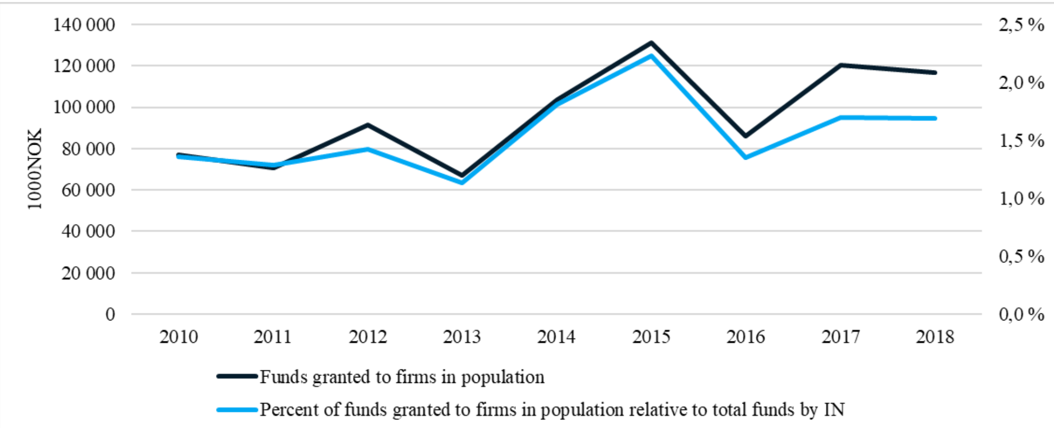

Figure 28 Funds granted to firms in population (2010-2018)

Source: Innovation Norway and thesis analysis

Figure 29 is a further breakdown of the numbers presented in Figure 28 into the types of funding. Grants has remained as the largest type of funds received by firms in the population over the entire period of 2010-2018. This is positive for the firms as there are no payback obligations connected to this type of funding. However, over the period, loans as type of funding more than doubled with a growth of 110%, while grants grew by 41%. A continuation of this trend will entail that in the coming years, loans will be the major share of the total funds received.

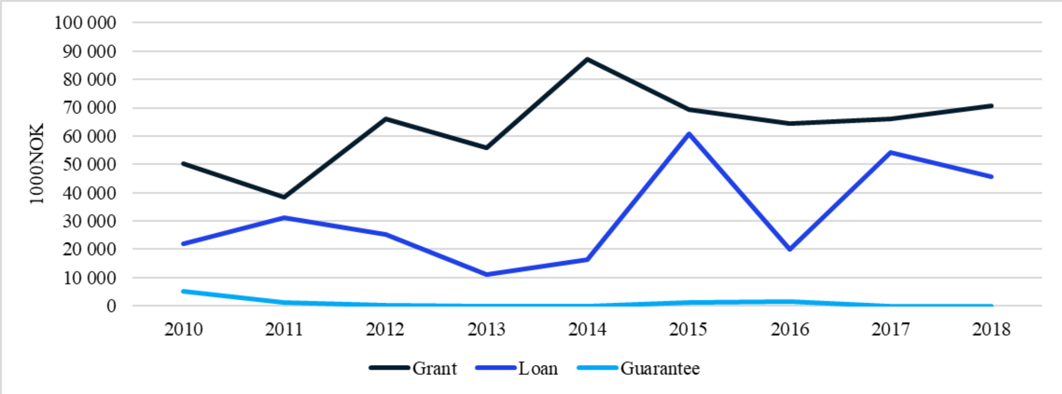

Figure 29 Funds granted to firms in population by type (2010-2018)

Source: Innovation Norway and thesis analysis

When investigating funds granted to the firms in the population by subgroup (Figure 30), no clear trend is visible in either of the subgroups over the period. However, Specialized subcontractors was the subgroup that received the most funds in 2018 in addition to experiencing a 95% growth in the period. While Diagnostic has been the subgroup that has consistently been granted the least, it experienced the greatest growth, amounting to as much as 131%. A reason for why Diagnostic has received the least is, as mentioned in Chapter 4.1, that the Diagnostic subgroup includes a larger share of large firms and corporations compared to the other subgroups.

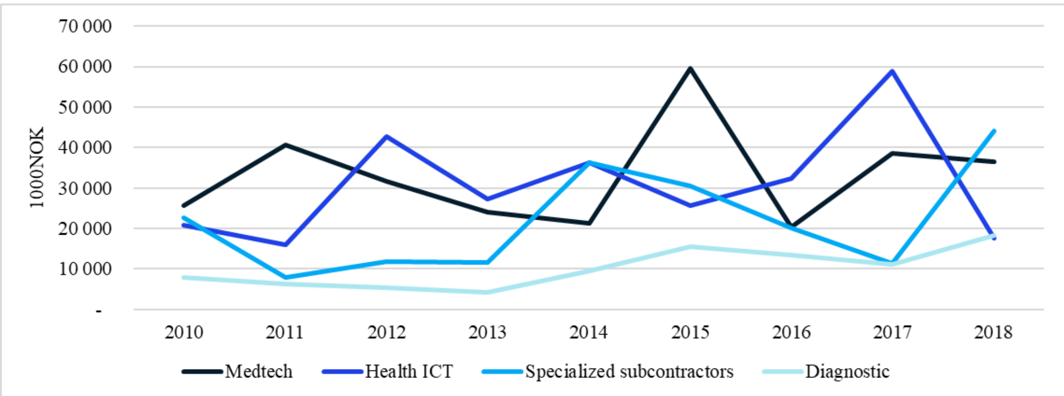

Figure 30 Funds to firms in population by subgroup (2010-2018)

Source: Innovation Norway and thesis analysis

R&D and Innovation attractiveness: Conclusions

The number of academic publications in health tech-related topics has experienced a tremendous growth over the period of 2010-2018, from 464 publications in 2010 to 1 299 in 2018, and a total growth of 180%. Further, UiO stands out as the institution with the greatest number of publications in the period, with a total of 27% of all publications. This is a positive finding as UiO is located in close proximity to Norway Health Tech, Oslo University Hospital and a large share of the firms in the cluster. The Research Council of Norway was the agency that funded the greatest share of the publications in the period, with a total of 14%. Additionally, The Research Council of Norway was the *only* Norwegian funding agency among the top seven agencies, which can be an indication that international institutions deem Norway as a strong research location. On the contrary, this could be a reason for concern as the findings derived from the research could be beneficial for other firms and institutions than the ones who are members of the Norwegian health tech cluster.

The trend in funds granted to the firms in the cluster by Innovation Norway has been somewhat variable over the period, yet, the growth in funds received amounted to 52%. On the contrary, funds granted to firms in the health tech cluster *only* made up 1.7% of the total funds granted by Innovation Norway in 2018. As described earlier, most firms in the industry are startups and SMEs, and hence in great need of both public and private funding in order to sufficiently innovate and develop products and services. Thus, we would wish that the 1.7% was much higher.

In total, the cluster scores a 9 on R&D and innovation attractiveness, which is an improvement compared to the 8 given by Sasson (2011). R&D and Innovation remains strong in the cluster, somewhat due to the infrastructure that Norway provides. Further, all subgroups show a strong focus on product innovation with a range of 57-88% of firms in each subgroup claiming to have introduced new products/services over the last three years. Sasson based his score on the highly innovative firms, mainly in Diagnostic, and the global nature of the industry due to the high levels of foreign investors.

4.5 Ownership Attractiveness

The ownership attractiveness of an industry is the extent to which it is profitable for its owners and attractive for new, as well as its ability to finance its activities and attract competent capital. The firms in the health tech industry often have large capital requirements, but the needs vary depending on the stage of development and in which industry the firms belong (Jakobsen et al., 2019).

Figure 31 illustrates the revenue development by each subgroup in MNOK for the period 2010-2018 and indicates a positive trend across the four. When examining the subgroups separately, Health ICT stands out as the most profitable of the four with a growth of 67% in the period, and a total revenue of BNOK 59 in 2018. Medtech remains as the subgroup with the lowest revenue generation, but still experiences a 43% growth within the period and a total revenue of BNOK 8.7 in 2018. Diagnostic and Specialized subcontractors experienced a growth of 46% and 6% respectively. Examining the subgroups combined, the largest growth was in 2015 with a total of 15%, while 2017 was the year with the least growth, with *only* 1%. The boost in 2015 is mainly due to the growth of 24% that Health ICT experienced, while the stagnation in 2017 is mainly due to Specialized subcontractors and Diagnostic who experienced a growth of -5% and 1% respectively. Overall, the subgroups collectively experienced a growth of 46% in revenues over the period. In comparison, the Norwegian ICT- and oil and gas industry respectively experienced a 34% and 14% growth in the same period. It must be taken into consideration that oil and gas is a well-established industry in Norway which limits its ability to grow, however it shows the major growth that the health tech industry has experienced in Norway from 2010-2018.

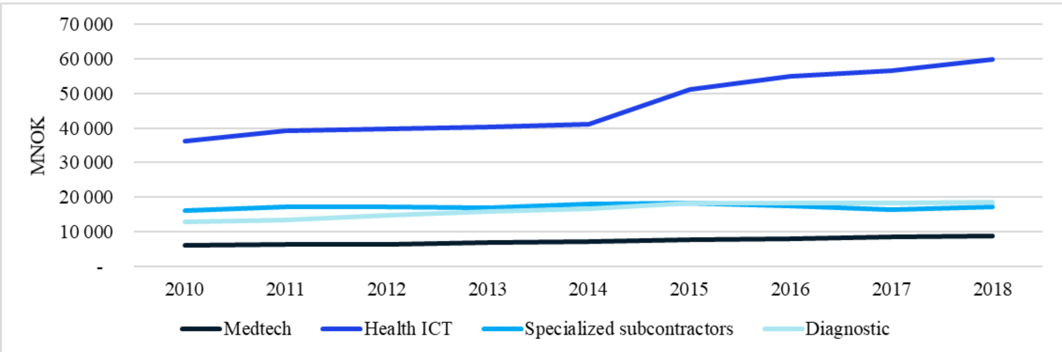

Figure 31 Revenue development by subgroup, MNOK (2010-2018)

Source: Menon Economics and thesis analysis

Figure 32 shows the percentage of firms and revenue by number of shareholders. As shown, the majority of the firms in the population have 0-2 shareholders (66%), and further account for 95% of the total 2018 revenues. 34% of the firms in the population have 3 or more shareholders and *only* account for 5% of the total 2018 revenue. These findings indicate that the largest firms, measured in revenue, are mainly controlled by few shareholders (0-2).

