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Critical competences for industrial renewal in Denmark and Finland

Olavi Lehtoranta | Mika Naumanen | Carter Bloch | Carita Eklund | Janne Huovari | Hannu Piekkola | Magnus Simons

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Olavi Lehtoranta, Mika Naumanen & Magnus Simons

VTT Technical Research Centre of Finland

Carter Bloch

University of Aarhus

Carita Eklund & Hannu Piekkola

University of Vaasa

Janne Huovari

Pellervo Economic Research PTT

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PL 1000 (Tekniikantie 4 A, Espoo)
02044 VTT
Puh. 020 722 111, faksi 020 722 7001

Teknologiska forskningscentralen VTT Ab
PB 1000 (Teknikvägen 4 A, Esbo)
FI-02044 VTT
Tfn +358 20 722 111, telefax +358 20 722 7001

VTT Technical Research Centre of Finland Ltd
P.O. Box 1000 (Tekniikantie 4 A, Espoo)
FI-02044 VTT, Finland
Tel. +358 20 722 111, fax +358 20 722 7001

Preface

This publication deals with the question of how broad-based innovation activity should be understood in business management. It provides examples of some technological and non-technological innovation activities and their competence requirements. All these are studied in the context of industrial renewal in Denmark and Finland.

We compare Denmark and Finland in terms of their economic structures and research and innovation policies. The role of different strategies, digital technologies and intangible capital in responding to globalization and other grand challenges, and their competence requirements are approached via company interviews and case studies conducted in both of these countries.

By critical competences we mean those core competences and capabilities of personnel, organizations and stakeholders that are most needed for selected strategies and technologies. Main parts of these are dynamic capabilities for innovation activities where innovations comprise business model innovations and product, process and service innovations.

This wide approach to innovation management in Denmark and Finland would not have been possible without our Danish colleagues and policy experts. We especially want to thank Thomas Blomgren-Hansen and Henrik Fosse from DASTI, the Danish Agency for Science, Technology and Innovation, for funding the Danish part of the project and for organizing an excellent workshop “Managing innovation in a changing world; Creating value in Danish and Finnish manufacturing” in Aarhus November 2015.

We also want to thank Tekes, the Finnish Funding Agency for Innovation, for the financial support that made the study possible. We are also grateful to the expert members of the steering group not mentioned above for their help and comments, especially Elise Ramstad, Christopher Palmberg, Jari Hyvärinen, Ari Leppälahti and Mervi Niemi.

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1. Introduction

The comparison of Danish and Finnish manufacturing industries is a key issue in this innovation research on the *renewal of manufacturing*. Besides in terms of technological and non-technological innovations we compare Denmark and Finland in terms of their economic structures and research and innovation policies. The role of different strategies, digital technologies and intangible capital in responding to globalization and other grand challenges, and their competence requirements are in focus. By critical competences we mean those core competences and capabilities of personnel, organizations and stakeholders that are most required for selected strategies and technologies. Main parts of these are dynamic capabilities for innovation activities where innovations comprise business model innovations and product, process and service innovations (Teece and Picano, 1994, Wallin (ed.), 2012).

The *organizational and marketing innovations* defined by the Oslo Manual (OECD, Eurostat 2005) are closely interrelated with product, process and service innovations. For example, process innovation can be seen in a wider way than just the direct production process innovation. It can also cover organizational or business process, and corporate or product image renewal.[1] From the process point of view, a careful description of the service concept, the interaction process, and the allocation of resources has been considered crucial (Edvardsson, 1997; Matthing et al., 2004). Recently, *value-in-use* has come to the fore as a central issue and the ways in which human and technological resources should be integrated to achieve novel solutions have attracted increasing interest. The approach of service-dominant logic (SDL) argues that the use-value of both material products and services is always co-created by the provider and the client, so that that the client should not be handled as a target of selling but as a collaboration partner. Thus,

1 The school of marketing and management has contributed to how we nowadays understand innovation as an outcome, as a process and as an organizational arrangement. An outcome can be an improvement, addition, recombination and formalization (Gallouj and Weinstein, 1997; Gallouj, 2002). The harmonised Community Innovation Survey (CIS) gives the following examples of marketing innovations: new aesthetic designs, new brand image, new sales channels, and new pricing methods. Furthermore it gives the following examples of organizational innovations: new management systems, new decision making systems and new ways to organize external relations. This is, however, not an exhaustive list of the content of non-technological innovations and it simplifies the definitions given by the CIS.

the economy and markets are characterized by two ubiquitous and continuous processes: value co-creation and resource integration (Vargo and Lusch, 2008, 2011).

This research project approached industrial renewal via interviews (e.g. on strategies adopted) and examination of intangible capital (IC), especially organizational capital. In quantitative studies non-R&D activities are classified into organizational (management and marketing) activities and ICT activities (i.e. activities of managing, developing and implementing ICT). The corresponding assets are measured as cumulative sums of intangible investments in organizational structures, brands, business models and ICT. The measurements of intangible investments are based on occupational data on the sums of wages and salaries in these groups. For R&D these measurements are broader than measurements based on the Frascati definition, but exclude tangible investments (Eklund, Bloch, Piekkola, Huovari, 2017).

This study concentrates on those critical competences for industrial renewal emphasized by the company representatives in Denmark and Finland. The target of the study is to find out what core competences are needed in order to succeed in implementing the strategies and technologies selected.

Structural and policy differences between Denmark and Finland will be considered in Chapter 2. They are based on general findings as well as on the qualitative and quantitative studies conducted in this project. Possible differences in innovation policy guidelines followed or going on in these countries have also been reviewed. Especially the focus is on strategic differences between these two small open economies. In Finnish innovation policy, e.g. in the *For Industry programme* (VTT, 2015) the key technologies adapted to the Finnish SME industries include industrial internet, additive manufacturing, automation, robotics and embedded intelligence. This programme has a strong basis in the use of digitalization. It seems that the Danish policy focus has been less concerned with industrial renewal. This issue has received less attention in Denmark compared to Finland which can potentially reflect the different structuring of innovation policy, where Danish innovation policy is more segmented or potentially more narrowly defined. However, digital opportunities and solutions have been mentioned as a sub-topic for “a high-tech society with innovation capacity” in the Danish Research 2020’s cross-cutting societal themes (Ministry for Higher Education and Science, Denmark, 2012). The report *Production panel 4.0* provides recommendations on how Danish companies can take advantage of advances in digitalization (Minister for Higher Education and Science, Denmark, 2016). This report will deal with improving digitalization of SMEs, reducing barriers to investment in digitalization by companies, Danish industry’s needs concerning digitalization and regulation and public support of development of business models for digitalization.

In Chapter 3 *critical competences for industrial renewal* in Denmark and Finland will be discussed. In this context, the structures and significance of intangible assets in the renewal of Danish and Finnish manufacturing industries will be summed up. This significance is measured in terms of value creation, in practice as value added per employee. The needs for macro- and microeconomic analyses

are well grounded since the manufacturing decomposition in Denmark and Finland is very different.

According to the OECD's *Future of Productivity* programme (OECD 2015), future growth will depend on 1) harnessing the forces of *knowledge diffusion*, which is shaped by four factors: global connectedness, experimentation with new ideas, investment in knowledge-based capital (KBC) and efficiency of resource allocation and 2) boosting productivity and reducing inequality by better allocating skills to jobs and fostering the growth of the more productive firms in general. As we can see, intangible capital and competence development are among the key issues in this approach.

Critical competences will be further examined in Chapters 4 and 5 based on case studies in Denmark and Finland. In Denmark, we conducted five case studies among manufacturing companies within the areas of energy, electronics and clean technology. In Finland, we conducted seven case studies among the machinery industry and their technology and service providers. Selected companies are characterized by a high level of technological development in sectors that are important for exports. Interviews in Denmark and Finland covered the same overall topics, though interviews in Denmark had a somewhat more general focus with less specific emphasis on IT based solutions. The main question addressed in the Danish study was how changes in manufacturing strategies and business models are implemented in practice and, in particular, what competences were needed in order to succeed in implementing these strategies.

As mentioned, competences are understood broadly in the study, to include employee competences, organizational capabilities, R&D and technological knowhow, products and solutions, processes, and customer relations. In Finland, we asked the companies for their views on new business models and practices related to the industrial internet, in developing the value creation, management and competences as well as in promoting the introduction of industrial internet solutions. In company interviews also new drivers for renewing manufacturing industries were enquired. It seems more than obvious that new intangible and technology platforms (e.g. digitalization, bio/circular economy and related skills, competences and capabilities) can be and already have been utilized for *boosting industrial renewal* in countries like Denmark and Finland.

2. Structural and policy differences between Denmark and Finland

2.1 Structural differences

2.1.1 Danish and Finnish economies

Denmark and Finland are small open economies in Northern Europe, with populations of 5.6 and 5.5 million. Denmark is a bit richer, but there is not big difference in GDP per capital. GDP growth in Finland was much higher than in Denmark from 1995 up to financial crisis. The Financial crisis had pretty equal sized impact on both countries. Their GDP was some 4-5% lower in 2011 compared to pre-crisis peak in last quarter of 2007. However, the dynamics were somewhat different. Growth slowed down considerably in Denmark already in 2007. The drop in output in 2009 was milder in Denmark (5 %) than Finland (8 %), but still substantial. Recovery in Finland was stronger in 2010. After 2011 countries started to diverge. Since 2012, GDP in Finland has contracted up to 2015, while in Denmark mean of growth rate was about 1 percent. After 2015 the GDP have grown equally in both countries. Compared to the pre-crisis level, Denmark surpassed it in 2015, while Finland is still below. There is for both countries, however, a big difference compared to better performing countries like Sweden and the USA with GDP more than 10 percent higher than the pre-crisis peak.

Even if the Danish economy is a bit larger than the Finnish one, the manufacturing sector employs 340 000 in Finland and 290 000 in Denmark (2015, Eurostat). Manufacturing in Denmark is much more export oriented. Particularly, after the financial crisis export has grown strongly in Denmark while in Finland there has been no growth. Export growth in Denmark has been fastest in chemicals and machinery. Productivity growth in manufacturing was clearly faster in Finland prior to the financial crisis. After the crisis Finnish figures are influenced by loss making of Nokia and productivity has varied a lot. In recent years, the manufacturing productivity in both countries has barely grown. Productivity is Danish manufacturing is clearly higher today that before the crisis, whereas in Finland productivity is still below the pre-crisis level. However, that is not a universal trend over all industries.

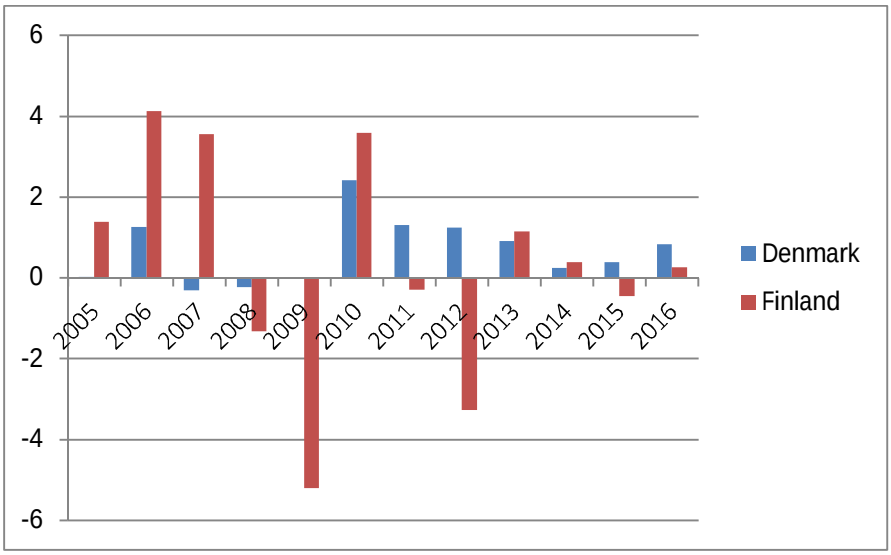

Figure 1. Annual change (%) in manufacturing labor productivity in Denmark and Finland 2005 – 2016 (Source: OECD).