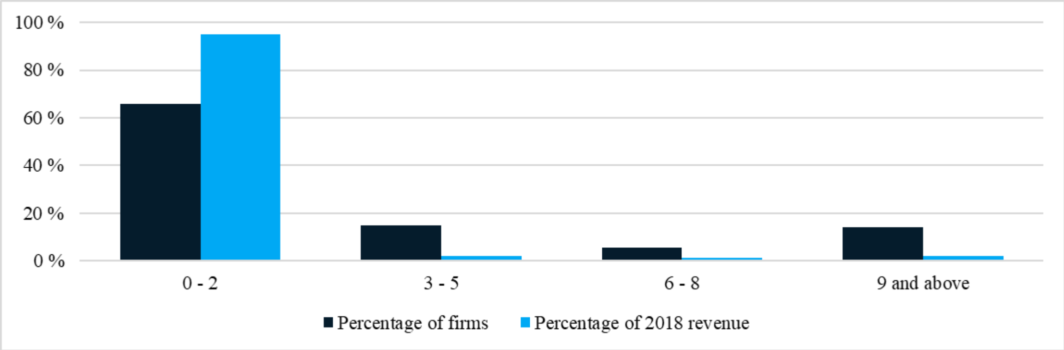

Figure 32 Percentage of firms and revenue by number of shareholders (2018)
Source: Menon Economics, Odin Bureau van Dijk and thesis analysis

Figure 33 breaks down the firms and their share of the 2018 revenues by the number of firms in the corporate group they are a part of. As made evident by the figure, there is a considerable difference between the firms' revenues and the type of corporate group they are a part of. The majority of the firms in the population (55%) are part of a small corporate group (0-2 firms), and these firms *only* make up 7% of the total 2018 revenues. The firms that are part of a corporate group consisting of 3-5 firms make up 3% of the revenues, and the firms who are part of corporate groups with 6-8 firms make up 2% of the revenues. The major difference is made evident with the revenues of the firms who are a part of a corporate group with 9 or more firms. These firms *only* make up 15% of the population but account for 88% of the total revenues.

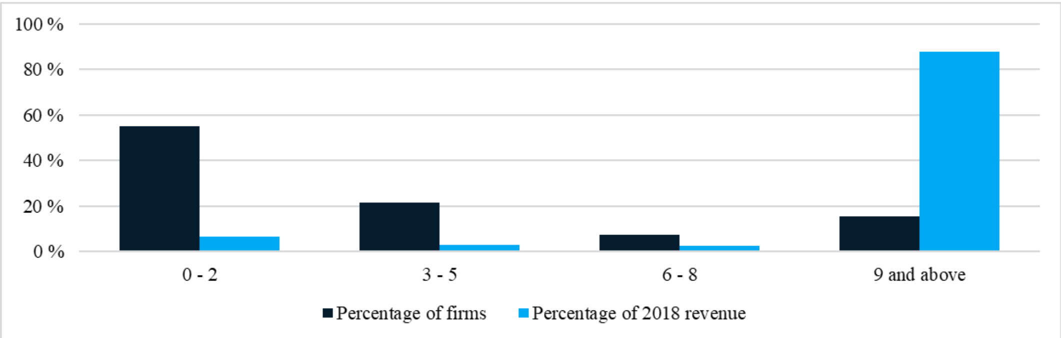

Figure 33 Percentage of firms and revenue by number of firms in corporate group
Source: Menon Economics, Odin Bureau van Dijk and thesis analysis

Looking into the ownership of the selected firms (Figure 34), we note that there is *only* one firm in the population that is owned entirely by a private equity firm. 57% of the firms are corporate owned, and these firms stand for 98% of the total 2018 revenues. Firms that are owned by one or more named individuals or families make up 36% of the firms in the population. The interesting finding here is that although these firms constitute more than one third of the population, they *only* make up 1% of the total revenues. It is also important to note that Figure 34 *only* includes 442 firms due to limitations in the data availability.

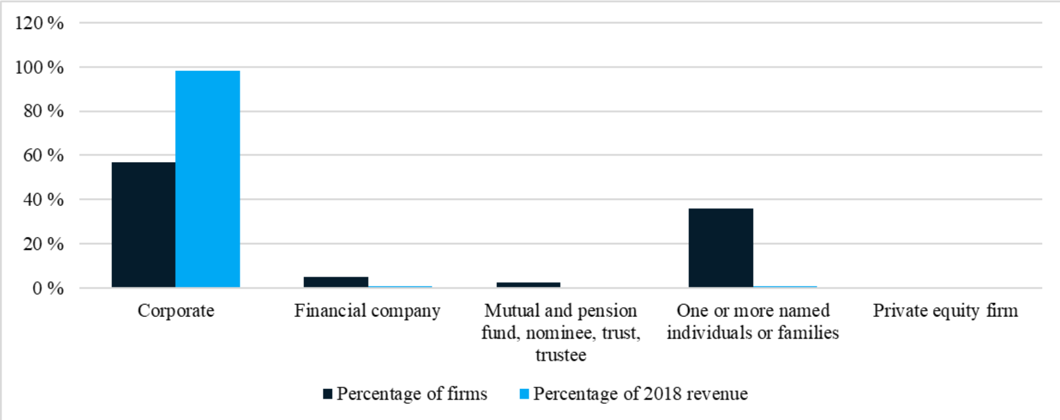

Figure 34 Percentage of firms and revenue by type of ownership[7]

Source: Menon Economics, Odin Bureau van Dijk and thesis analysis

Private investment

Sasson (2011) discussed the lack of private investments in the health industry, finding that capital was not readily invested in long term health-related projects that were perceived as very risky. He also noted that Norway had few competent capitalists who were able to evaluate the complexity and advanced projects within health tech, which resulted in a lack of capitalists that invest in such projects (Sasson, 2011).

10 years after his analysis, the lack of private investment remains as a main challenge for the industry. There are different and complex reasons behind this, but the most evident is the long commercialization processes that characterizes the industry. The industry is characterized by firms that are in the *J-curve* which is a precommercial phase where the costs are higher than the revenues. This in turn poses a barrier for private investors as the long time it takes from idea-to-product-

[7] *Only* accounts for 442 firms in the population.

to-market imposes a risk (Jakobsen et al., 2019). One of the measures taken to face this challenge is the establishment of Catapult Life Science (hereafter Catapult). Catapult is an early stage production center in product development, and the production of substances for clinical studies. The purpose of the Catapult center is to provide new businesses the opportunity to test their products on a smaller scale before the product is ready for large scale production and to be introduced to the market (Jakobsen et al., 2019).

Another major challenge is the lack of business policy in the area of health tech. Till now it has been almost *impossible* to make money from health tech in Norway. In competition with the public sector and with a slow and fragmented market, investors have stayed away from this market choosing to rather invest in *safer* industries, like the oil and gas, real estate and tourism industry in Norway (Schreurs, 2019). Measures taken by Norway Health Tech to try to face this challenge has been to create meeting places with the emphasis of teaching the startups in the cluster how to pitch and present their ideas/products to investors. The cluster organization also offers matchmaking between investors and firms, in which the important focus is to build competence among investors who are interested in the industry. By hosting networking and collaborative events, the aim is that private capital becomes more knowledgeable of the health tech industry which is an important first step for attracting private capital to the industry (Norway Health Tech, n.d. b).

In a survey conducted by Menon (2019), 40% of the firms in the population reported that they received new equity in 2018. The shares vary from subgroup to subgroup. The subgroups were asked if they received equity in 2018, and for the subgroups relevant for this study, 70% of the Medtech firms, 42% of the Health ICT firms, 25% of the Specialized subcontractors and 43% of the Diagnostic firms responded yes. Further, Menon found that the firms received equity from a series of sources, including business angels and venture funds. None of the firms in the asked population received equity from overseas venture capital funds, but there were six firms who raised capital from foreign industrial investors. About 13% of the raised capital came from foreign investors. There were also relatively few firms that had a professional owner fund. In the private placement conducted in 2018, 15% came from Norwegian venture funds and 12% came from seed money (Jakobsen et al., 2019).

Ownership attractiveness: Conclusions

The health tech firms are becoming increasingly more profitable with a total growth of 46% from 2010-2018. This growth is mainly driven by the 65% growth in Health ICT. Further, the revenues generated by Health ICT firms made up 57% of the total revenues in the cluster.

Corporate ownership makes up the largest fraction of ownership type in the cluster (57%), followed by family owned/by one or more individuals (36%). The corporate owned firms accounted for 98% of the total revenues in 2018, while the family owned/by one or more individuals *only* accounted for 1% of the revenues. This supports the claim that a large share of the total firms are startups/SMEs.

The industry is characterized by a timely idea to-product-to-market process which in turn is holding private investors away. Further, private investors still tend to choose *safer* industries rather than health tech, due to the lack of business policy in the industry. Also, the industry is still in lack of foreign investors.

In total, the cluster scores a 4 on ownership attractiveness, compared to a 3 in 2010. Hence, there has been a slight improvement since Sasson (2011), somewhat as a result of the increased importance and attention the industry has received, along with the initiatives taken to increase the knowledge for private investors by Norway Health Tech. Yet, attracting the right capital remains a great challenge for the cluster. Sasson based his score on the low long-term investments in health-related projects. He further found that competent owners from well-established industries in Norway are not willing to migrate into the health industry, especially with projects that are perceived as risky.

4.6 Environmental Attractiveness

Examining whether an industry has the potential to meet the ever occurring environmental demands is best fulfilled by measuring all the relevant environmental and sustainability metrics, such as carbon footprint, greenhouse gas emissions to air and water, waste and energy consumption and recyclability of products. For this chapter, measuring how the firms in the health tech industry score on relevant metrics would provide the optimal foundation to assess the environmental attractiveness of the industry in the most accurate manner. Further, how the different firms score on the metrics would vary, depending on which subgroup in the industry they are a part of. For instance, it is expected that the environmental impact of firms in Health ICT differ from that of the firms in Medtech. Although environmental impact and sustainability are becoming increasingly important, there is still a lack of universal metrics that reveal how industries are performing on these dimensions. Due to the lack of quantitative data on the metrics specific for each firm in the population, environmental attractiveness is thus best assessed from secondary data providing a general overview of the current state of the industry and how it scores.

The health tech industry has till now not been known for being an excessively pollutive industry. Industries, such as the oil and gas- or automotive industry have received more attention for their carbon footprint than health tech. However, this does not imply that the health tech industry has the potential to meet all sustainable solutions and environmental demands. In Norway today, we see that sustainability is becoming increasingly important in all types of industries for all types of firms. A report on sustainability conducted by PWC highlights this and found that in 2019 there were 30% more firms in Norway that would implement their business strategies according to the UN Sustainable Development Goals, than in 2018. It also found that from 2017 to 2019 there had been a doubling in the number of Norwegian firms that prioritized sustainability goals (Løvstad, Young & Øen, 2019). Norway Health Tech shares these views and has announced that the cluster organization will work actively towards meeting the UN Sustainable Development Goals (Norway Health Tech, 2018a). A point in the current Norwegian Government's political agenda is to build a sustainable national healthcare system. To do so, the Government highlights the presence and usage of novel and innovative solutions that will help reduce pollutions in this industry (Regjeringen, 2018).

The continuing focus on environmental and corporate social responsibility (hereafter CSR) is further highlighted in the health tech industry from the perspective of the Norwegian Specialist Health Service. In 2018, all health enterprises in Norway were environmentally certified in accordance with NS-EN ISO 14001 which is an environmental management system that organizations use to improve their environmental performance (Helse Midt-Norge, 2019). A report conducted by the Norwegian Specialist Health Service on the CSR of the four health regions in Norway presents the specialist health service's climate accounts. The climate accounts for 2018 calculated that the four regions in total accounted for approximately 420 ton of CO2-emissions. These emissions where mainly a result of (in ascending order) energy use, transportation of patients, transportation of employees and use of gas (Helse Midt-Norge, 2019). The health tech industry can help reduce emissions in several of these aspects with their products and services, for instance through an increased use of videoconferences for health services which to a certain extent can reduce the need for transportation of patients and employees. Also, deploying health ICT to replace old and inefficient systems can increase efficiency and thus reduce the energy usage within the specialist health service sector.

It is evident that many of the products and services that come from the health tech industry have the potential to help meet future environmental demands, yet there are still environmental challenges related to the products and services that come from this industry. Most of the products health tech firms offer, particularly firms in Medtech and Diagnostic, are machines and devices that are made of plastics, metals and other non-decomposable elements. The industry's challenges related to pollution and recycling are growing in parallel to the growing demand for the industries' products and services. A report by the United Nations University recognizes e-waste as one of the biggest and fastest growing global generators of emissions, with *only* 20% of the total waste being recycled properly (The Global E-waste Statistics Partnership, 2017). Further, the report found that the total e-waste, defined as products with a battery or plug, rose with 8% in the period 2014-2016. As the application of ICT in the health-sector continues to grow, electrical and electronic equipment continues to revolutionize the industry. With this, the dilemma of disposal of large amounts of "old" technology arises. Also, important to note is the large energy requirements that the deployment of health ICT generates

(Scott, Palacios & Maturana, n.d.). The general mindset today is that the deployment of health ICT will help face and meet the many environmental challenges that exist in today's society, however recent studies also address that deploying ICT in itself has severe environmental impacts as it represents large energy requirements and disposal of "old" technology (Arushanyan, 2016).

Environmental attractiveness: Conclusions

The assessment of the environmental attractiveness of the health tech industry must be done in the context that all industries essentially pollute and have a carbon footprint. Although this is an industry with a considerably lower carbon footprint than other manufacturing industries such as the oil and gas- and automotive industries, the industry has some clear challenges. These challenges are mainly related to the products and services that come from the industry with emphasis on e-waste and the large energy usage that the deployment of ICT has. Facing these challenges will be of high importance for the industry to be able to meet future sustainable solutions and environmental demands. On a more positive note, other industries can deploy services and products from the health tech industry which will help meet their environmental challenges. An example of this is technology for videoconferences within health services which potentially can reduce the needs for transportation by cars, planes or other means of transport. We see this as an industry that even with current environmental challenges will have the ability to meet future sustainable solutions and environmental demands. In total, the cluster scores a 7 on environmental attractiveness, which is equal to the score in 2010 (Sasson, 2011). Sasson did not present the analysis behind this score, which limits the comparability.

4.7 Knowledge Dynamics

The centrality of knowledge dynamics

The six dimensions analyzed in the previous chapter define the industry's ability to excel, and thus represent the preconditions for an industry to benefit from the knowledge externalities. For the industry to be able to benefit from the six dimensions in the model, there is a need for knowledge-related linkages between the industry actors and the creation of a dynamic environment. The dynamic force in the industry is a function of competitive- and collaborative linkages, as well as the overlap across industries. Further, knowledge sharing through the transaction of employees across firms and industries has been perceived as a key mechanism in achieved cluster benefits (Marshall 1920, Jaffe et al. 1990, Almeida & Kogut 1999). The collaborative and competitive linkages are positively affected by the clusters respective cluster organization. Thus, this chapter assesses the role of the cluster organization and how it seeks to strengthen the knowledge externalities of the cluster through the arrangement of events, matchmaking and enabling an innovation ecosystem.

The role of cluster organizations

Cluster organizations, among them Norway Health Tech, actively work towards strengthening the clusters ability to score on the attractiveness dimensions of *The Emerald Model*. More than anything, the cluster organizations work strategically towards influencing the knowledge dynamics in the cluster, between all actors, such as the firms, institutions and the Government. Hence, the cluster organizations seek to increase the pyramid in *The Emerald Model*, as visualized in Figure 4 in Chapter 2.3.

Collaboration in the health tech industry, as in most other industries, occurs in many forms, such as the horizontal relationships between similar firms, vertical relationships between suppliers and customers and other types of connections between firms, R&D and/or financial institutions and government agencies. An important facilitator for these relationships and linkages in the health tech industry is the cluster organization, Norway Health Tech. Norway Health Tech works as a facilitator to the extent where it has built an innovation ecosystem and is able to connect its members with other firms, innovation institutions, investors among other actors. A central role in doing so is through events, and in 2018 alone, Norway

Health Tech held 54 events, and was a part of 19 collaborative conferences and events (Norway Health Tech, 2018a). In addition, the cluster organization hosted 52 events in 2017, with as many as 1900 participants (Norway Health Tech, 2018b). Norway Health Tech highlights *The Educational Forums* as a great source of knowledge sharing. Among the forums, *QA Regulatory* is the most established. This forum seeks to address and discuss the most common regulatory challenges that the firms in the cluster are facing (Norway Health Tech, 2018b).

Furthermore, the cluster organization is strong driver for developing reports that benefit the Norwegian health industry. For instance, Norway Health Tech is a part of a consortium that since 2016 has published a report on the value of the Norwegian health industry. In this consortium we find strong actors as Innovation Norway, The Confederation of Norwegian Enterprise (NHO), and other cluster organizations, as Oslo Cancer Cluster and The Life Science Cluster (Jakobsen, Lind, Engebretsen & Skogli, 2020).

In 2017, the members of Norway Health Tech had an innovation rate of 96% (Norway Health Tech, 2018b). This is strongly driven by the close dialogue and strong collaboration Norway Health Tech has with central R&D an innovation institutions, as Innovation Norway, Siva, Sintef and The Research Council of Norway. Innovation Norway manages the cluster program that Norway Health Tech has been a part of for the last 10 years. Further, SIVA has a product-oriented program called The *Norwegian Catapult Programme.* This program, which is run in partnership with Innovation Norway and The Research Council of Norway, was established with the purpose of stimulating the product process from concept to market for SMEs (Norsk Katapult, n.d.). Norway Health Tech assisted SIVA in developing the catapult program and has in later years had several members that have received and applied for funds from it. Further, Norway Health Tech seeks to inspire Norwegian health tech firms to produce in Norway, and to leverage the knowledge of the economically efficient production sites. Through matchmaking, Norway Health Tech connects product innovating firms to production firms that are a part of the NCE Raufoss cluster (Norway Health Tech, 2018a).

Norway Health Tech works intensively with strengthening the international opportunities for its members. For instance, Norway Health Tech coordinates the two prestigious EU projects, INNOLABS and Cross 4 Health, which creates growth and acceleration opportunities for SMEs. Furthermore, the cluster organization creates, executes and participates in several acceleration programs, including Health Tech Nordics, Export Acceleration Program (Minneapolis, USA), Test, Scale Competence (Toronto, Canada), and others in Singapore, UK and Germany (Norway Health Tech, 2018a).

As a result of the many initiatives implemented, the cluster organization has experienced a strong growth in its member base. As presented in Figure 35, Norway Health Tech got 108 new members over the period 2013-2018, which amounts to a growth of 67%. Of these 108 firms, 54 became members of the cluster organization in 2018. This indicates a growing perception among firms on the potential value gain of being a member of the cluster. Further, a larger member base entails a larger set of nodes where knowledge sharing can take place.

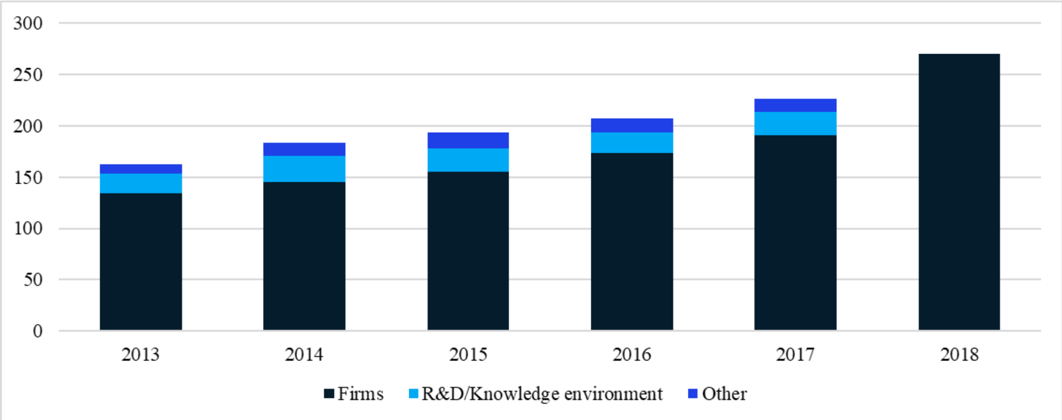

Figure 35 Development of members in Norway Health Tech (2013-2018)[8]

Source: Norway Health Tech (2018a, 2018b)

The Norwegian health tech innovation ecosystem

In the field of innovation studies, a significant claim is that innovation is systemic, leading to the appearance of the innovation ecosystem as a concept. This concept claims that the different aspects and factors that enable innovation are best viewed as a part of a greater system (Fransman, 2018). The process of product innovation, from idea-to-market, is a demanding process that *cannot* be undertaken independently. Through cultural closeness, institutional support, and most importantly, geographic proximity, the innovation ecosystem seeks to ease this process. Research institutions, incubators/accelerators, venture capitalists and Governments are common and central in the innovation ecosystem, that work along

[8] Breakdown of 2018 member-data is not available.

the innovation scaling stages, from ideation to sustainable scale (International Development Innovation Alliance, 2019). Yet, Norway has kept allegiant to the Triple Helix model, an innovation model that is claimed to be highly old-fashioned. Reve claims that the Triple Helix model omits the presence of the two most important innovation actors, namely the entrepreneurs that have created new enterprises from novel ideas, and the venture capitalists that dear to risk capital to invest in the innovation (Reve, 2018).