2.1.2 R&D funding

When taking a look at the development in the overall volume of R&D funding, we operate with the two OECD R&D categories: HERD and GOVERD. HERD (Higher Education Expenditure on R&D) covers all R&D performed in the higher education sector and includes both publicly and privately funded R&D. GOVERD (Government Expenditure on Intramural R&D) covers all R&D performed in the Government sector and includes both publicly and privately funded R&D. We show all the measures as share of GDP in order to be able to make meaningful comparisons across the two countries.

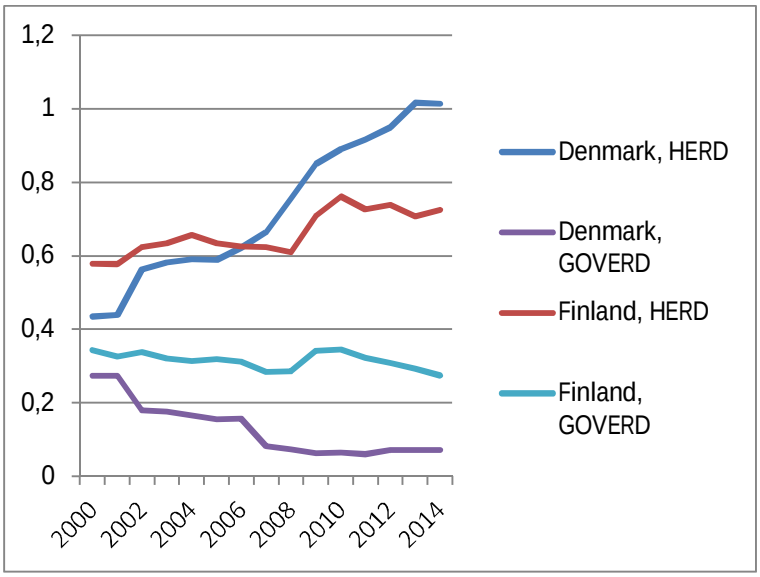

Figure 2. HERD (Higher Education Expenditure on R&D) and GOVERD (Government Expenditure on Intramural R&D) developments as share of GDP in Denmark and Finland 2000 – 2014.

The Danish government expenditures on intramural R&D were below the levels of Finland (and Sweden) at the early 2000s. Since then, and in particular since 2006, the Danish growth has been significant and Denmark has now passed both countries. The development has been quite stable in Finland throughout the period. Notice however, that the financial crisis in 2009 and the subsequent drops in GDP influence the figure. For Finland, the increase in the volume of funding as a share of GDP does not result from increased R&D investments but from decreasing GDP figures. In real terms, HERD investments have remained relatively stable for Finland during the years 2010 –2014 and GOVERD investments declined.

On the other hand, the relations between private R&D (BERD) and HERD and GOVERD have remained relatively stable during 2006 – 2014 for Finland. In Denmark, public R&D funding covers now a bigger share of overall R&D funding.

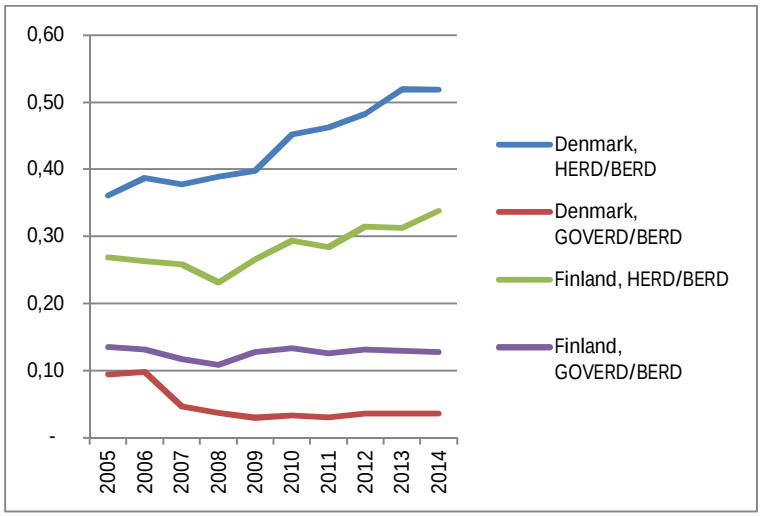

Figure 3. Relations between private R&D (BERD) and HERD and GOVERD in Denmark and Finland 2000 – 2014.

As can be seen from these two figures, the universities have become dominant in the Danish and been relatively dominant in the Finnish system throughout the period. In Finland, a substantial degree of public research is carried out by government research institutions. This sector decreased dramatically in Denmark, where universities took the responsibility of almost all public research for the latest decade as a consequence of a large scale merger process implemented in 2007.

The share of labor force employed in research and product development, which requires a high level of competence and constitutes one of the cornerstones of the knowledge-intensive economy, has traditionally been high in Finland, remaining close to two percent. However, the share is in decline. The trend has possibly been affected by the economic situation, with companies cutting their R&D expenditure after 2008 for the first time after the turn of the millennium and decrease in public R&D funding in real terms since 2011. On the other hand, the proportion of people working in Denmark's research and development activity has grown by one-third within a decade, bringing it up to Finland's high level.

According to the international evaluation of the Finnish research and innovation system (MEE & MEC, 2009) the Finnish higher education and public research system is fragmented in three dimensions. Firstly, resources are scattered in three different types of organizations with overlapping tasks – universities, polytechnics and public research institutes. Secondly, these institutions are scattered around the country with several rather small units. Thirdly, the universities have been internally fragmented in several rather small units. In total, there are 14 universities in Finland that conduct research in 54 fields of science that further are divided into 297 units. From these 54 fields 27 are represented in six or more universities. The level of research was not clearly above the world average in any of these 27

fields (top 10 index > 1.15). There are 26 polytechnics (also known as Universities of Applied Sciences), and 12 public research institutes, which also have several regional extents.

Public-private cooperation and knowledge transfer

Public-private collaboration occurs mainly between firms and the eight Danish universities as well as the nine public research institutes. While the universities are the main research performers and major collaboration partners, the research institutes are the main providers of commissioned R&D for the private sector and there are specific aims to service the needs of SMEs. Moreover, Danish firms collaborate more with foreign universities than with Danish universities.[2] However, those firms (mainly larger companies and not small firms) which do cooperate with Danish universities, mainly for applied research projects, assess the cooperation as positive.[3]

Finland has a well-developed engagement between university and business sectors, although the current economic crisis is affecting its research and innovation landscape and activities. Performance is notably good in terms of public-private co-publications, the share of enterprises working with academia, numbers of start-up companies and the number of university-business research agreements. Finland also has a high degree of researcher mobility to the business sector. It also implemented the EC knowledge transfer recommendation to a high degree. A range of programmes are in place to support university-business collaboration and engagement and Finland is advanced in terms of open innovation.

Business R&D

The intensity of the Finnish (and Swedish) BERD was well above the Danish one ten years ago. However, the BERD intensity has been on a slight downward trend in these countries for the past ten years. On the other hand, the BERD intensity grew steadily in Denmark between 2006 and 2009 and stabilized at around 2% of the GDP from 2010 onwards with manufacturing and business services being almost equal contributors to BERD. Moreover, Denmark has a strong private non-profit R&D aspect to public research efforts. These figures are not included in calculations here. Were they, it would be apparent that Denmark in fact has one of the highest levels of privately-funded public R&D expenditure of the EU28. This is partly because some of the largest corporations are either owned by foundations or large foundations own important R&D companies, which have traditionally funded research through donations.

2 Danmarks Forskningspolitiske Råd, 2011. http://ufm.dk/publikationer/2012/arsrapport-fra-danmarks- forskningspolitiske-rad-2011

3 Oxford Research, 2011 http://techtrans.dk/fileadmin/webmasterfiles/techtrans/Temah%C3%A6fter/Private_virksomheders_samarbejde_med_danske_universiteter_2011.pdf

In Finland, the GDP share of BERD has decreased since 2010 to below 2005 levels. The decline is more evident after 2011 and is related to the severe drop in R&D expenditure in manufacturing in the period 2011-2012. A small part of this overall decline in BERD was compensated for by an increase of R&D expenditure in services, notably in both ICT and professional activities sectors. Equally, the share of services is very high (up to 50% in many manufacturers) among manufacturing companies at present, and therefore a much greater share of BERD is focused on services than the statistics indicate.

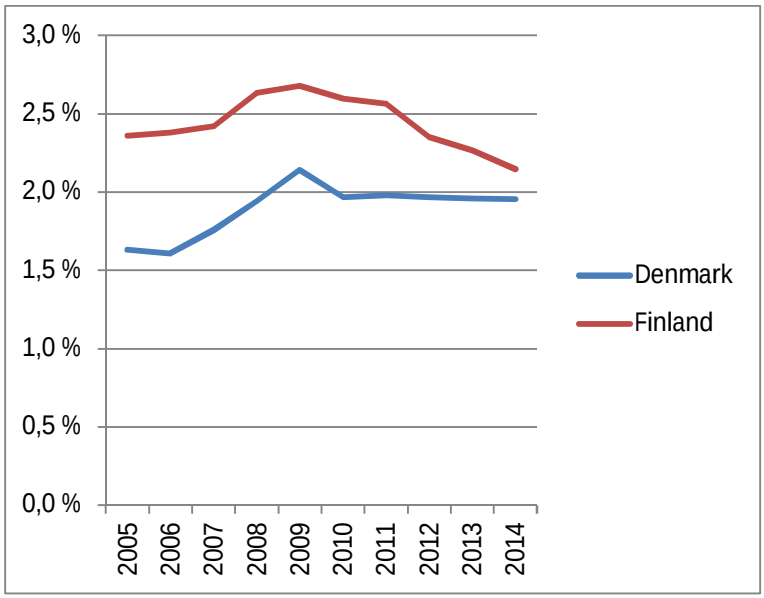

Figure 4. GDP share of private R&D (BERD) in Denmark and Finland 2005 – 2014.

Judged in absolute terms, companies' R&D investments have been falling in Finland since 2011, adding up to a total decrease of around one billion euros. The drop from 2014-2015 was 360 million euros. However, Statistics Finland estimated in 2016 that there will not be any further drop in business R&D expenditure. The drop during the recent years shows the effect of Nokia's fortunes, since taken by operational area the major drops have been in software and in the electronics industry.

2.1.3 Intangible capital

To assess innovative competences and firm-level productivity in Denmark and Finland, we have calculated firm-level intangible investments and capital stocks based on occupation data (see Eklund, Bloch, Piekkola, Huovari, 2017). Here,

firm-level data is aggregated to national and industry level. Industries included are most of the manufacturing and private services, but excluding construction and financial services. Intangible capital is divided into three components, namely, organizational capital, R&D capital and information and communication technology (ICT) capital.

The level of intangible capital as a ratio to a value added is higher in Finland than in Denmark, after 2010 around 90 percent in Finland and 70 percent in Denmark. That is not surprising, since most of the intangible assets results from R&D activity and Finland has been one of the leading countries in R&D activity, and the level of R&D activity has been in past much higher in Finland that in Denmark. That is evident also when measuring with more conventional indicators, like R&D expenditures or investments in intellectual property products. (for private R&D see Figure 4 and intellectual property products see Figure 10).

The intangible capital ratio to value added has also been rising in both countries, in Finland, even somewhat more that in Denmark. For Finland, this is in contrast with R&D expenditure ratio that has been decreasing in recent years. First, it should be noted that the rise of the ratio is due to decrease in value added during and after the financial crisis. In absolute terms, intangible capital peaked in Finland in 2008 and has declined since. So in Finland, the entire rise in intangible capital ratio is due to decline in value added. However, R&D expenditures have declined much faster that our measure of intangible capital or investments. Based on our measure of intangible capital, the decline in R&D activity has not been as sharp as one would conclude from R&D expenditures or R&D investments. But also, in R&D statistics, R&D expenditures have declined more that R&D personnel.