The cluster has experienced a *boost* in knowledge sharing events, which is partly a result of the implementation of specific measures by Norway Health Tech over the last years. Among the most critical was the establishment of Medical Growth House, a 3000 square meter co-working space located at Oslo Science Park which has been a facilitator for innovation in the ecosystem. This co-working space to date consists of more than 60 firms (Norway Health Tech, n.d. c). The co-working space enables interaction points between firms (both members and non-members of the cluster) which proves important for knowledge sharing. Further, Aleap a health-incubator established in 2016 by Oslo municipality, Innovation Norway and SIVA, and owned by Norway Health Tech, Inven2 and Oslo Science Park is a key initiative in boosting knowledge- and resource-sharing in the industry. By facilitating value creation and innovation, Aleap enables an ecosystem platform for ambitious entrepreneurs and startups. Along with Norway Health Tech, they enable a dynamic community that promotes knowledge sharing, learning and collaboration, in addition to supportive work in regulative processes and market research (Aleap, n.d.)

Another central aspect is the fact that Norway Health Tech is located in Oslo Science Park. Oslo Science park is a co-working area that seeks to offer ambitious entrepreneurs and firms with a great place to start and scale their business, by providing a physical infrastructure. The science park is the home of several clusters, such as The Life Science Cluster, and is further located with close proximity to central universities in Oslo, such as UiO, in addition to other central cluster actors. Further, by being an arena for seminars, events and various conferences, the science park enables a physical innovation infrastructure for the ecosystem (Oslo Science Park, n.d.).

Knowledge dynamics: Conclusion

Knowledge dynamics is a central aspect in a clusters ability to leverage the knowledge externalities that are present. In this process, the cluster organization plays a central role. Since the results presented in Sasson (2011) and Reve and Sasson (2012), Norway Health Tech has worked systematically in strengthening the knowledge dynamics of the cluster. Through the establishment of co-working spaces as Medical Growth House, increased cooperation with R&D institutions as SIVA, and the establishment of the health-incubator, Aleap, Norway Health Tech has achieved in doing so. Further, the cluster organization has intensified the arranging of events and conferences that have been received with appreciation by cluster members. In turn, this has led to a strong growth in number of members in the cluster organization, which strengthens the potential knowledge sharing for existing members.

In total, the cluster scores a 6 on Knowledge dynamics, compared to a 3 in 2010. Hence, there has been a strong improvement since Sasson (2011) that is mainly driven by the clear initiatives undertaken by Norway Health Tech to strengthen the overall cluster, but specifically on the knowledge dynamics.

5. Discussion and Implications

This chapter seeks to connect the theory derived in Chapter 2, with the analysis presented in Chapter 4. Further, it aims to discuss around, and answer, the research question presented in Chapter 1, namely *Has the Norwegian health tech cluster improved over the period of 2010-2018?* From Chapter 4 we get a view on the current state of the Norwegian health tech cluster. The major findings will be discussed in the beginning of the following section. Followingly, a discussion on the development of the cluster will be conducted in the same section. The ambition here is to elaborate on the state of the cluster in 2010, by examining the respective scores on the attractiveness dimensions and its resulting *Emerald Model*, and comparing it to the state in 2018. The findings will provide the foundation for the firm strategy- and public policy recommendations that are to be presented in Chapter 5.2.

5.1 The Norwegian Health Tech Cluster

The Norwegian health and biotech industry in 2010

The Norwegian health and biotech industry was by Reve and Sasson (2012) defined as an emerging knowledge industry. In the analysis by Sasson (2011), the author found a range of strengths and weaknesses the industry had. Below follows an exhaustive list with a brief description of Sasson's key findings.

Weak value creation, but strong concentration around the Oslo region

Sasson found that the value creation in the health industry was lower than other industries in Norway, with an average of *only* MNOK 0.6. On the contrary, the industry was strongly centered around the Greater Oslo Region where a large share of the total revenues was generated. For instance, 58% of the Diagnostic-firms, who accounted for 30% of the sector's revenues, had their base in the Oslo region.

Diagnostic and treatment will survive globally

For a firm to survive in an international market, it must outperform other international actors. A way to measure this is by examining the firms share of foreign sales relative to the total sales. The analysis found that Diagnostic and

Treatment were best suited to survive internationally as foreign sales amounted to 83% and 62% respectively of the firm's total sales.

Mixed signals from education and talent attractiveness

Sasson found that there was a lack of investment in educational programs that had the ability to provide firms with knowledge to further build upon. Further he found that the overall number of students in health-related fields had remained constant, while the number of Master students was moderately negative. This was a finding of *great* concern, as it potentially limits the number of students enrolled in PhD-studies which is crucial for several sectors in the health industry.

On the human capital side, the author found the health industry to be highly professionalized, as 57% of the employees had a university degree. 44% of employees held a bachelor's degree, compared to a national average of *only* 20%. On the contrary, Treatment and Diagnostic, the sectors in the industry that had received the greatest amount of public investments, had a decrease in their relative share of employees with a university degree. Further, he found a weak increase in number of employees with a scientific- and technological background, which he deemed as crucial for a fast-growing industry.

More research intensive than other industries, yet lacking competent owners

The author found that the health industry was significantly more innovative than other Norwegian industries. However, this was *only* the case in regard to product innovation, and not service. Further, the industry was found to be quite research intensive, with a steady growth in both the absolute number of academics in the research community, and in the number of publications.

Among the greatest areas of concern for the health and biotech industry was the lack of competent owners. New industries, as biotech was at the time Sasson conducted his study, generally struggling with attracting owners that were defined as competent. The author found that a large share of the firms in the health industry had foreign owners. Further, he found that close to 90% of the firms had owners that *only* owned 1-2 firms. Serial-owners are generally a great source of knowledge and experience for new ventures.

Current state of the Norwegian health tech cluster

The industry is still an emerging growth industry, and health tech as a concept is still *young* and under development. Yet, with the emerging global societal challenges, there is a constant growth in the demand for the products and services from health firms. The health expenditure per capita in Norway more than doubled over the period of 2008-2018 and amounts to an increasingly large share of the national GDP. As the health sector in Norway is publicly financed, it imposes great costs on the Government. Yet, one out of three firms in the health industry are *born global,* indicating that they are international from the day they receive their first revenues (Jakobsen et al., 2019). This highlights the potential value creation on a global scale, and the reason why the Norwegian Government mention the health sector, with health tech as a central aspect, as a key area for increased revenue generation and value creation for the coming years on a national scale (Regjeringen, 2019a).

This study was initiated with the goal of determining the development of the cluster and highlights the potential gain that lies in the industry. In the following, an in-depth reflection on the key findings derived from the study will be presented.

Strong value creation and high concentration around the Oslo region

Overall, the health tech cluster had an average value creation per employee in 2018 of MNOK 1.6. The biggest driver behind this number is Diagnostic, with an average value creation per employee of MNOK 2.3 in 2018. This is a strong improvement since 2010, when the average value creation in the health sector was MNOK 0.6 per employee.

A subject of concern is that Medtech, which is one of the core pillars in health tech, overall is *underperforming* compared to the other subgroups in the industry. As presented in Chapter 4.1, Medtech accounts for the smallest share of total revenues despite accounting for the greatest share of firms in the industry. One can claim that such a central aspect of an industry, as Medtech is, should have a stronger performance than what it has had. In 2018, as many as 75.5% of firms in Medtech had revenues less than or equal to MNOK 10. Further, there were no Medtech firms with revenues greater than BNOK 1, while this was the case for 7.4% of firms in Health ICT. Over the period of 2010-2018 Medtech had the lowest contribution to the total value creation in the cluster, amounting to 2.8% of the total value creation in 2018, while Health ICT amounted for 31.1%. Additionally, Medtech was among the subgroups with the lowest growth in value creation over the period, amounting to 24%. The reason for this trend in Medtech is that the subgroup is highly characterized by a large number of startups and SMEs that are yet to create value and generate profits from their products and solutions. Further, the idea-to-product-to-market process in Medtech is more time- and capital consuming than of for instance Health ICT. It is also worth mentioning that medtech products usually have a lifecycle of *only* 18-24 months before an improved product is introduced to the market (MedTech Europe, 2020).

Further, the cluster is still highly concentrated around the two regions Oslo and Viken. 48% of the firms are located in the two regions, and these firms accounted for 89% of the total revenues in the cluster. Further, 56% of Health ICT firms, and 54% of Diagnostic firms are located in Oslo and Viken. Health ICT and Diagnostic are the two subgroups with the greatest contribution to the total revenues, and respectively accounted for 57% and 18% of the 2018 revenues.

Increasing attractiveness of health tech studies

As a result of the increasing attention and relevance of health tech, there was a strong growth in the total number of students in health tech-related studies in 2010-2018 (27%), indicating a strengthening of the attractiveness of the cluster. Yet, the number of students undertaking a Bachelor in health tech-related studies decreased with 8% in 2015-2018, which in turn can negatively influence the number of students undertaking a Master and/or PhD. We note that there has been an increased investment in relevant educational programs, leading to the establishment of several new studies that are directly health tech oriented. Due to this, we expect a change in the negative trend in the number of bachelor students in the coming years. We especially highlight the emergence of relevant studies in Oslo, at institutions as UiO and OsloMet, which will be a central talent-pool for the many firms located in this region. Yet, it is important to note that the investment in new relevant studies currently is not at a sufficient level.

A highly innovative cluster

The Norwegian health tech cluster remains as a research intensive and highly innovative cluster. From 2010-2018 there was a growth of 180% in number of publications on topics related to health tech. This number was strongly driven by highly influential institutions, such as UiO, NTNU and Sintef. The publications were mainly financed by foreign funding agencies, such as The European Union, The U.S. Department of Health & Human Services and The Natural National Science Foundation of China. This is a two-fold finding: On one side this can indicate a lack of retention, as valuable findings can end up in the position of the foreign firms and agencies, rather than to the benefit of local firms. On the contrary, this strongly underlines the increased attention from global scientists, investors and public authorities and the positioning as an innovative nation, and especially in health tech. This is visible through the high number of firms claiming to have introduced new products and/or services in 2016-2018.

Lack of home market and competent owners

The two main challenges the Norwegian health tech cluster is facing, is the lack of a national market for health tech products and services, and the absence of competent owners and private capital. The two challenges are of significant matter, as they have collectively led to a slowdown in the development of a future-oriented industry that is typically characterized by being fast-growing. Further, the challenges are among the reasons for why the Norwegian health tech cluster is lagging behind similar clusters in neighboring countries as Denmark and Sweden.

The size of Norway, measured in number of habitants, naturally limits the national growth potential for the firms in the cluster, *forcing* them to aim internationally to survive. Further, the firms are facing strong structural barriers, as the Norwegian market is characterized by *only* having *one* customer, namely the Government. Additionally, there is a lack of business policy, and a somewhat negative culture in the market, which is characterized by a week collaboration between firms and the Government. The Norwegian Government is known for being old-fashioned and passive in their procurement policies, which has hampered the appearance and introduction of new products, services and technologies that would benefit the firms, end-users and the public sector.