In Denmark, intangible capital started to decline earlier, after 2006, as recession started in Denmark already before the financial crisis. In contrast to Finland, in Denmark intangible investments and capital started to increase right after 2009. Thus, in resent year, the rise in intangible capital ratio in Finland follows from a large decrease in value added, while in Denmark the rise follows from increased investment in intangible capital.

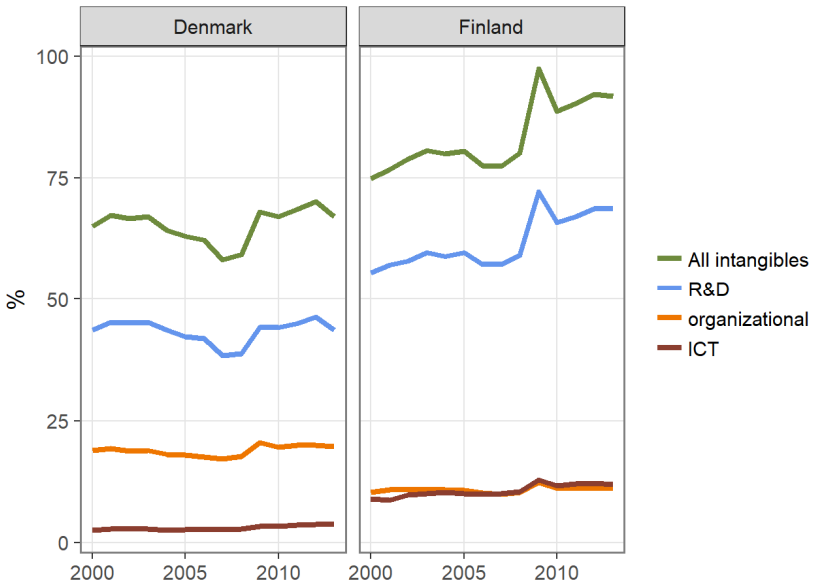

Figure 5. Intangible capital in Denmark and Finland 2000-2013 related to value added decomposed to R&D capital, organizational capital and ICT capital, in 2010 prices.

A composition of intangible capital differs between Denmark and Finland. In both countries R&D capital forms most of intangible capital, but in Finland a share is bigger. Since 2010 in Denmark a R&D capital ratio per value added has been 45 percent that is around 66 percent of all intangible capital. In Finland, a R&D capital ratio to value added is around 68 percent and that is around 75 percent of all intangible capital.

Even bigger difference is in organizational and ICT capital. In Finland, organizational and ICT capital stocks are almost of equal size, around 12-13 percent of total intangible capital. In Denmark, organisational capital forms a much bigger share of intangible capital stock, 29 percent, and ICT capital only around 5 percent.

A large difference in organizational and ICT capital might be due to classification difference in occupation statistics. That is, however, unlikely to be the main reason. The difference is concentrated in few industries, and in other industries the ratio of ICT capital is more equal in both countries. In Finland, the ICT ratio is much higher in electronics manufacturing and computer programming services than other industries.

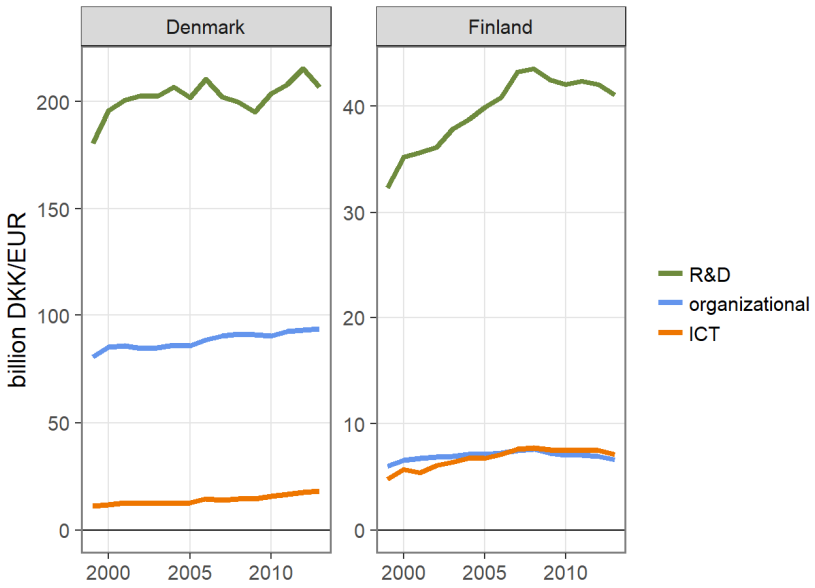

Figure 6. Intangible capital in Denmark and Finland 2000-2013 decomposed to R&D capital, organizational capital and ICT capital, in 2010 prices.

Over all, a major part of the difference between Denmark and Finland in intangible capital comes from the R&D capital in electronics manufacturing. In other industries, the difference is much more modest. If Finnish firms invest more in R&D capital, it seems that Danish firms invest much more in organizational capital. That is case in the national level as well as in most industries. It is noticeable, that in Finland industries, which are investing heavily in other forms of intangible capital, are investing so little in organizational capital.

In Denmark it seems, that firms are investing quite fixed share of value added in organizational and ICT capital, while in Finland the share varies much more between industries. In other business services a share is almost in par with Danish firms, while in manufacturing a share is much smaller.

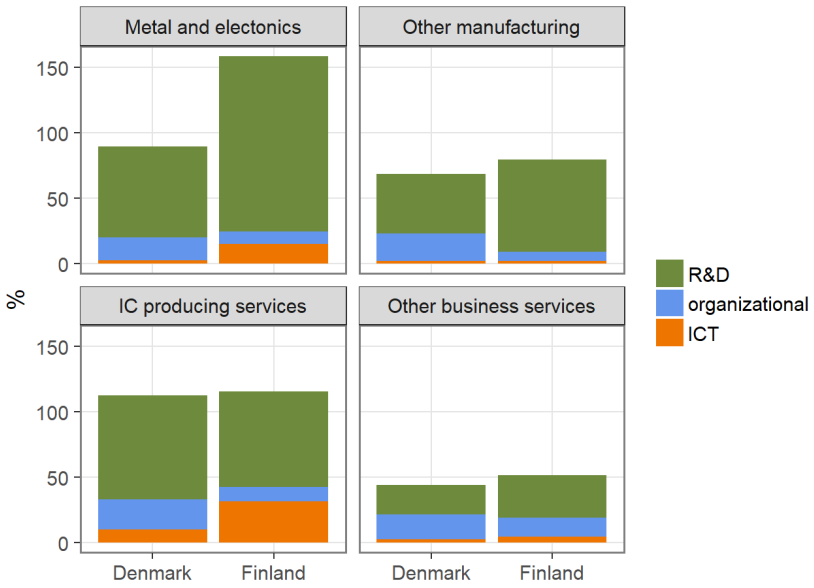

Figure 7. Intangible capital in Denmark and Finland 2013 in selected industries related to value added.

2.1.4 Industry level differences

The performance of the Finnish economy has been lagging well behind most countries in the euro area. Finland has lost much of its cost competitiveness in global markets for reasons related to the high cost level and losses in multifactor and labor productivity. Limited investment in non-R&D innovation expenditures over recent years could be one explanation for the lack of success in converting the R&D inputs into viable products. On the other hand, it may indicate a lack of innovation, e.g. good investment objects. Low level in the investment in non-R&D innovation expenditures characterizes not only Finland but also Denmark. Denmark is ranked 27th, which is particularly low and signals a lack of upgrades across the R&D sectors. On the output side, exports of medium and high-technology products as a share of total product exports is also rather weak, ranked 19th, which signals a greater need for increasing domestic R&D in key sectors.

When examining the added value the Danish and Finnish industries produce, we follow the approach of Gal (2013), slightly modified though. Productivity, in its broadest interpretation, is meant to capture the efficiency by which inputs are turned into outputs (Hulten, 2001). Gal (2013) presents an array of productivity measures which can be calculated using the OECD-ORBIS database. Gross output or total revenue based labor productivity is the most widely available, but its

most immediate problem is that it does not control for intermediate input usage. In other words, a company with a lot of reselling activity (e.g. retail companies) will probably rank very high in this measure. Value added based labor productivity takes care of this problem, as value added itself is the difference between output (sales or revenue) and intermediate inputs (including resold goods, typical in retail trade).

Based on correlations across levels and growth rates (see Gonnard and Ragoussis 2013), the best substitute for value added is simply using its definition based on factor incomes. This entails adding up factor incomes going to employees (total wage bill) and to capital owners (profits). In ORBIS, the empirical counterparts to these variables are the COSTS_EMPLOYEES and EBITDA (Earnings Before Interest Taxes Depreciation and Amortisation).

In our industry classification, we follow the grouping used in the EU-KLEMS database (O'Mahony and Timmer, 2009). First, we explore which firms belong to the top 10% best performing firms in each industry. Then, the percentage of firms of a given industry and in a given country is within the top 10% group is calculated. Third, we calculate the average value added in each industry for the years from 2006 to 2015. We note that labor productivity does not control for differences in capital intensity across firms. However, we assume that within an industry, capital intensities do not vary too much between firms to distort the analysis.

The figure below shows the percentage of firms from Denmark, Finland and Sweden that are able to make themselves to the top 10% best performing firms (labor productivity vice) in each industry over the 2006 – 2015 period of time. One could expect certain results, e.g. the Nordic companies' high presence in wood and paper industry, but the strong position of Swedish IT and IT service firms is remarkable.

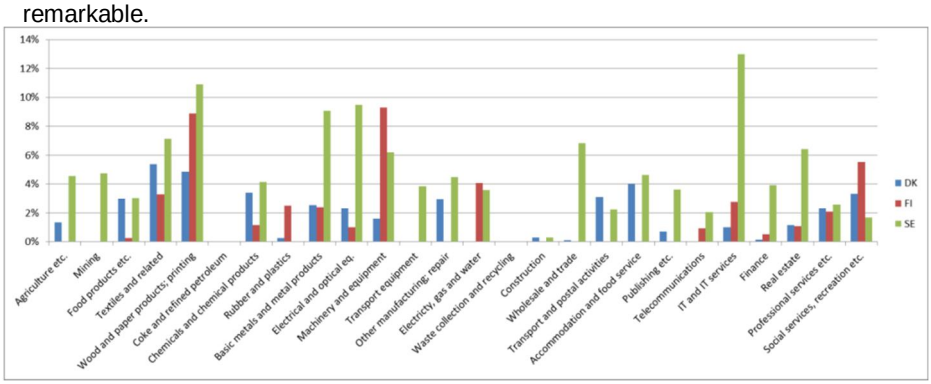

Figure 8. Percentage of the top 10% best performing firms (labor productivity vice) in each industry over the 2006 – 2015 period of time in Denmark, Finland and Sweden.

In order to see, how big a role these high productivity firms play for each country's economy, we calculate the added value they have produced on average within their industries annually.

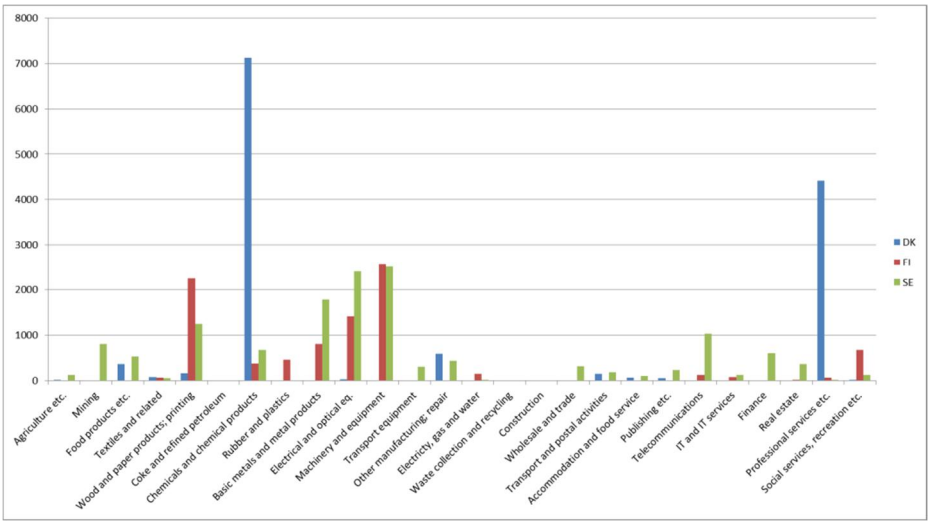

Figure 9. The average added value the frontier firms have produced within their industries annually during 2006 – 2015 in Denmark, Finland and Sweden.

Industrial structures in Finland and Denmark deviate a lot from each other. The strongest industries in Finland are machinery and pulp and paper industries and in Denmark pharmaceuticals. When we sum up the different manufacturing industries together, we can see that machinery investments are pretty much equal in Denmark and Finland but there is big difference in intellectual property products (Figure 10). The development is mostly explained by just two industries: electronics in Finland and pharmaceuticals in Denmark. The investments in intellectual property products have increased in the Danish pharmaceutical industries whereas they have declined in the Finnish electronics industry. Moreover, Denmark, in contrast to Finland, is investing more heavily in university-based research and development and doctoral education in the fields of health and welfare, engineering and natural sciences.

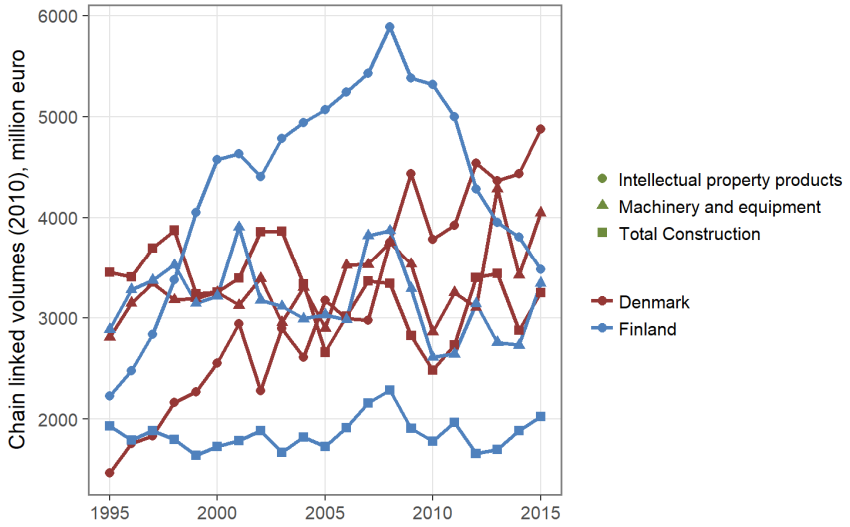

Figure 10. Volumes of construction, machinery and intellectual property products investments in manufacturing industries Denmark and Finland.

2.1.5 Company level differences

In Denmark, the value adding frontier firms are clearly in pharmaceuticals and in professional services, where the figures are dominated by a single company, A.P. Moller - Maersk A/S. One can note that although there are some high productive Danish firms in manufacturing industries, they must be relatively small as the value add they have produced is almost non-existent and cannot be seen in the Figure 9. As can be seen from Table 1, Danish pharmaceutical companies, enzymes producers and medical device manufacturers have been able to populate Global Frontier Firms' list and stay there for a number of years – a rare achievement. It must be asked whether these public R&D investments and the way they have been managed, via scientific merits, for example, have benefitted the aforementioned industries instead of the manufacturing industries in general. Namely, there are not too many Danish companies in Global Frontier Firms' list in more traditional industries, and those few present are relatively small. Finland and Sweden are much stronger in this regard.

Table 1. The most value adding frontier firms in Denmark between 2006 – 2015.

Company name, description	Year of the highest VA/L	times in top 10%	Industry	VA/L th EUR	VA th EUR
A.P. MOLLER - MAERSK A/S, a business conglomerate, has activities in a variety of business sectors, primarily within the transportation and energy sectors	2008	3	Professional services etc.	131	15 643 798
NOVO NORDISK A/S, a multinational pharmaceutical company, key products include diabetes care medications and devices	2015	10	Chemicals and chemical products	271	11 014 658
NOVOZYMES A/S, a biotechnology company focusing in the research, development and production of industrial enzymes, microorganisms, and biopharmaceutical ingredients	2015	4	Chemicals and chemical products	183	1 186 554
COLOPLAST A/S, develops, manufactures and markets medical devices and services related to ostomy, urology, continence, and wound care	2015	6	Other manufacturing; repair	124	1 178 173
H. LUNDBECK A/S, a pharmaceutical company engaged in the research and development, production, marketing, and sale of drugs for the treatment of disorders in the central nervous system (CNS)	2011	7	Chemicals and chemical products	199	1 139 055
CHR. HANSEN HOLDING A/S, supplier of food cultures, probiotics, enzymes and natural colors	2015	8	Food products etc.	188	485 000
DAMPSKIBSSELSKABET NORDEN A/S, a shipping company operating in the dry cargo and tanker segment worldwide	2008	4	Transport and postal activities	734	415 238
SCHOUW & CO A/S, an industrial conglomerate that makes long-term investments in leading businesses in which active and developing ownership is performed	2015	3	Wood and paper products; printing	119	283 156
PANDORA A/S, a jewelry manufacturer and retailer	2009	1	Other manufacturing; repair	107	249 766
BANG & OLUFSEN A/S, a consumer electronics company that designs and manufactures audio products, television sets, and telephones	2007	1	Electrical and optical eq.	96	229 823

The high productivity of Danish pharmaceutical companies is reflected in their R&D investments, too. In Denmark, pharmaceutical BERD is the highest and seems to be on an ascending path (26% growth in four years), which could also be due to the increasing demand through exports in which this sector is a leading international player. On the other hand, machinery and equipment BERD has

been declining since 2011 which may be in part due to a lack of investment during the financial crisis.

Manufacturing is, by a clear margin, the biggest contributor to Gross Value Added (GVA) in Finland. However, its share has significantly decreased in recent years from 23.3% in 2007 to 15.4% in 2012. Part of this decline is due to the contraction of the manufacture of computer, electronic and optical products sector (C26) the value-added of which declined from over 8 billion euros in 2007 to less than 800 million in 2012. Within manufacturing, the biggest sector in terms of GVA is manufacturing of machinery and equipment, which is also one of the leading sectors in terms of BERD, followed by manufacturing of paper and paper products and manufacturing of food products, beverages and tobacco products.

Table 2. The most value adding frontier firms in Finland between 2006 – 2015.

Company name, description	Year of the highest VA/L	times in top 10%	Industry	VA/L th EUR	VA th EUR
NOKIA OYJ, a multinational communications and information technology company	2008	1*	Electrical and optical eq.	108	13 646 000
KONE OYJ, one of the largest manufacturers of elevators and escalators worldwide, and also provides maintenance services and modernization	2015	6	Machinery and equipment	74	3 694 700
UPM-KYMMENE OYJ, a forest industry company	2006	6	Wood and paper products; printing	114	3 259 000
STORA ENSO OYJ, a pulp and paper manufacturer	2015	1	Wood and paper products; printing	122	3 131 000
WARTSILA OYJ, manufactures and services power sources and other equipment in the marine and energy markets	2009	1	Machinery and equipment	90	1 664 000
RAUTARUUKKI OYJ, manufacturer and supplier of metal-based components and systems to the construction and engineering industries; acquired in 2014 by the Swedish steelmaker SSAB	2007	3	Basic metals and metal products	94	1 384 000
OUTOKUMPU OYJ, producer of stainless steel	2015	2	Basic metals and metal products	119	1 314 000
SANOMA OYJ, a leading media group in the Nordic countries with operations in over 10 European countries	2015	1	Wood and paper products; printing	121	738 000
NOKIAN RENKAAT OYJ, produces tyres for cars, trucks, buses, and heavy-duty equipment	2012	8	Rubber and plastics	174	704 700
ELISA OYJ, a telecommunications, ICT and online service company	2007	2	Telecommunications	221	665 900

* Nokia's data is missing from years 2006, 2007 and 2009; it had probably made itself to top 10% in those years also.

Manufacture of computer, electronic and optical products is the leading sector in terms of R&D expenditure in Finland. There is a mild negative trend in the R&D expenditures in this sector from 2008 to 2011 followed by a sharp decline in 2012. In 2013 and 2014, R&D expenditure dropped further. Since 2008, Nokia's investments in research and development have fallen with about four billion euros. However, Nokia remains by far Finland's biggest investor in R&D, because in 2014 its investments in R&D activity (2.493 billion euros) were over ten times those of the next most significant investor, ABB (203 million), and even more than the next 99 companies put together (2.404 billion euros).

As far as services are concerned, there is a significant increase of the R&D expenditure in the information and communication services after 2009, particularly in 2013. R&D expenditure in IT services increases whereas at the same time it decreases in the manufacture of computer, electronic and optical products. In other words regarding the IT sector we observe a shift of the R&D activities from manufacture to services.

A very eye-catching character of the change of the Finnish research and innovation system since the 1990s has been its internationalization. For instance, foreign ownership of Finnish companies' stock exchange value has constantly increased, and it was in 2012 over 50 per cent. At the same time, Finnish companies have internationalized rapidly. Starting in the 1990s, the number and personnel of Finnish companies' international subsidiaries has grown strongly. While in the end of the 1990s, the number of international personnel in these companies was only over 100,000 persons, in the beginning of 2010s, the number was already approximately 600,000 (Sauramo and Oesch, 2013). While the major part of firms R&D investments is still made in Finland, firms are also making significantly R&D investments abroad, raising the question about the future of Finland as a target of R&D investments (Ali-Yrkkö and Rikama, 2013).

2.1.6 Broad intangible capital: innovativity and performance of Finnish firms

Innomitta II project provides broad estimates of intangible capital (IC) divided into organizational capital (OC), R&D and information and communication capital ICT. As a part of Innomitta II project, Piekkola and Rahko (2017) analyze innovation performance of Finnish manufacturing and market service firms. In the analysis, balance sheet data and data on skilled employees are linked to European Communal Innovation Survey (CIS) and to R&D survey data. In Finland, innovation and R&D survey data are of similar size with about 2,300 firms annually, and form a panel extending over 13 years from 2001 to 2013.

In the analysis, the R&D survey and innovation survey data are linked to the employer-employee panel data also. The linked employer-employee data (LEED) encompass the private sector firms with an average of more than 10 employees. Industry-wise, the dataset covers manufacturing (NACE C) and market services (G, H, I, J, L, M, N) without financial services (K). Incorporating market services in the analysis is valuable for IC producing services (J, L, M) since many technology

firms in Finland have earlier been a part of a manufacturing firm. These are also the industries with more than double of R&D per employee than those in manufacturing. The data include a rich set of variables that cover compensation, education, and profession. The employee data in the full sample cover, on average, 700,000 employees annually in 1995-2013 while the innovation survey sample 2001-2013 cover, on average, 331,430 employees annually.

The occupations follow the International Standard Classification of Occupations.[4] Piekkola (2016) applies similar method using Federation of Finnish Employer occupational data with functional classification (management, research, development, computer, marketing etc. combined with skill level of being at least expert). IC workers are divided to organizational capital (OC) workers related to management and marketing, R&D workers and information and communication technology (ICT) workers. Appendix A in Piekkola and Rahko gives a detailed description of the innovative-work coding in IC type work. Most of the occupations within the top three major groups (Managers, Professionals and Technicians and Associate Professionals) are assumed to be engaged in IC activities that contribute to the accumulation of knowhow within the firm. Workers are deemed to be ICT workers in certain IC occupations if their educational field is computing, OC workers if their education field code is Social Sciences and Business, and R&D workers if their educational field is technical. Sourcing R&D this way from occupational data is useful for tracking R&D work in service firms where there is typically no separate R&D plant or related team work.