The lack of competent ownership is still a critical barrier to growth for the health tech cluster, and the fragmented market, as described above, is among the key reasons for the lack of competent owners and private capital in the cluster. Another central aspect is the long commercialization process for firms throughout the industry, and a pre-commercial phase with costs that exceed the revenues. Investing in health-related projects is still perceived as risky by private investors.

The Norwegian health tech cluster, 2010 versus 2018

The analysis conducted in Chapter 4, by Sasson (2011) and the reflections presented in the beginning of Chapter 5.1 has resulted in specific numerical scores on the respective dimensions of *The Emerald Model*, both for the state of the cluster in 2010 and in 2018. These scores are presented in Table 5. Further, Figures 36 and 37 visualise the attractiveness of the cluster by presenting the characteristic emerald, which works as a great indication and summary of how the cluster has developed over the years. An instant indication from the two figures is the increased height of the pyramid. This is a result of a strengthened and improved knowledge dynamics in the cluster. As described in Chapter 4.7, this is to a great extent due to the initiatives undertaken by Norway Health Tech. Further, strengthening the knowledge dynamics of a cluster is among the main tasks a cluster organization has. Hence, this indicates Norway Health Tech has to some extent successfully responded to the specific findings and recommendations as presented by Sasson in 2011.

Another area of great improvement has been on the cluster attractiveness of the cluster. This is to a great extent driven by the strenghtened and increased value creation per employee, and the further fortification around the Greater Oslo Region. Furthermore, one out of three health tech firms are born global, which support the claim of international potential for the Norwegian cluster.

	Attractiveness in 2010	Attractiveness in 2018
Cluster attractiveness	3	6
Educational attractiveness	6	7
Talent attractiveness	4	5
R&D&I attractiveness	8	9
Ownership attractiveness	3	4
Environmental attractiveness	7	7
Knowledge dynamics	3	6

Table 5 State of the Norwegian health the cluster (2010 and 2018)
Source: Et Kunnskapsbasert Norge, 2012 and thesis analysis, 2020

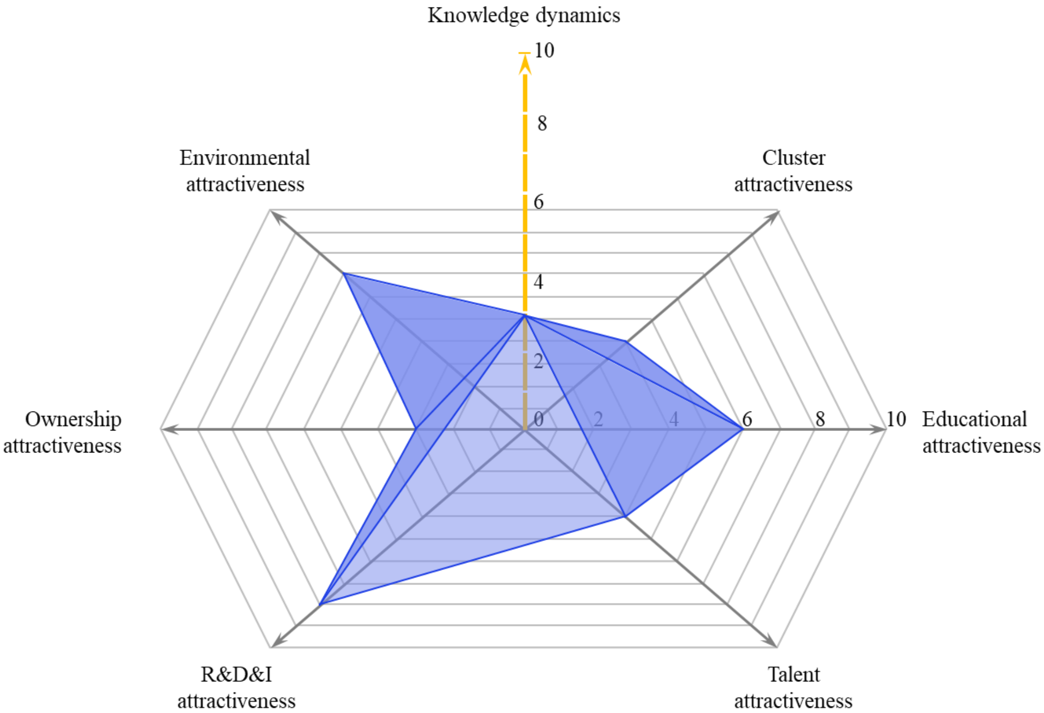

Figure 36 Health and biotech Emerald Model (2010)

Source: Et Kunnskapsbasert Norge, 2012

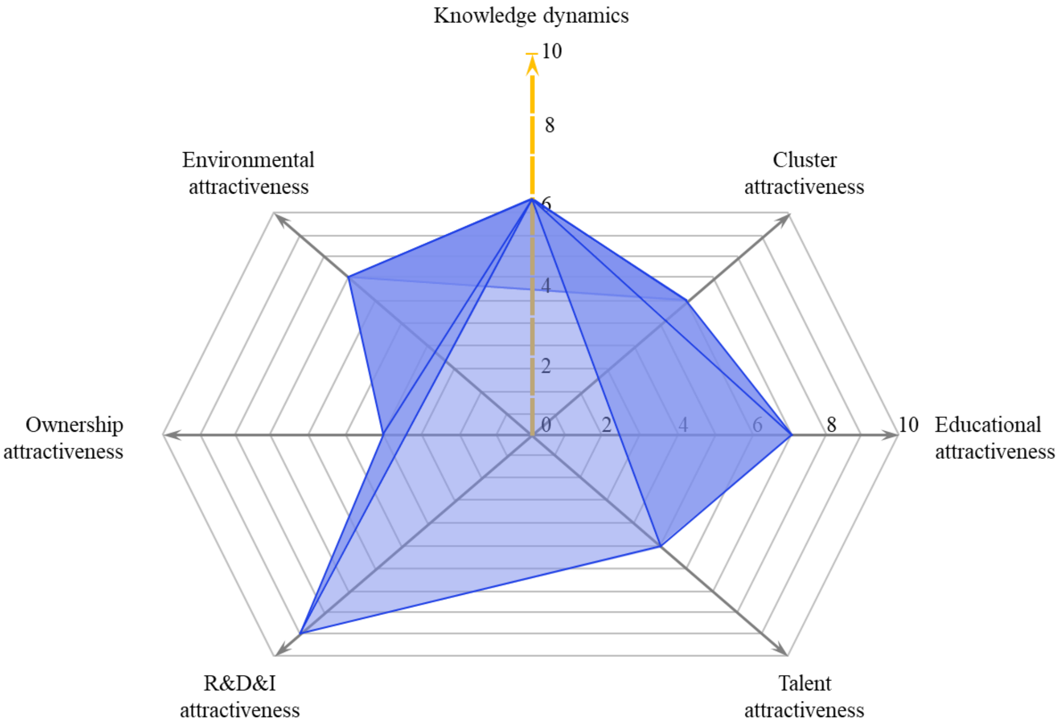

Figure 37 Health tech Emerald Model (2018)

Source: Analysis by authors of this thesis, 2020

5.2 Firm Strategies and Public Policy Recommendations

The cluster is developing, but at a slower pace than desired. It suffers from structural barriers as outlined under *Current state of the Norwegian health tech cluster* in Chapter 5.1. These barriers are hampering the cluster's ability to grow and for the firms to scale their business.

One out of three health tech firms are born global, indicating international revenues from day one, and great international ambitions and opportunities. Hence, the beginning of this section outlines general firm strategies that are recommended for the cluster's current, and future firms that have international ambitions. Further, in order to overcome the barriers as described above, a set of initiatives *need* to be implemented by public officials. These initiatives all aim at setting a collective overall strategic direction for the Norwegian health tech industry, and thus the cluster.

Firm strategies

Deepen vertical and horizontal cooperation for long-term value creation

To ensure international competitiveness of the Norwegian health tech cluster, firms are urged to intensify B2B vertical and horizontal collaboration and knowledge exchange. As the cluster includes firms that are present in all value chain steps, there are potential benefits from strengthened interorganizational ties in research intensive sectors in the industry, to increase competitiveness against international and national fast-moving competitors. For instance, strengthening the collaboration and communication with the treatment side of the health industry, i.e. hospitals, has the clear potential of increasing accuracy of product offering relative to the need.

Furthermore, Norway Health Tech is urged to further enhance collaboration with other health tech related clusters in Norway, and especially the Oslo region, as e.g. The Life Science Cluster. For instance, in Denmark, four regional health tech clusters have collaborated in creating an innovation network called Danish Healthtech, to centralize competencies and foster innovation. Additionally, the core partner of the innovation network is a consortium of five leading Danish universities (Danish Healthtech, n.d.).

Invest in unique and disruptive technologies and sufficiently manage the J-curve

With the increasing attention and centrality of products and services offered by health tech firms, it is likely that both the national and international markets will experience a boost in the appearance of new firms that are able to offer such. In an industry characterized by great first-mover advantages, we highlight the need of unconventional thinking and problem solving to find pioneering innovations that "pave the way" globally for the Norwegian health tech cluster. Furthermore, as the cluster to a great extent is characterized by firms that are in the *J-curve*, there is a need for effective business planning. The initial phases of the *J-curve* pose a challenge for the firms, and it is important that the firms do not outgrow their own potential. However, overcoming the initial phases entails a strong potential for value creation.

Intensify internationalization of products

In a recent report by MedTech Europe, the European medtech market is estimated to be worth BEUR 120 in 2018. Furthermore, the European market is estimated to make up only 27% of the global market, while the US represents the largest market (43%). These figures highlight the potential benefits that lie in the international market (MedTech Europe, 2020). As described in Chapter 4.1, Norway has a trade deficit of medtech products that has amounted to more than MEUR 600 since 2015 (MedTech Europe, 2016). This can indicate a lack of competitiveness of domestic products relative to the international. While the Norwegian medtech market is small in size, the trade deficit indicates that domestic procurers are sourcing internationally rather than locally. Hence, Norwegian health tech firms should intensify their focus on the large international markets. For instance, while the Finnish and Danish medtech market were not among the top 10 biggest markets in Europe in 2018, they had the fifth and sixth highest exports per inhabitant, amounting to EUR 329 and 325 respectively. Further, Finland had the sixth biggest trade surplus, while Denmark had the eighth in 2018 (MedTech Europe, 2020).

Public policy recommendations

Enhance collaboration with health tech actors and commercialize health services

To somewhat reduce the challenge health tech firms are facing with regards to the lack of home market, the current collaboration between the Government, Norway

Health Tech and cluster members needs to be remarkably improved. Strengthening the dialogue between the public and Norway Health Tech has the potential to somewhat help the Government transit from the old-fashioned procurement process, to one that fosters innovation and entrepreneurship. Furthermore, health tech firms must aim towards entering international markets in order to succeed in the long run. Investing in Norway Health Tech has the great potential of reducing barriers of entering these markets. Additionally, the level of bureaucracy and administrative costs need to be reduced in order to ease the public tender process in the health industry, which many firms currently are struggling with, especially startups and SMEs. As we know, the health tech cluster is highly characterized by these types of firms. This has the potential to attract entrepreneurs, promote entrepreneurship and incentivize the investment in health tech projects that are perceived as risky.