Figure 11 shows employment share of innovative type workers in the full sample and for survey R&D in the R&D survey sample. It is assumed that only part of this type of workers' working time goes to innovative activities. This share is 70% for R&D work, 20-25% for OC work and 50% for ICT work.

[4] http://www.ilo.org/public/english/bureau/stat/isco/

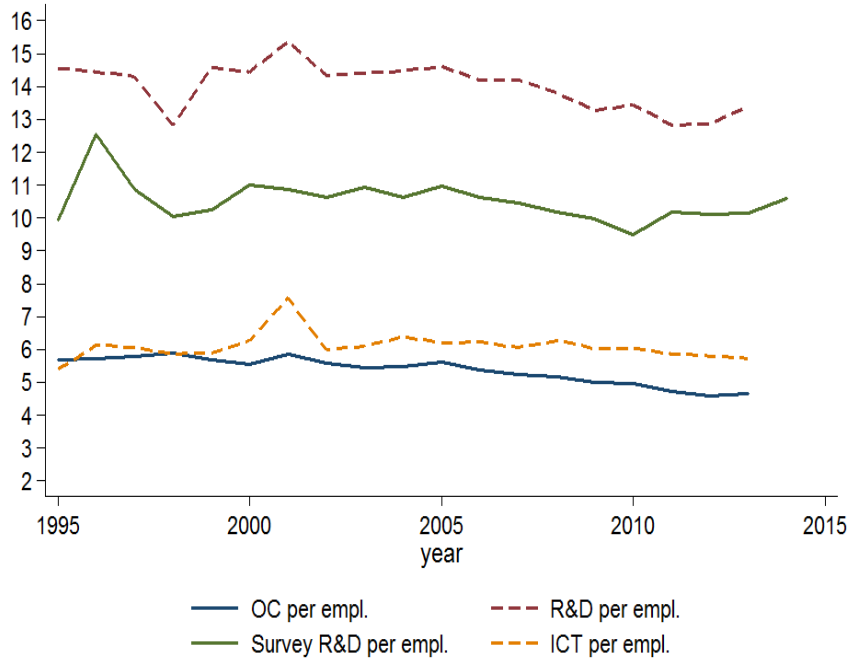

Figure 11. Intangible capital work per all work for firms in innovation sample

The figure shows that the shares of IC workers have not increased over time. Moreover, it is seen that our occupational definition of R&D work is broad so that nearly 14% of work relates to R&D according to our definitions. If employment figures from survey R&D data are used, the share is 11%. Finally, OC and ICT work shares are about 5%. All in all, the firms in innovation survey form a sample of knowledge firms where almost one fourth of worktime goes to innovative activities. An important part of new R&D accrues from firms that are becoming more international – also in the way that over half of the firms have international ownership at the moment.

Figure 12 shows the intangible capital investment per employee. Broad R&D investment per employee (blue line) has increased moderately over time being now around 4,600 € per employee, while survey R&D investment per employee (from innovation survey, dashed red line) has increased over the years from 4,900 to 6,600 € per employee. The figure also shows the high procyclicality of the survey R&D investment with the peak values closer to 8,000 € in years 1996 and 2008. OC and ICT investment intensity (dashed green line) has increased from 5,300 to 6,000 € per employee. We can conclude that even though the share of IC workers has not increased over time the skill-level and relative salaries have increased relative to other workers.

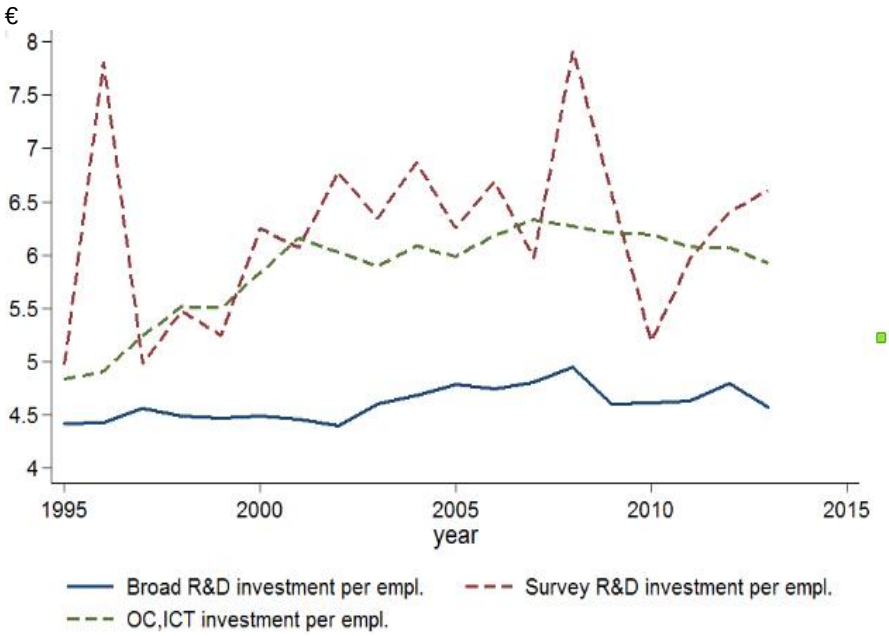

Figure 12. R&D and OC, ICT intensity in 1995-2012 (thousand 2010 euros)

Table 3 summarizes some key values in the Piekkola and Rahko (2017) analysis. It shows that the mean value of broad R&D asset 50,400 € is almost four times to that of survey R&D asset of 14,000 € (both in 2010 euros), but median values are close to each other. Standard deviation of broad R&D is hence much larger than that of survey R&D. IC resources devoted to OC and ICT are the highest with a median value of 8,000 €. Hence, these general knowledge assets should not be ignored. Return on asset (ROA) is measured here by operating profits divided by book value of asset. Fixed assets are poorly shown in balance sheets and vary a lot causing the return on asset to vary extensively between firms of different type. The average ROA is 4.3% which is close to median value 4.7%. For 95% of firms ROA is between 8.1% and 0.05% (outliers at bottom 1% and top 99%-percentile of the distribution are first dropped from data).

Table 3. Innovativity and performance of Finnish firms.

Variable	Mean	Q1	Median	Q3	Std
Innovation survey sample					
Value added per empl.	90.3	47.8	68.1	101.0	398
Return on asset	0.043	-0.16	0.47	0.12	0.19
Employment	184	20.2	46.8	128	761

Tangible investment	12.0	1.25	3.54	9.3	71.6
Book value	74.6	1.54	4.73	17.6	652
Firm age	18.0	14.0	20.0	21.0	5.96
Broad R&D per empl.	50.4	2.92	6.21	13.1	6288
Survey R&D per empl.	14.3	1.61	4.26	12.3	69.8
OC, ICT per empl.	20.7	3.82	8.11	20.7	76.4

With a further analysis of the data, Piekkola and Rahko (2017) find that:

- product innovations appear to be significant factors for productivity improvement since productivity is about 90% higher in firms with product innovations
- process innovations alone have no effect on productivity but improve profitability
- OC and ICT are important for productivity when combined with product innovations; organizational capital interact positively with product innovations.
- tangible capital improves productivity, but its role is rather small
- foreign-owned firms have higher productivity; this does not, however, lead to higher profitability

Results support the hypothesis that product innovations increase the effective use of a process innovation or its quality. Process innovations alone do not enhance productivity, but improved reorganization of processes increase the return on assets.

Piekkola and Rahko (2017) is extended here to cover small firms with 10-49 workers and not only SMEs with 10-249 workers. The aim was to analyze the behavior of start-up firms although these firms typically are on the lower bond in this sample of small firms. It is found that small firms have larger shares of estimated broad R&D than the survey R&D, and the predicted value of this broad R&D explain innovation behavior better than survey R&D. Hence, CIS innovation survey fits poorly in the analysis of innovation behavior of small firms.

Similarly to the firms in general, knowledge capital (OC, ICT) enhances product innovations in small firms. In small firms, innovation intensity is unrelated to the size of the firm. In large firms, the relation is positive which can be explained by size: the higher is the number of employees, the greater is the chance that someone of them innovates. In general, it seems that the innovation processes are not too different in small firms compared to the bigger firms.

Small firms with a major part of foreign ownership are more likely to innovate. However, contrary to the general finding, small foreign-owned firms are less likely to do product innovations. It seems that international investors have not been particularly interested in small innovative firms. A firm has to be large enough for

foreign investors to become interested. In this respect, it can be relatively hard to find foreign funding for innovative operations.

Concluding remarks

Piekkola and Rahko (2017) indicate that foreign-owned firms form a substantial part, if not a dominating part of innovative firms. Hence, in order to develop the Finnish innovation system further, we need to attract more foreign investments for innovative activities. This target is perhaps equally important than the need to have public finance to support new start-ups.

From a methodological viewpoint, register-based occupational and survey R&D data have comparable implications for product and process innovations in large firms. However, register-based occupational data give valuable information on innovative resources of small firms. CIS survey is not large enough to cover smallest firms properly. Survey-based R&D does not explain the innovativeness of small firms and, hence, Innomitta II way of measuring innovative resources is valuable especially for the analysis of the smallest firms.

Economics measure productivity differently from the way business does it. For example, an important way to measure performance in business is by returns on asset. An important finding is that profitability effects are positive for process innovations although these do not increase productivity, at least if not combined with product innovations. Process innovations' positive profitability implications suggest that process innovations are important for improving efficiency, but this may be because of the improvement of cost efficiency rather than an increase in output.

2.2 Policy differences

2.2.1 Innovation policy framework

Three channels through which policies shape aggregate productivity

Knowledge is nowadays translating into the value: in many cases, there are ample of manufacturing resources and capacity available, the key question being who can manage the use of those resources in the most capable and efficient manner. Productivity is about "working smarter", rather than "working harder": it reflects our ability to produce more. Competition shifts from physical resources to capabilities because they can be scarce. It requires deep understanding of the market and customers to know what to produce, when and where. This phenomenon can be titled as competitive use of resources.

A new OECD research shows that the main source of the productivity slowdown is not so much a slowing of innovation by the most globally-advanced firms, but rather a slowing of the pace at which innovations spread out throughout the economy – a breakdown of the diffusion machine. Labor productivity at the global technological frontier increased at an average annual rate of 3.5% in the manufactur-

ing sector over 2000s, compared to just 0.5% for non-frontier firms, while the gap is even more pronounced in the services sector (Andrews, Criscuolo and Gal, 2015). The gap between those high productivity firms and the rest has been increasing over time.

The relative strength of such global frontier firms likely reflects their capacity to "innovate", optimally combine technological, organizational and human capital in production processes throughout global value chains and harness the power of digitalization to rapidly diffuse and replicate leading-edge ideas. More significantly, the rising gap between those high productivity firms and the rest raises key questions about the obstacles that prevent all firms from adopting seemingly well-known and replicable innovations. Future growth will depend on harnessing the forces of knowledge diffusion, which propelled productivity growth for much of the 20th century. This is particularly vital in the services sector, given that services account for an increasing share of economic activity, and logistics, finance, business services and communications are the oil that greases the wheels of globalization.

These new (global) frontier technologies do not immediately diffuse to all firms. At first, they are only accessible to the most productive firms in an economy (i.e. national frontier firms). Then, over time they can represent a source of technological diffusion to laggards, but presumably only once they have been adapted to national circumstances by national frontier firms. This is consistent with evidence that the productivity growth of laggard firms within a country is more strongly related to productivity developments of the most advanced domestic firms as opposed to those of the globally most advanced (Andrews, Criscuolo and Gal, 2015; Bartelsman, Haskel and Martin, 2008; Iacovone and Crespi, 2010).