Further invest in educational programs and human capital

While the appearance of health tech-related study programs indicates an increased investment in the area, the investment needs to be further increased to ensure a substantial development of talent in the form of practitioners and researchers. By for instance investing heavily in national study programs in medtech, biotech, health ICT and such, the Government would indicate that health tech is of high national priority, which in turn attracts future students, talent, investors and attention in general to the industry. Long-term attractiveness of health tech among investors and talent is crucial for the cluster to transit from an emerging to developed cluster.

Establish aid and fund schemes

The access to public aid and fund, and risk/venture capital is critical for a firm's ability to succeed and scale. A weak access to these sources of capital impose great barriers for firms, this is the case for the health tech cluster, and health industry in general. Health tech is becoming increasingly important, as the Government highlights the health industry, with health tech as a key area, as a future area for increased revenues and greater value creation (Regjeringen, 2019a). For the industry to reach this potential, there is a strong need for the establishment of new public aid schemes and/or preferential taxation arrangements that are solely to the benefit of health tech firms.

5.3 Strengths and Limitations

This study has provided some extensive insights on the current state, and development, of the Norwegian health tech cluster. Nonetheless, the insights and their contribution should be seen and evaluated in respect to their completeness, and in relation to its related strengths and limitations.

Strengths

The close collaboration with Norway Health Tech, the cluster organization of the cluster that has been the unit of analysis of this study, is among the most eminent strengths of the study itself. This collaboration has been a source of great insights and data that otherwise would not be available. Further, the fact that Torger Reve has been the supervisor of the study, strengthens the comparative aspect of it, as he was a central part in the study conducted by Sasson (2011). It is also worth mentioning that partnering with Norway Health Tech, and having Torger Reve as the thesis supervisor, enabled us to get in touch with Menon, and thus to get access to the highly needed data. As made visible under data collection in Chapter 3, and in the analysis in Chapter 4, most of the analysis in this study is based on the data provided by Menon. The fact that the data is provided by a credible actor as Menon, strengthens the overall reliability and validity of the study

Parallel with the increase in new global challenges and disruptive health crises, as the Covid-19, the health tech cluster, and this study, have become increasingly relevant. While a health crisis is a threat for most industries and firms, it is not necessarily so for health tech firms. This is visible through the massive attention around health tech products and services, and increased interest in health tech firms on the various stock markets. We believe that this positive trend will be of strong value for the cluster's ability to attract capital, as health tech might be perceived as a less risky field to invest in, in the coming years. In turn, this will strengthen the cluster where it currently is the weakest, namely at attracting competent capital.

Furthermore, there is an overall trend in which Governments, investors and the societies in general are valuing sustainable products and solutions to a greater extent. Health tech firms have the possibility to have a central role in providing these products and services. In a survey provided by Menon in a recent health report, 75% of the respondents view the increased focus on sustainability as an opportunity, while *only* 5% deem it as a challenge (Jakobsen et al., 2020).

Limitations

The main limitation with this study is related to the choice of population. While we are limiting our research to the four subgroups Medtech, Health ICT, Specialized subcontractors and Diagnostic, Sasson (2011) conducted an analysis of the entire health industry and its activities. The sole reason for this divergence is due to the choice of maximizing the focus and orientation of this study around the health tech aspect of the health industry. This entails that the study findings are of utmost relevance for Norway Health Tech. Yet, we recognize Sasson (2011) as a suitable benchmark for this study, as the data collection has been conducted with the purpose of keeping the analysis comparable. Furthermore, Reve is a common denominator in both studies, which strengthens comparability.

The availability of data has to some extent been restricted, which again has limited the analysis of given dimensions in the study. This is strongly linked to the fact that health tech as a concept is still quite new, which naturally limits the availability of valid data. For instance, while Statistics Norway provides annual data on the emission of greenhouse gasses per industry, this is not available for health tech as it is yet to be defined as a specific industry in Norway. For the dimensions where relevant data was unavailable, the dimensions were analyzed in a broader sense. This poses a weakness of the replicability of the study. For instance, to sufficiently assess the environmental attractiveness of the cluster, a survey could be provided to the members of the cluster. In a potential survey, the firm representatives could numerically grade how the firm performs on a set of environmental metrics, e.g. on emission of greenhouse gasses. With a significant number of respondents, we would be able to obtain more meaningful insights on how the cluster is performing on the different environmental metrics.

Finally, the subjective nature of *The Emerald Model* should be taken into account when interpreting the findings of this study. While the analysis of the respective attractiveness dimensions is based on valid input in the form of quantitative data, the final score that is provided is still to some extent subject to the authors subjective opinion. However, we emphasize the fact that the score itself is not where the value resides, but rather in the analysis that has led to it.

5.4 Future Research

The potential for future research is two-folded and based on the limitations of this study: One side focuses on strengthening the theoretical model, while the other focuses on strengthening a potential future study on the same topic.

While the existing literature within the fields of clusters and *The Emerald Model* provide comprehensive insights, they are somewhat under-investigated. In order to strengthen the reliability and validity of the model, we highlight the need for further conceptual and empirical investigation on cluster theory, and testing of *The Emerald Model.*

Further, as these studies have proven to be of substantial benefit for the Norwegian health tech cluster, referring to Sasson (2011), we suggest implementing some sort of continuity of conducting a similar study in the coming years. For instance, a study on the state of the Norwegian health tech cluster in the coming 5-10 years could derive interesting findings. This as the cluster is set to mark the transition from emerging to developed. Furthermore, it will be interesting to see the post Covid-19 situation and effects, and to support or disregard our claims that health tech firms are benefiting from the pandemic.

Lastly, for a potential new and similar study on the Norwegian health tech cluster we recommend a triangulation approach in the data collection. By combining qualitative and quantitative data in a complementary way, the two data sources can be compared to determine whether there are any connections and/or differences between them (Creswell, 2009; Creswell, Plano Clark, Gutmann & Hanson, 2003). This would strengthen a potential study and provide data where it is otherwise limited.

6. Conclusion

Health tech as an industry is still a new concept and remains unknown for many. Yet, with the growing demand of the products and services offered by the industry, it is fair to claim that the concept will be on *everyone's* mind in the coming years.

This study was set to examine the development of the Norwegian health tech cluster over the period of 2010-2018, by evaluating the cluster in relation to the dimensions of *The Emerald Model.* The study found that the cluster has improved on several of the dimensions in the model, while some remain *unchanged* relative to the state in 2010. In particular the cluster has improved *significantly* on cluster attractiveness and knowledge dynamics, which we believe is a result of the explicit strategic actions the cluster organization, Norway Health Tech has initiated since the publication of *Knowledge Based Health* in 2011 (Sasson, 2011). These are pleasant findings as they support the initial hypothesis derived in Chapter 1.3.

Furthermore, the study has identified a set of challenges the cluster currently is facing, and that are limiting its growth possibilities. In order to overcome these barriers, a set of recommendations have been presented to the firms in the cluster, as well as public policy recommendations. We found the need for strengthened vertical and horizontal collaboration among the actors in the cluster in order to ensure long-term value creation. Firms are further encouraged to invest in unique and disruptive technologies that will ensure global competitiveness of the firm itself, as well as the cluster. On the public policy side of the recommendations, there is a strong need for further investment in relevant educational programs. Lastly, there is a need for aid and fund schemes that are established with the purpose of benefiting and boosting the innovation and entrepreneurship of the Norwegian health tech firms.

The study provides contribution to the field of *The Emerald Model* which has yet to be applied at a sufficient scale in academia. We hope this study will further encourage and motivate researchers to examine the field of cluster attractiveness and apply *The Emerald Model*. Furthermore, as the Norwegian health tech cluster is still emerging, we encourage others to take on the baton to do a further investigation of the field, as we did with Amir Sasson.

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Appendix

Exhibit 1 – Media Analysis

Below follows an exhaustive list of words included in the media analysis in Chapter 1.1.

"Helseteknologi, medtech, healthtech, technology, helseinformatikk, biotech, biotek, biotechnology, bioteknologi, medtek, healthtech, helsetek, biokjemi, biochemistry, health-tech, neurosciences, helse-ikt, helse-ict, nanoteknologi, nanotechnology"

Exhibit 2 – Health Tech-Related Study Fields

Below follows an exhaustive list of study fields included in the analysis in Chapter 4.2.

"Allmenn maskinteknikk, Arktiske anlegg, ingeniør – bachelor, Automasjon, ingeniør – bachelor, Automatisering og elektronikkdesign - bachelorstudium i ingeniørfag, Automatisering og elektronikkdesign - bachelorstudium i ingeniørfag – deltid, Automatisering og elektronikkdesign - y-vei bachelor i ingeniørfag, Automatisering og elektronikkdesign - y-vei bachelor i ingeniørfag deltid, Automatiseringsteknikk, Bachelor i ingeniørfag – Automatiseringsteknikk, Bachelor i ingeniørfag – Bygg, Bachelor i ingeniørfag - Bygg-Fleksibel, Bachelor i ingeniørfag - Bygg konstruksjon-fleksibel, Bachelor i ingeniørfag - Bygg Nettbasert, Bachelor i ingeniørfag - bygg konstruksjon, Bachelor i ingeniørfag - bygg prosjektstyring og ledelse, Bachelor i ingeniørfag - bygg prosjektstyring og ledelse-fleksibel, Bachelor i ingeniørfag - bygg vann- og avløpsteknikk, Bachelor i ingeniørfag – bygg landmåling, Bachelor i ingeniørfag – bygg landmåling-fleksibel, Bachelor i ingeniørfag - Data, Bachelor i ingeniørfag - datateknikk, Bachelor i ingeniørfag - Elektro, Bachelor i ingeniørfag - Elkraft, Bachelor i ingeniørfag - Elkraft-nettbasert, Bachelor i ingeniørfag - industriell design og teknologiledelse, Bachelor i ingeniørfag - maskin, Bachelor i ingeniørfag – maskin Lean Manufacturing, Bachelor i ingeniørfag – maskin fleksibel, Bachelor i ingeniørfag – maskin nettbasert, Bachelor i ingeniørfag - Produkt og systemdesign, Bachelor i ingeniørfag - Produktutvikling og design, Bachelor i ingeniørfag -