One of the key questions with respect to manufacturing renewal is how SMEs can be competitive against big international competitors. In this competition one needs much more than traditional factory or machine automation. The value of digital or virtual engineering is exceeding the value of actual or physical engineering. For the maximization of knowledge diffusion, policies that improve the allocation of scarce resources – labor, capital and skills – are crucial. OECD countries differ significantly with respect to these structural factors – implying that diffusion comes easier to firms in some economies than others. There are three key channels through which different public policies shape productivity performance (OECD, 2015):

- experimentation with new knowledge and technologies in the globally most advanced firms and their subsequent diffusion to the most advanced firms at the national level
- the diffusion of globally available knowledge and technologies to both advanced and laggard firms at home; and
- the efficient reallocation of resources to enhance the aggregate impact the within-firm productivity improvements that will be realised from the previous two key channels.

Innovation systems

Hekkert et al. (2007) propose a set of seven functions to be applied when mapping the key activities in innovation systems, and to describe and explain shifts in technology specific innovation systems. Six of these functions, with a loose mapping to two channels through which policies shape aggregate productivity, are listed in the table below and establish the basis for the discussion of the Danish and Finnish innovation policy practices in this chapter. The seventh function, resource mobilization, can be seen to coincide quite closely with the third OECD's key channel, efficient reallocation of resources.

Table 4. Six functions of technological innovation systems interacting with two key channels through which different public policies shape productivity performance

Function	Policy	Channel	Outcome
Experimentation with new knowledge and technologies			
Guidance of the search	Design and implementation of research and innovation policies	Identifying the drivers of knowledge demand	Reducing the (perceived) degree of uncertainty in technology development
	Set long term policy goals	Co-ordination and channelling knowledge demands	Generate a momentum for change
Knowledge development	Public investment in RDI	Ensuring quality and excellence of knowledge production	Securing long term investment in research and innovation
	Support RDI collaboration on speculative leading-edge technologies	Coherence between RDI thematic focus in the public and private sector and economic specialization	Pushing the global technological frontier via more radical innovation and knowledge absorption from the science base
	Labor market and education policies	Providing qualified human resources	Making the most of human capital
Entrepreneurial experimentation	Market-neutral innovation policy	Creative destruction and continuous renewal	More experimentation, innovative entrants bring new ideas and pressures incumbents to inno-
		Dealing with	

	Policy support for risk taking	barriers to private RDI investment	vate Promote experimentation
Market formation	Public procurement Up-scaling to international markets	Formation of temporary niche markets Mitigate buyers' uncertainty about new technology	Learn about the new technology Reach sufficient scale to compete on global markets
Diffusion of globally available knowledge and technologies			
Knowledge diffusion	Support RDI collaboration between private firms and public research entities Attract investments by multinational enterprises	Transmission and diffusion of frontier knowledge and technologies Facilitating global learning spillovers	Facilitating circulation between university, public research institutes and business sectors Profiting from international knowledge
Counteract resistance to change	Support functional dynamics Efficient public services	Enhance the legitimacy of emerging innovation system Enable interactions at national technology frontier	Generation of positive external economies Support dynamism in the society

The central idea behind our innovation system approach is that innovation and diffusion of technology is both an individual and a collective act. The innovation system approach encompasses individual firm dynamics as well as particular technology characteristics and adoption mechanisms. The Figure 13 presents one innovation system "in action", namely, the discovery of Neste CityFutura fuel (Hongisto et al. 2001; Loikkanen 2012).

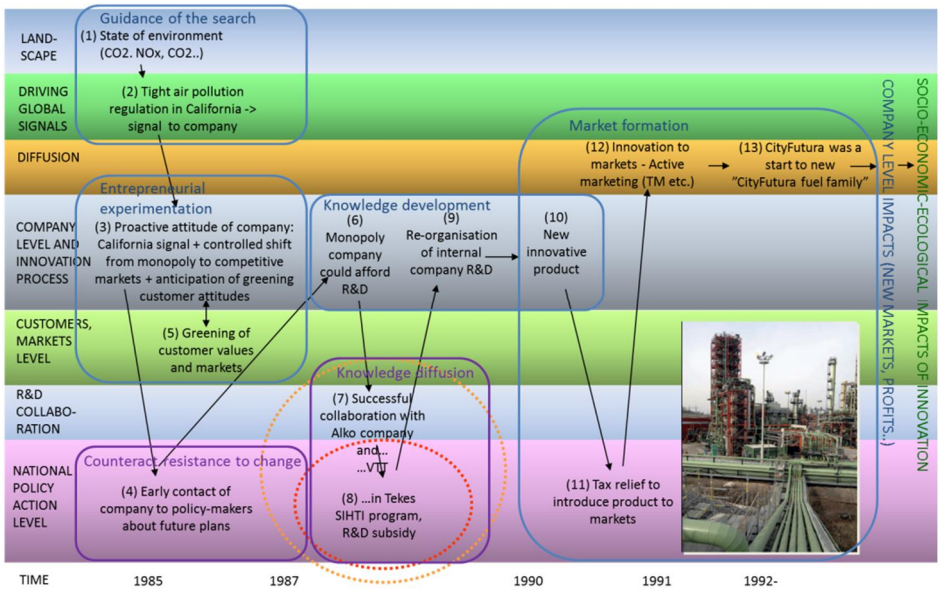

Figure 13. Development of CityFutura fuel by Neste Ltd (modified from Hongisto et al. 2001; Loikkanen 2012); functions relating to the OECD channel of Experimentation with new knowledge and technologies are presented in blue colour and to Diffusion of globally available knowledge and technologies in violet.

Applying the systemic aspect of the systems of innovation approach in order to understand technological change has large implications. The systemic character of technological change explains why technological change is often a very slow process and why it is so difficult to influence. After all, the rate and direction of technological change is not so much determined by the simple competition between different technologies, but predominantly by the competition between various existing innovation systems, both fully developed and emerging ones (Hekkert et al., 2007).

As an example, we present in the Figure 13 how the aforementioned functions interacted positively and influenced each other in the Neste CityFutura fuel case. The function fulfilment led to positive feedback loops that strengthened each other and led to the building up of momentum to create a process of creative destruction within the incumbent system. A common trigger for virtuous cycles in the field of sustainable technologies is function 1, guidance of the search. In this case, societal problems are identified and government goals are set to limit environmental damage. These goals lead to new resources which, in turn, lead to knowledge development and increasing expectations about technological options (de Jong, 2004). The Figure 13 presents one company's technology commercialization case. Hence, is not directly applicable to a national innovation policy framework.

2.2.2 Guidance of the search

Guidance of the search refers to those activities within the innovation system that can positively affect the visibility and clarity of specific wants among technology users (Hekkert et al, 2007). There must then be sufficient incentives and/or pressures for the organizations to choose to enter a developing technological innovation system. This function is the combined strength of such factors.

An example about the guidance of the search function is the long-term goals that are set by different governments to reach a certain politically important goal in the future. This ambition grants a certain degree of legitimacy to the related technology development and stimulates the allocation of resources for this development. One example is formed by the ambitious goals set by the Californian Air Resources Board in 1990, to oblige the major car manufacturers to bring zero emission vehicles to the market in 2003. Frenken et al. (2004) showed that this long term policy goal led to an increase in R&D activities to develop low emission vehicles.

Design and implementation of research and innovation policies

In Denmark, the 1990s saw a strong academic reorientation after the growth of strategic research in the previous decade. This reorientation came with new instruments, new funding channels, higher PhD volume and stronger internal management at the universities. The Danish National Research Foundation was created with effect from 1993 to supply long-term support to new Centres of Excellence. This support was solely based on academic quality criteria. It was agreed that the balance between institutional funding and project funding should be maintained at the level that was reached during the early 1990s. Moreover, an overhead system was established in 1995, which reduced the pressure on the institutional funding further.

Also in 1993, a new Danish university act was passed with the main goal of increasing the influence of society on the universities by including external representatives in the boards. The universities started to receive a larger share of the total public research funds at the expense of the public research institute sector, which according to critics were dominated by too small units, unclear quality criteria and non-standardized frame conditions (Aagaard 2011). Following these changes in the early part of the decade, the following 10-15 years were characterized by relative stability in both funding balances and frame-conditions.

A new University Act from 2003 introduced boards with a majority of external members as the superior authority of universities and prescribed employed leaders. The Act emphasised that the universities' new management should make strategic selections of research areas and give high priority to these areas (Aagaard and Mejlgaard, 2012). This reform was implemented together with a merger process which reduced the number of universities from twelve to eight. Similarly, 12 out of 15 public research institutes were transferred to one of the eight remaining universities. The result was a large concentration of resources within a few

select institutions, and a clear break with the former division of labor between academic research and the more applied research of the public research institutes. In reality, the majority of the public research institute sector was closed down (Aagaard 2011).

In the early 1990s, Finland was struck by a severe economic crisis which led to very high unemployment and a banking crisis and strengthened market-orientation. At the same time, economic globalization, European integration and rapid technological development have laid foundations for increasingly market- and competitiveness-oriented policies. As a result, economic efficiency, competitiveness and growth were emphasized as increasingly important governmental objectives. The additional research and development funding programme became especially important for the Finnish development at this point in time. The programme increased public funding in the innovation system altogether by over 540 million euros, being a substantial increase of resources (Prihti et al., 2000). Research capacity of the system extended significantly. The additional funding scheme strengthened especially universities and research funding agencies.

During the 1990s, other changes also took place, which strengthened the innovation system in various dimensions. For instance, the number of higher education and post-graduate students was increased significantly, and new system of post-graduate schools made the researcher training more systematic. Furthermore, research- and innovation-related collaboration and interaction increased significantly both domestically and internationally (Nieminen, 2005). These measures strengthened visibly Finland's innovation base and as a result the increase in publication activity and patent applications was significant (Academy of Finland, 2003).

In economic terms, the country recovered relatively rapidly as the rise of the ICT cluster and increased private and public R&D investments boosted the Finnish economy to considerable renewal. ICT sector became the third strong industrial sector alongside the traditional strongholds of metal and paper industries. As result of the ICT-driven growth, Finland was ranked as one of the most competitive countries in the world in the beginning of the 2000s (IMD, 2002).

Indeed, after a positive development until the early 2000s, structural problems of the economy started gradually to culminate. Finland started to loose export shares starting already approximately 2001-2002 due to the move of component manufacturing overseas. Pulp and paper industries faced the falling trend on worldwide paper consumption, and after the mid-2000s, Nokia-led ICT cluster started to lag behind US and Korean competitors in smart mobile technology. Since 2008-2009, the economy faced deepening global and European financial problems (Kilponen, 2015; Borg and Vartiainen, 2014).

Also in Finland, it was decided to pool resources, create bigger and fewer units and profile units according to their strategic strengths. This process was started in 2006, and it is still continuing. As a result, universities have been merged, and their number has been reduced from 20 to 14. Similarly, the number of polytechnics has been reduced from 36 to 26. Finnish universities have also been since the year 2009 independent corporations under public law or foundations under

private law, which has made their operations and structures more flexible (Tirronen and Nokkala, 2009). Also, the government decided to merge some public research institutes and reallocate innovation funding from public research institutes and Tekes to so-called strategic research supporting political decision-making and Prime Minister's Office (Prime Minister's office, 2013).

Set long term policy goals

In 2013, the Danish Government launched Denmark's first comprehensive innovation strategy "*Denmark – a nation of solutions*" based on collaborative efforts between the involved ministries, i.e. the Ministry of Higher Education and Science, the Ministry of Business and Growth and other relevant sectoral ministries, as well as stakeholders from the Danish innovation system. The innovation strategy is the outcome of a strategy process that started in March 2012 and was completed by the end of 2012 (Danish Government, 2012). The process involved an extensive consultation with relevant stakeholders and actors in the innovation system.

In connection with the new innovation strategy the Danish Government started a process that led to the creation of the first INNO+ catalogue "*INNO+: The Innovative Denmark*" [5] presented in September 2013 (Danish Government, 2013). It is the result of an extensive process through which a wide range of stakeholders from industry and interest organizations, knowledge institutions, ministries and research councils, etc. identified the essential and most promising areas for strategic investments in innovation in Denmark. INNO+ identifies 21 concrete focus areas for research and innovation that are geared towards finding solutions to the grand societal challenges. The thematic focus is on transportation, environment, urban development, food, bio-economy, health, production, digital solutions and energy. In that regard, INNO+ shares many of the main areas of the EU Framework Programme Horizon 2020.

The Finnish research and innovation system is divided into four operational levels. The Finnish Parliament and the National government rule the highest level. In matters related to research, technology and innovation policy, the latter is supported by a high-level advisory body, the Research and Innovation Council (RIC). The RIC advises the government and its ministries on strategic issues (such as policy priorities and budget allocations, as well as on the evaluation and development of national innovation system as whole) and coordinates science and innovation policies across ministries, whereas the implementation of these policies is the responsibility of respective thematic ministries.

The latest recommendations of the Research and Innovation Council identified the important reforms needed in research and innovation policy to be the introduction of new means and models to strengthen innovation activity, the establishment of attractive hubs of expertise, internationalization, structural development of higher education, the reform of research institutes and research funding, infrastructure policy and setting up the tenure track system. The RIC points out knowledge areas

5 http://ufm.dk/en/publications/2013/inno-catalogue

and sectors, which are important for Finnish economy and wellbeing, including: ICT, especially mobile and software knowhow, clean solutions in energy, environment and material efficient technologies (cleantech), bio- and nanotechnologies, health and wellbeing and arctic knowhow.

Table 5. Innovation policies relating to the guidance of the search

Policy	Denmark	Finland
Design and implementation of research and innovation policies	New Danish university act in 1993: strengthened the authority of the vice-chancellors both externally and internally, a result was a shift of power from the representative organs to the elected leaders New Ministry of Science, Technology and Innovation in 2001: assumed the overall responsibility for both research- and innovation policy University act in 2003: boards with a majority of external members Reform of RDI institutions in 2006: merger process which reduced the number of universities from twelve to eight; 12 out of 15 research institutes were transferred to one of the eight remaining universities The different research councils were merged into one entity (Innovation Fund) in 2014, see Chapter 2.2.3	National innovation system is introduced as a central policy concept in 1990 National innovation strategy by the Government in 2008 Research and Innovation Council's (RIC) new guidelines 2014–2020 aiming to improve the R&I system and governance including the establishment of Council of Strategic Research (SRA) in 2014 The university reform (with the new University Act in 2010) increased the autonomy of universities, making them autonomous legal entities. This has been followed by mergers of several universities decreasing the amount of universities to 16. New Polytechnics Act in 2014: polytechnics were made independent legal entities The reform of research institutes in 2015

Setting long term policy goals	Danish National Research Foundation (DNRF) from 1993 to supply long-term of support new "centers of excellence" solely based at academic quality criteria The first comprehensive innovation strategy, "Denmark – nation of solutions" in 2013: seeks to guide policy making in innovation related matters The first INNO+ catalogue in 2013: defines 21 areas for research and innovation that are geared towards finding solutions to the grand societal challenges	The 'Research and Innovation Policy Guidelines for 2011-2015' (Research and Innovation Council) and the 'Growth through expertise, Action plan for research and innovation policy' are two key policy documents which set out at national level the policy guidelines on the required measures

2.2.3 Knowledge development

Public investment in RDI

The second function of an innovation system relates to knowledge development. Mechanisms of learning are at the heart of any innovation process. For instance, according to Lundvall: "the most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning" (Lundvall, 1992). Innovation at the frontier partly depends on basic research, which drives fundamental advances in technological knowledge and in turn opens up windows of opportunity for future research (Nelson, 1959; Aghion and Howitt, 1996). Publicly-funded research often plays a crucial role in the development of new general purpose technologies (Sheehan and Wyckoff, 2003). Evidence suggests that government, both as a buyer of technology and as funder, e.g. of research in universities and public research centres, provides significant knowledge spillovers. This tends to underpin significant increases in research and development expenditures and patents of private companies (Draca, 2012; Moretti, Steinwender and Van Reenen, 2014 and Azoulay et al., 2015).

In general, the trajectory of investment in research and development has fluctuated, and in the financial crisis of 2007-2009 it was considered something of a dividing issue. During the crisis and immediately after it, investment in R&D generally fell. After this the development in different countries has been so divergent as to have led to the creation of three distinct classes. This three-way distinction

has been explored recently by the Global Innovation Index (2016). Belonging the first category are those countries in which R&D investments did not drop during the financial crisis, and in which they have grown strongly since then. These countries include China, South Korea and Denmark. In the second category are the countries in which R&D investments fell during the crisis, but have since then risen. Such countries are for instance the Netherlands, Estonia, Germany, Norway and the United Kingdom. The final category contains the countries where R&D investment dropped during the crisis and has remained below pre-crisis levels. Finland is in this category, as are, among others, Sweden, Canada, Spain, Greece, Portugal and Romania.

In Denmark, the main responsibility for research and innovation and its funding is placed within the authority of the Ministry of Higher Education and Science. Certain other ministries like the Ministry of Climate, Energy and Building, the Ministry of Food, Agriculture and Fisheries, the Ministry of Environment and the Ministry of Foreign Affairs have larger R&I programmes. These R&I programmes have had stable funding over the past couple of years and at the same time overlap only to a very limited extent with the major funding instruments under the Ministry of Higher Education and Science. The ministries have specific agencies which implement the respective policies.

Due to the severe economic situation in Finland, the PM Sipilä's Strategic Government Programme introduced significant budget cuts to public expenditure from 2016 onwards, with direct impact on the allocations and implementation of the national R&I policy. The proposed reductions in Government R&D budget allocations for 2015–2016 were in total of 157 million euros (-9.4%) and were distributed so that the public research institutes and Tekes were hit the most, -24% and -23% respectively.

Support RDI collaboration on speculative leading-edge technologies

To the extent that small firms collaborate with universities to develop technologies core to their business, the benefits to productivity will be realized relatively quickly. By contrast, larger and more productive firms are more likely to collaborate with universities on speculative leading-edge technologies, which are at the pre-competitive stage and less readily applicable to the firm's core business (Santoro, Alok and Chakrabati, 2002). While this form of R&D collaboration is likely to push the frontier knowledge forward over time, the gains to productivity may be less immediate.

In Denmark, the 2000s saw the establishment of a number of strategic or innovation-oriented research funding channels, including the Danish Council for Technology and Innovation, the Danish Council of Strategic Research and the Danish National Advanced Technology Foundation. These changes in the funding system were dominated by three tendencies: a shift from institutional funding towards project funding, a shift from basic research towards strategic research, and finally a shift from the funding of many small projects towards fewer and larger projects

(Aagaard 2011). In particular from 2006 and onwards these changes were followed by a significant increase in total public R&D investments

Most of the direct funding for private R&I is channeled through the Innovation Fund Denmark which administers strategic research programmes in areas of political priority. It funds research projects and gives advice to applicants. With the establishment of the Innovation Fund Denmark in 2014, the funding landscape has been considerably streamlined. Moreover, fragmented programs and schemes have been combined and reorganized.

The Innovation Fund is also contributing to increased university-industry collaboration. Programmes sometimes require but in any case stimulate public-private collaboration. Large-scale projects are projects with a typical size of more than 700,000 and in some cases of up to 7 million euros. They are typically carried out collaboratively in a public-private partnership.

Academy of Finland allocates research funding to leading-edge scientific research, promotes scientific research and research environments and the application of research results, supports international scientific cooperation and acts as an expert in science policy. The evaluation of the Academy of Finland was concluded in 2013 (MEC, 2013). The evaluation recommends that the Academy's role should be extended into strategic research funding. The Ministry of Education and Culture is also encouraged to consider transferring budget funds from university core funding to the Academy in order to boost the volume of research funded by means of competitive bidding.

If we assume that public-private co-publications characterize how R&D collaboration on speculative leading-edge technologies is supported in a country, there are clear differences between Denmark and Finland. Denmark has 182 and Finland 155 public-private co-publications per million of population compared to 29 for the EU-28 (113 for Sweden). In Denmark, these fields are pharmaceuticals, chemical engineering, biochemistry and neuroscience, on average over the period 2003-2013. In Finland, the areas with the highest percentage of public-private co-publications are energy, engineering, materials science and computer sciences.[6]

6 Source: JRC IPTS RIO elaboration on Scopus data collected by Sciencemetrix in a study for the European Commission DG RTD (Campbell, 2013). The share of public-private co-publications is derived from the Scival platform and is also based on Scopus data (September 2015). SciVal ® is a registered trademark of Elsevier Properties S.A., used under license. The data on public-private co-publications is not fully compatible with the data included in the IUS, due to differences in the methodology and the publication database adopted.

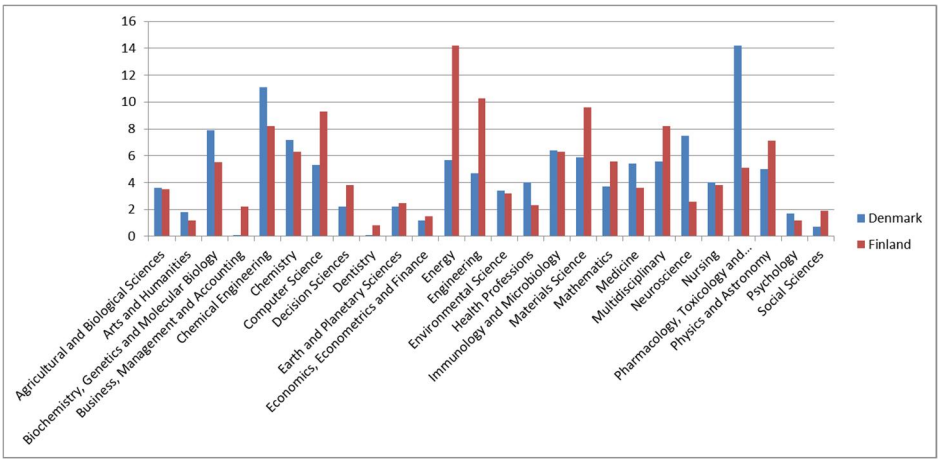

Figure 14. Co-publications by field 2003-2013. Scopus database.

Labor market and education policies

While increases in the number of highly educated workers have significantly boosted labor productivity over the past 50 years, the rate of increase in the stock of human capital is projected to slow. At the same time, the increasing economic importance of knowledge is projected to raise the returns to skills, thus underpinning further increases in wage inequality within countries (Braconier, Nicoletti and Westmore, 2014). In order to mitigate this unfavorable combination of slowing growth and rising inequality, it will become increasingly important to allocate skills efficiently.

Doctoral training

The PhD education produces a reservoir of qualified and competent researchers from where the research institutions can recruit future researchers (Mejlgaard et al., 2012). Similarly, the PhD education introduces research students to the norms and values which define the researcher community. PhD education therefore lies at the core of any nations' research capacity and is seen as the primary source of research productivity and innovation. It is thus a question of vital importance to universities and nations how PhD education is shaped (Nerad and Heggelund 2011; Hollingsworth 2008).

Denmark recognizes that an important prerequisite for knowledge transfer is a critical supply of human resources. The shortage of human resources in science and technology and especially of engineers has been addressed by stakeholders in the private sector. The government addressed this problem via education policy and the numbers of PhD candidates in engineering doubled from 2003 to 2010.

The successful Industrial PhD programme has contributed to an increased absorptive capacity in the private sector.

The strengthening of the PhD education was initiated in the late 1980s when the so-called “Forskerakademi” (The Researcher Academy) was established. The increase in the number of graduating Danish PhD students is resulting from two policy actions. First, in 1990s, the Ministry of Finance in collaboration with Ministry of Science, Technology and Innovation recommended increasing the volume of graduated PhDs by 500 per year. Secondly, the so-called Danish Globalization Strategy from 2006 further increased this target and stated that the number of graduated PhDs by 2010 should be doubled from the 2004 level. Rather than mainly aiming for the reproduction of the public science system these increases were targeting the wider labor market based on the notion that a larger share of highly skilled PhDs (in the private sector in particular) would be an asset in an increasingly competitive globalized knowledge economy. As a consequence of this notion, the increase in volume was highly selective as 90 percent of the increase was to take place within the natural, medical and technical sciences as these areas were perceived to contribute the most to innovation and growth.