Skipsdesign, Bachelor i ingeniørfag - Vann- og miljøteknikk, Bachelor i ingeniørfag - Vann- og miljøteknologi, Bachelor i ingeniørfag - anvendt mikro- og nanoteknologi, Bachelor i ingeniørfag - automatisering med robotikk, Bachelor i ingeniørfag - automatisering med robotikk y-vei, Bachelor i ingeniørfag - Brannsikkerhet, Bachelor i ingeniørfag - Brannsikkerhet Y-vei, Bachelor i ingeniørfag - bygg, Bachelor i ingeniørfag - data, Bachelor i ingeniørfag - dataingeniør sikkerhet og nettverk, Bachelor i ingeniørfag - elektro, Bachelor i ingeniørfag - elektro elkraft, Bachelor i ingeniørfag - elektro for fagteknikere, Bachelor i ingeniørfag - Elektro Y-vei, Bachelor i ingeniørfag – elektro automasjon, Bachelor i ingeniørfag – elektro automasjon og robotikk, Bachelor i ingeniørfag - elektronikk, Bachelor i ingeniørfag - elkraftteknikk, Bachelor i ingeniørfag - fornybar energi, Bachelor i ingeniørfag - geomatikk, Bachelor i ingeniørfag - HMS, Bachelor i ingeniørfag - kjemi, Bachelor i ingeniørfag - logistikk, Bachelor i ingeniørfag - maskin, Bachelor i ingeniørfag - maskin for fagteknikere, Bachelor i ingeniørfag - materialteknologi, Bachelor i ingeniørfag - mikro- og nanosystemteknologi, Bachelor i ingeniørfag - mikro- og nanoteknologi, Bachelor i ingeniørfag - olje- og gassteknologi, Bachelor i ingeniørfag - produktdesign, Bachelor i ingeniørfag - sikkerhet, Bachelor i ingeniørfag - SMART produktdesign, Bachelor ingeniør - Y-vei industriell elektronikk, Bachelor ingeniør - Y-vei industriell elektronikk fleksibel, Bachelor ingeniør - Y-vei satellitteknologi, Bachelor ingeniørfag - Elektronikk Y-VEI, Bachelor ingeniørfag - Allmenn bygg, Bachelor ingeniørfag - Bygg og industri, Bachelor ingeniørfag - bygg y-vei, Bachelor ingeniørfag - Datateknikk, Bachelor ingeniørfag - Datateknikk Y-vei, Bachelor ingeniørfag - Elektro, Bachelor ingeniørfag - Elektro-, Kraft- og Romteknologi, Bachelor ingeniørfag - Elektronikk, Bachelor ingeniørfag - Elkraft, Bachelor ingeniørfag - Elkraft Y-vei, Bachelor ingeniørfag - Elkraft Y-vei fleksibelt, Bachelor ingeniørfag - fornybar energi, Bachelor ingeniørfag - fornybar energi (nettbasert), Bachelor ingeniørfag - Industriell Elektronikk, Bachelor ingeniørfag - Industriteknikk, Bachelor ingeniørfag - Kraftdesign, Bachelor ingeniørfag - Kraftdesign Y-VEI, Bachelor ingeniørfag - maskin, Bachelor ingeniørfag - maskin y-vei, Bachelor ingeniørfag - Prosessteknologi, Bachelor ingeniørfag - Satellitteknologi, Bachelor ingeniørfag bygg - y-vei fleksibel, Bachelor ingeniørfag maskin- y-vei fleksibel, Bachelor ingeniørfag prosessteknologi - y-vei fleksibel, Bachelor ingeniørfag prosessteknologi y-vei, Bachelor ingeniørfag prosessteknologi y-vei fleksibel, Bachelorstudium i ingeniørfag - Bioteknologi og *kjemi, Bachelorstudium i ingeniørfag - bygg, Bachelorstudium i ingeniørfag - bygg, TRESS, Bachelorstudium i ingeniørfag - bygg, Y-veien, Bachelorstudium i ingeniørfag - data, Bachelorstudium i ingeniørfag - data, TRESS, Bachelorstudium i ingeniørfag - data, Y-veien, , Bachelorstudium i ingeniørfag - elektro, Bachelorstudium i ingeniørfag - elektro, TRESS, Bachelorstudium i ingeniørfag - elektro, Y-veien, Bachelorstudium i ingeniørfag - elektronikk og informasjonsteknologi, Bachelorstudium i ingeniørfag - Energi og miljø, Bachelorstudium i ingeniørfag - industriell design, Bachelorstudium i ingeniørfag - industriell design, TRESS, Bachelorstudium i ingeniørfag - kjemi, Bachelorstudium i ingeniørfag - kjemi, TRESS, Bachelorstudium i ingeniørfag - kjemi, Y-veien, Bachelorstudium i ingeniørfag - Maskin, Bachelorstudium i ingeniørfag - maskin, TRESS, Bachelorstudium i ingeniørfag - maskin, Y-veien, Bygg, Bygg og anleggsfag, Bygg, ingeniør - bachelor, Bygg, ingeniør - bachelor (3-semester), Bygg, ingeniør - bachelor (nettbasert), Bygg, ingeniør - bachelor (y-vei), Bygg, ingeniør (3-semesterordning) - bachelor, Bygg, ingeniør (nettbasert) - bachelor, Bygg, ingeniør (y-vei) - bachelor, Byggdesign, 3-årig ingeniørutdanning - bachelor, Byggingeniør - bachelorstudium i ingeniørfag, Data, Data - bachelorstudium i ingeniørfag, Data, 3-årig ingeniørutdanning, Datateknikk ingeniør - bachelor, Datateknikk ingeniør - bachelor (3-semester), Datateknikk ingeniør - bachelor (nettbasert), Datateknikk ingeniør - bachelor (y-vei), Datateknikk ingeniør (3-semesterordning) - bachelor, Datateknikk ingeniør (nettbasert) - bachelor, Datateknikk ingeniør (y-vei) - bachelor, Datateknologi - bachelorstudium i ingeniørfag, Datateknologi - bachelorstudium i ingeniørfag - deltid, Droneteknologi ingeniør - bachelor, Elektro, Elektro - bachelorstudium i ingeniørfag, Elektro - 3-årig ingeniørutdanning, Elektro ingeniør - bachelor, Elektro ingeniør (y-vei) - bachelor, Elektronikk, Elektronikk 3-årig ingeniørutdanning - bachelor, Elektronikk ingeniør - bachelor, Elektronikk ingeniør - bachelor (3-semester), Elektronikk ingeniør - bachelor (y-vei), Elkraftteknikk, Elkraftteknikk - bachelor, ingeniør - (3 semester), Elkraftteknikk 3-årig ingeniørutdanning – bachelor, Elkraftteknikk ingeniør - bachelor, Elkraftteknikk ingeniør - bachelor (3-semester), Elkraftteknikk ingeniør - bachelor (y-vei), Elkraftteknikk ingeniør (y-vei) - bachelor, Energiteknologi, Gass- og energiteknologi - 3-årig ingeniørutdanning, Geovitenskap - Bachelorstudium i ingeniørfag, Havteknologi, Industriell elektronikk, ingeniør - bachelor, Industriell elektronikk, ingeniør (3-semesterordning) - bachelor, Industriell elektronikk -*

ingeniør (y-vei) bachelor, Informatikk og automatisering, 3-årig ingeniørutdanning - bachelor, Ingeniørfag byggdesign -bachelorprogram, Ingeniørfag data - bachelorprogram, Ingeniørfag elektro, automatiseringsteknikk -bachelorstudium, Ingeniørfag elektro, energi, elkraft og miljø - bachelorstudium, Ingeniørfag elektro, energi, elkraft og miljø - bachelorstudium Y-vei, Ingeniørfag elektronikk, bachelorprogram, Ingeniørfag elektronikk - Y-veien bachelorprogram, Ingeniørfag energi- og elkraftteknikk - Y-veien, bachelorprogram, Ingeniørfag energi- og elkraftteknikk - bachelorprogram, Ingeniørfag flyteknikk - bachelorprogram, Ingeniørfag flyteknikk - Y-vei bachelorprogram, Ingeniørfag fornybar energi - Y-veien bachelorprogram, Ingeniørfag fornybar energi - bachelorprogram, Ingeniørfag maskin - bachelorprogram, Ingeniørfag maskin - Y-vei bachelorprogram, Ingeniørfag Mekatronikk - bachelorprogram, Ingeniørfag bygg og anlegg - bachelorstudium, Ingeniørfag bygg og anlegg - bachelorstudium Y-vei, Kjemi, Kjemi Miljøbioteknologi - bachelorstudium i ingeniørfag, Kjemi og miljø - bachelorstudium i ingeniørfag, Kommunikasjonssystemer, Marinteknikk, Maskin, Maskin (nettbasert) - bachelor, ingeniør, Maskin 3-årig ingeniørutdanning, Maskiningeniør - bachelor, Maskiningeniør (3-semesterordning) - bachelor, Maskiningeniør (nettbasert) - bachelor, Maskiningeniør (y-vei) - bachelor, Maskiningeniør - bachelorstudium i ingeniørfag, studieretning konstruksjons- og materialteknikk, Maskiningeniør - y-vei bachelor i ingeniørfag, Maskinteknisk design - 3-årig ingeniørutdanning bachelor, Nautikk - bachelor (ingeniør), Nautikk ingeniør - bachelor, Nettbasert Bachelor ingeniørfag - Allmenn bygg, Nettbasert bachelor ingeniørfag - bygg, Nettbasert Bachelor ingeniørfag - Bygg og industri, Nettbasert Bachelor ingeniørfag - Datateknikk, Nettbasert Bachelor ingeniørfag - Industri, Nettbasert Bachelor ingeniørfag - Prosessteknologi, Petroleumsgeologi - Bachelorstudium i ingeniørfag, Petroleumsteknologi - Bachelorstudium i ingeniørfag, Plan og infrastruktur - 3-årig ingeniørutdanning bachelor, Produksjonsteknikk, Prosess- og gassteknologi - bachelor ingeniør (ordinær og y-vei), Prosess- og gassteknologi, ingeniør (ordinær og y-vei) - bachelor, Prosessteknologi, ingeniør - bachelor, Prosessteknologi, ingeniør - bachelor (3-semester), Prosessteknologi, ingeniør - bachelor (nettbasert), Prosessteknologi, ingeniør - bachelor (ordinær, y-vei, 3-semester), Prosessteknologi ingeniør - bachelor (y-vei), Prosessteknologi ingeniør (3-semesterordning) - bachelor, Prosessteknologi ingeniør (nettbasert) - bachelor, Prosessteknologi ingeniør (y-vei) - bachelor, Ren energi- og prosessteknologi, Ren energi- og prosessteknologi, *Satellitteknologi ingeniør - bachelor, Satellitteknologi ingeniør - bachelor (3-semester), Satellitteknologi ingeniør - bachelor (nettbasert), Satellitteknologi ingeniør - bachelor (y-vei), Satellitteknologi ingeniør (3-semesterordning) - bachelor, Satellitteknologi ingeniør (nettbasert) - bachelor, Satellitteknologi ingeniør (y-vei) - bachelor, Sikkerhet og miljø - bachelor ingeniør, Sikkerhet og miljø - bachelor ingeniør (ordinær og y-vei), Sikkerhet og miljø ingeniør - bachelor, Teknisk realfag - bachelorstudium i ingeniørfag, Undervannsteknologi - drift og vedlikehold, Y-vei ingeniørfag - kybernetikk/mekatronikk, Y-vei ingeniørfag - maskin, Y-vei, ingeniørfag - maskin, vann- og miljøteknikk, Bachelor - 3D-grafikk, Bachelor - Multimediaprogrammering, Bachelor - Spilldesign, Bachelor i 3D-grafikk, Bachelor i matteknologi, Bachelor i spilldesign, Bachelor i teknisk bygningsvern og restaurering, Bachelor i tradisjonelt bygghåndverk og teknisk bygningsvern, Bachelorstudium i innovasjon og prosjektledelse, Geomatikk, Bachelor i Bioteknologi, Bachelorprogram i informatikk: bioinformatikk, Kjemi og biokjemi, Molekylærbiologi og biologisk kjemi, Biologisk kjemi - bioteknologi - bachelorstudium i biologisk kjemi, Biomatematikk - bachelorstudium, Aerospace Control Engineering - sivilingeniør master, Akvatisk økologi - felles masterprogram, Applied and Engineering Mathematics (Master's Programme), Bore- og brønnteknologi - Master i teknologi/sivilingeniør (to-årig), Bygg- og miljøteknikk - masterstudium (2-årig), Bygg - masterprogram, Byplanlegging - Master i teknologi/siv.ing., Bærekraftig energiteknologi - Master i teknologi/siv.ing., Chemical Engineering (Master's Programme), Coastal and Marine Engineering and Management (Master's Programme), Communication Technology (Master's Programme), Computer Science - master, Computer Science - sivilingeniør master, Datateknikk - masterstudium (2-årig), Datateknologi - masterstudium (2-årig), Datavitenskap, Electric Power Engineering (Master's Programme), Electrical Engineering - master, Electrical Engineering, sivilingeniør - master, Electronic Systems Design (Master's Programme), Elektronikk - masterstudium (2-årig), Embedded Computing Systems (Master's Programme), Energi og miljø - masterstudium (2-årig), Energibruk og energiplanlegging - masterstudium (2-årig), Engineering Design - master, Engineering Design - sivilingeniør master, Environmental Engineering - Master of Science Degree Programme, Environmental Engineering (Master's Programme), Environmental Monitoring and Nature Management in the Northern Oil and Gas Producing Regions, Experience-based Master degree in Technology and Operations* *management, Experience-based Master in Information Security, Fornybar energi - masterprogram, Geotechnics and Geohazards (Master's Programme), Global Manufacturing Management (Master's Programme), Helse, miljø og sikkerhet - masterstudium (2-årig), Helseinformatikk - master, Hydropower Development (Master's Programme), Industrial Asset Management – Master's Degree Programme, Industrial Design (Master's Programme), Industrial Ecology (Master's Programme), Industrial Engineering - master, Industrial Engineering - sivilingeniør master, Industriell design - masterstudium (2-årig), Industriell kjemi og bioteknologi - masterstudium (2-årig), Industriell kybernetikk - masterstudium (2-årig), Industriell økonomi - Master i teknologi/siv.ing., Industriell økonomi og teknologiledelse, masterprogram, Informasjons- og kommunikasjonsteknologi - masterprogram, Informasjonsteknologi, datateknikk - Master program, Informasjonsteknologi, datateknologi - Master program, Information Systems (Master's Programme), Innovative Sustainable Energy Engineering (Nordic Master's Programme), Integrert bygningsteknologi - sivilingeniør, Integrert bygningsteknologi - sivilingeniør master, Konstruksjoner og materialer - Master i teknologi/siv.ing., Kybernetikk og robotikk - masterstudium (2-årig), Ledelse av krevende maritime operasjoner, Light Metals Production (Master's Programme), Light Metals, Silicon and Ferroalloy Production (Master's Programme), Marin teknikk - masterstudium (2-årig), Marine- and Offshore Technology – Master's Degree Programme, Marine Technology (Master's Programme), Maritime Engineering (Nordic Master's Programme), Master i Brannsikkerhet, Master i Brannsikkerhet - deltid, Master i mat og teknologi, Master i mikrosystemteknologi, Master i offshoreteknologi, Master i Produkt og systemdesign, Master i Produkt og systemdesign - Deltid, Master i simulering og visualisering, Master i Skipsdesign, Master i Skipsdesign - deltid, Master i teknologi - Data/IT, Master i teknologi - Elektroteknikk, Master i teknologi - Industriell teknologi, Master i teknologi - Ingeniørdesign, Master i teknologi - Integrert Bygningsteknologi, Master i teknologi - Satellitteknologi, Master i visualisering og simulering, Master i visualisering og simulering - deltid, Master in Electronic Systems and Instrumentation, Master in Sustainable Manufacturing, Master of Science in Chemical Engineering, Master of Science in Coastal and Marine Civil Engineering, Master of Science in Electric Power Engineering, Master of Science in Geotechnics and Geohazards, Master of Science in Hydropower Development, Master of Science in Industrial Ecology, Master of Science in Information Systems, Master of*

Science in Innovative Sustainable Energy Engineering, Master of Science in Light Metals Production, Master of Science in Marine Technology, Master of Science in Medical Technology, Master of Science in Natural Gas Technology, Master of Science in Oil and Gas Technology, Master of Science in Petroleum Engineering, Master of Science in Petroleum Geosciences, Master of Science in Reliability, Availability, Maintainability and Safety (RAMS), Master of Science in Silicon and Ferroalloy Production, Master of Science in Telematics - Communication Networks and Networked Services, Master of Science Programme in Geotechnics and Geohazards, Master of Science Programme in Industrial Ecology, Master of Science Programme in Information Systems, Master of Science Programme in Reliability, Availability, Maintainability and Safety (RAMS), Master of Science, Electrical Power Engineering, Master of Science, Energy and Environmental Technology, Master of Science, Energy and Environmental Technology - Online Programme, Master of Science, Hydropower Development, Master of Science, Industrial IT and Automation, Master of Science, Industrial IT and Automation - Industry Master, Master of Science, Industrial IT and Automation - Online Programme, Master of Science, Marine Technology, Master of Science, Petroleum Engineering, Master of Science, Petroleum Geosciences, Master of Science, Process Technology, Master of Science, Process Technology - Online Programme, Master's Programme in Coastal and Marine Engineering and Management, Master's Programme in Embedded Computing Systems, Master's Programme in Security and Mobile Computing, Master's Degree Programme in Structural Engineering and Building Technology, Masterstudium i energi og miljø i bygg, Masterstudium i energi og miljø i bygg - deltid, Materialteknologi - masterstudium (2-årig), Medical Technology (Master's Programme), Mekatronikk, masterprogram, MSc in Environmental Engineering, MSc in Light Metals, Silicon and Ferroalloy Production, MSc in Project Management, MSc in Security and Mobile Computing, MSc Programme in Project Management, Multimedia and Educational Technology, Master's Programme, Natural Gas Technology (Master's Programme), Nordic Master's Programme in Innovative Sustainable Energy Engineering, Nordic Master's Programme in Maritime Engineering, NTNUs Entreprenørskole - masterstudium i entreprenørskap (2-årig), Offshore Field Development Technology – Master's Degree Programme, Offshore Technology – Master's Degree Programme, Online Master of Science, Industrial IT and Automation, Online Master Program in Energy and Environmental Technology, *Online Master Program in Process Technology, Petroleum Engineering - Master of Science Degree Programme, Petroleum Engineering (Master's Programme), Petroleum Geosciences (Master's Programme), Petroleum Geosciences Engineering - Master of Science Degree Programme, Petroleumsfag - masterstudium (2-årig), Polymer Technology (Nordic Master's Programme), Produktutvikling og produksjon - masterstudium (2-årig), Project Management (Master's Programme), Reliability, Availability, Maintainability and Safety (RAMS) (Master's Programme), Risikostyring - Master i risikostyring, Risk Management – Master's Degree Programme (Master i teknologi/siviling.), Robotteknologi og signalbehandling - Master i teknologi/siv.ing., Samfunnssikkerhet - Master i teknologi/siv.ing., Satellite Engineering - master, Security and Mobile Computing (Master's Programme), Silicon and Ferroalloy Production (Master's Programme), Sustainable Energy (Master's Programme), Technology and Safety in the High North - master, Technology Management - Master Programme, Teknisk samfunnssikkerhet - Master i teknologi/siv.ing., Telematics, Telematics - Communication Networks and Networked Services (Master's Programme), Telemedicine and E-health - master, Undervannsteknologi, Undervannsteknologi - masterstudium (2-årig), Veg og jernbane - masterstudium, Wind Energy (Master's Programme), Master i økonomi og ledelse - siviløkonom, deltid, Master i økonomi og ledelse, Siviløkonom, Regnskap og revisjon - Siviløkonom, masterprogram, Siviløkonom / Master of Science in Business, Siviløkonom / Master of Science in Business, ett årig påbygning, Siviløkonom / Master of Science in Energy Management, Siviløkonom / Master of Science in Sustainable Management, Økonomi og administrasjon (desentralisert) - master (siviløkonom), Økonomi og administrasjon, siviløkonom - master, Biological Chemistry - Master of Science Degree Programme, Biologisk kjemi - masterstudium i biologisk kjemi, Biotechnology (Master's Programme), Bioteknologi, Bioteknologi - masterstudium, Biovitenskap, Elektronikk, informatikk og teknologi, Entrepreneurship, Entreprenørskap, Entreprenørskap - masterstudium, Helse- og sosialinformatikk - erfaringsbasert masterprogram deltid, Master i natur-, helse- og miljøvern, Masterstudium i natur-, helse- og miljøvern, Masterstudium i natur, helse- og miljøvern - tilrettelagt for bioingeniører, Masterstudium i natur-, helse- og miljøvern - tilrettelagt for lærere, Helse, miljø og sikkerhet - masterstudium, Molekylær biovitenskap, Matematisk-*

naturvitenskapelige fag (PhD), Medisin (PhD), Teknologi (PhD), Økonomisk-administrativ utdanning (PhD) "

Exhibit 3 – Criteria's for Health-Related Academic Publications

Below follows an exhaustive list of criteria included in the analysis of chapter 4.4.

"Health tech, helse, helseteknologi, medtech, healthtech, technology, helseinformatikk, biotech, biotek, biotechnology, bioteknologi, medtek, healthtek, helsetek, biokjemi, biochemistry, health-tech, medisin, medicine, health ict, helse ikt, biotechnology applied microbiology, biochemical research methods, biomedical engineering, civil engineering, nanoscience, nanotechnology, neurosciences"