In the Figure 15, we depict the three most important fields of graduating PhD students. Denmark has experienced strong growth in the number of graduated PhD students during the last decade. In Denmark, the medical sciences have experienced the strongest growth and have also the highest volume. On the other hand, in Finland the latest decade has seen a stagnating and at times even decreasing development in the number of graduated PhD students.

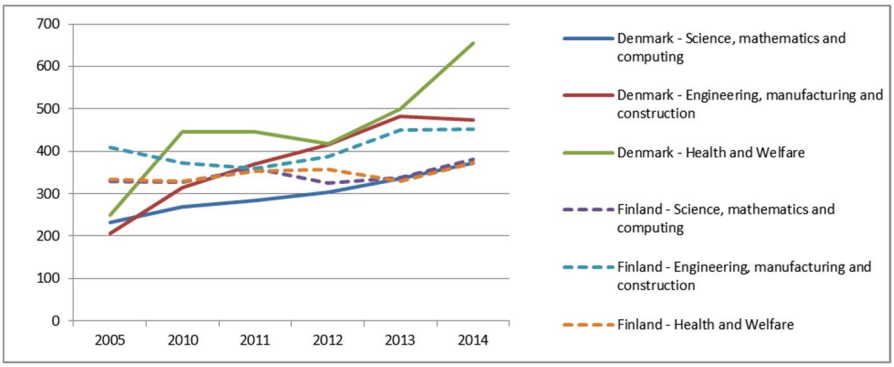

Figure 15. Number of graduated PhD students within the three most important fields in Denmark and Finland 2005 – 2014.

Public investments in education and life-long learning

The share of technological-scientific degrees describes the labor force available to companies in these sectors, as well as the nation’s potential for innovations in these domains. Techno-scientific degrees are those that include all higher educa-

tion examinations in biology, physics, mathematics and statistics, information technology, engineering and technology, material production and processing, architecture and construction. Finland has traditionally had a high number of first-term students in these fields. In 2014, Finland had the third-highest share of first-term students in engineering in the OECD countries, after Mexico and South Korea. (OECD Education at a Glance, 2016)

In Denmark, engineers are perceived as being essential for a future growth of new knowledge intensive sectors (DASTI, 2014). The Danish government has focused on this challenge for a number of years and the issue is pervasive in policy debates and documents. Denmark has set explicit graduation targets for young cohorts. More specifically, to ensure an adequate supply of advanced skills to the economy, Denmark has been investing in schemes to attract more students in science, technology, engineering and mathematics (STEM) disciplines. These include in particular financial incentives for students to increase tertiary enrolment (OECD, 2012). As a result of this policy the number of newly enrolled students has increased significantly over the last years and the numbers of PhD candidates in engineering doubled from 2003 to 2010.

Moreover, life-long learning has become an essential element of updating people's working life skills and maintaining competitiveness. It ensures that workers have the capacity to learn new skills and adapt to changing technologies. At the same time, lifelong learning provides a means of reducing unemployment and preventing social exclusion. In the OECD countries, on average 50 percent of adults participate in education during a 12-month period, either within the education system or in externally provided education and training. Spearheading the ranking are New Zealand and the Nordic countries, with around 65 percent in each of them.

In Denmark, life-long learning has been a policy priority for several years in the National Reform Programmes. Denmark is a country with a flexible, mobile labor force and it also has a long tradition of on-the-job training and funding schemes. In this policy context, the Quality Reform (agreed in 2007) further institutionalized the processes for upgrading of skills, qualifications and further education amongst the labor force.

Table 6. Innovation policies relating to knowledge development

Function	Denmark	Finland
Public investment in RDI	Increasing public R&D funding: Innovation Fund Denmark (2014) joined research, technology development and innovation grants from the Danish Council of Strategic Research, the Danish National Advanced Technology Foundation and the Danish Council for Technology and	The latest Government decision on central government spending limits for 2014 – 2017 sets the long-term budgetary plans for R&I policy: reallocation of €50m from universities' institutional funding to competitive funding (Acad-

	Innovation into one new focused organization. Denmark is among the countries with the highest GERD in the EU.	emy of Finland), and further cuts to university institutional funding. The funding for Tekes has decreased by a quarter.
Supporting RDI collaboration on speculative leading-edge technologies	Focus on world-class universities based on development contracts and bibliometric indicators as a basis for distribution of the increased university core funding: a substantial share of funding is allocated on a competitive basis. Universities mainly cooperate with larger companies, both in terms of value added and in terms of number of employees: these firms are very satisfied with the cooperation (Oxford Research, 2011)	The mergers of the centres of excellence by the Academy of Finland to form larger centres to help solve the problem of funding being spread too thinly Reform of research institutes and research funding (2013) as well as new funding model for universities are meant to drive for excellence The new university funding model and reform with an attempt to lay greater emphasis on quality came into force in 2013
Labor market and education policies	Doubling of PhD student intake in the period 2004-2010: the increase was highly selective as almost 90 percent of the increase took place within the natural, medical and technical sciences Both the “traditional” model of PhD education as well as the Industrial PhD Programme, a combination of industrial experience and academic research. The reform of the state education grant system and framework for higher education programmes in 2013: Improve the cost-effectiveness of the education system, reducing drop-out rates and increasing the number of apprenticeships.	Emphasis has moved from doctoral education more towards post-doctoral career development Research and Innovation Policy Guidelines for 2011–2015 defines a measure to attract international students, researchers and experts: universities have introduced a tenure track as the core academic career system to offer well-supported career path

2.2.4 Entrepreneurial experimentation

The role of the entrepreneur is to turn the potential of new knowledge, networks, and markets into concrete actions to generate and take advantage of new business opportunities. Entrepreneurial experimentation implies a probing into new technologies and applications, where many will fail, some will succeed and a social learning process will unfold (Kemp et al., 1998). Entrepreneurs can be either new entrants that have the vision of business opportunities in new markets, or incumbent companies who diversify their business strategy to take advantage of new developments. Well-functioning product, labor and risk capital markets as well as policies that do not trap resources in inefficient firms help firms at the national frontier to achieve a sufficient scale, enter global markets and benefit from innovations at the global frontier.

This function can be analyzed by mapping the number of new entrants, the number of diversification activities of incumbent actors, the number of experiments with the new technology and the breadth of technologies used and the character of the complementary technologies employed (Hekkert et al, 2007).

Market-neutral innovation policy

Innovation policies, including R&D fiscal incentives, collaboration between firms and universities and intellectual property rights (IPR) protection, should be designed to ensure that they do not excessively favor applied vs basic research and incumbents vs young firms.

A level playing field that does not favor incumbents over entrants is crucial, but this feature is often missing from many policies. For example, it is important that R&D tax incentives are designed so as to be equally accessible and beneficial to incumbent, young firms and start-ups. A new OECD research finds little evidence that economies with more generous R&D tax incentives are more able to learn from the global frontier (Saia, Andrews and Albrizio, 2015). Furthermore, while more generous R&D tax subsidies for small and medium-sized enterprises (SMEs) might raise the productivity of national frontier firms towards the global frontier benchmark, these effects are offset by the fact that such policies may reduce the relative size of national frontier firms (Andrews, Criscuolo and Gal, 2015).

A tax refund for losses stemming from R&D costs has been available to Danish businesses since 2012. To be eligible the costs must relate to developing new or significantly improved materials, mechanisms, products, processes, systems or services. The refund will consist of the tax value of the loss incurred. Given that the Danish corporate income tax rate was set at 24.5% for 2014, the maximum refund to be claimed by a group is therefore DKK 6.125 million (approx. 820,000 euros).

In Finland, governmental support to research and innovation has mainly been channelled through direct funding and this seems to continue. The incentives for

business R&D are very low in Finland compared to other OECD countries.[7] There are currently no tax incentives for business R&D in Finland. The government budget for 2013 included two tax incentives aimed at growth seeking businesses. The tax incentive for private investors targets business angels investing equity in SMEs. The incentive provides a possibility to postpone paying capital gains taxes as long as those gains are re-invested in qualifying businesses. The R&D tax incentive was a deduction from corporate income taxes tied to the wage costs of R&D personnel in Finland. In 2014, the government decided to terminate it due to the lowering of corporate tax. Starting 2015 the only special tax incentive for R&I is targeted to business angels.

Policy support for risk taking

The innovation process is inherently uncertain and the highly skewed nature of the returns on venture capital (VC) investments suggest that the rapid success of frontier firms in some IT markets is impossible to predict a priori, even amongst the savviest VC investors (Kerr, Nanda and Rhodes-Kropf, 2014). Venture capital financing has a sizeable positive impact on innovation and growth (Kortum and Lerner, 2000; Samila and Sorenson, 2011). The productivity and size of national frontier firms also increases with the depth of markets for seed and early stage VC (Andrews, Criscuolo and Gal, 2015). The same is true concerning the ability of economies to learn from the frontier, while learning is also positively associated with the extent of policy support for seed and early stage VC, as proxied by the number of tax and equity policy instruments provided to nurture this market. This is consistent with research showing that: i) greater policy support for seed and early stage VC (SES-VC) is associated with a lower age at which firms receive such financing (Andrews and Criscuolo, 2013); and ii) countries with more developed markets for SES-VC tend to invest more heavily in knowledge based capital (Andrews, Criscuolo and Menon, 2014).

In 2012, the ERAC peer review pointed to difficulties in increasing the Danish innovation capacity and growth of SMEs (European Commission, 2012). Danish support for innovation in SMEs had been relatively underemphasized and the instruments were deemed too small. In 2013, the Market Development Fund[8] (formerly 'Business Innovation Fund') was restructured to a market maturation fund to ensure that more innovative products and solutions reach the market for the benefit of growth and job creation in Denmark.

Moreover, the Growth Fund, a state investment fund, provides venture capital to entrepreneurial growth companies. Since 1992 the Growth Fund has, in cooperation with private investors, co-financed growth in 5,400 Danish companies with a total commitment of approx. 2 billion euros. The Growth Fund invests equity or provides loans and guarantees in collaboration with private partners and Danish

7 http://ifuturo.org/documentacion/Science%20Technology%20and%20Industry%20Outlook%202014.pdf

8 http://markedsmodningsfonden.dk/in_english

financial institutions. In 2014, the companies which the Fund has co-financed represented a total turnover of approx. 9 billion euros and employed more than 41,000 people all over the country. The Growth Fund is an appropriate measure for supporting on-going business development in sectors of high societal importance. The Innovation Fund has been a significant step forward in terms of providing efficient and effective funding.

In Finland, the policy reforms are targeted at increasing the number of high-growth innovative companies as they are considered to be major contributors to employment of tomorrow. The innovative high-growth companies are also considered as a means to diversify the Finnish economic structure. It was decided already in 2006 that Tekes should have stronger impact on generating new start-ups, growth companies and new business lines in existing companies. Indeed, despite introducing significant cuts to public R&D expenses, the Research and Innovation Council guidelines for 2015–2018 aims to enhance the funding, equity capital and risk-taking capacity of start-ups and young innovative companies (YIC). The cuts to Tekes' budget are likely to harden the funding for large businesses and research organizations as the needs of young companies and SMEs will be prioritized. Combined with the additional investments to Tekes Venture Capital Ltd, it is evident that the focus of the Finnish R&D system will take a further shift towards start-ups and YICs in the coming years.

Tekes is the main public actor for YICs and growth-oriented start-ups. The Young Innovative Companies programme was launched in 2008. By providing funding up to 1.25 million euros (covering up to 75 % of the total costs), YIC aims to substantially accelerate the global growth of the most promising small companies. The programme is very selective and designed for companies that aim for international ambitious growth and that have been in operation less than 6 years and have proven its business concept. Funding is provided in three phases (€250,000 grants + €250,000 grants + €750,000 loans), each dependent on the achievement of specific milestones. By 2015, a total of 260 companies have been selected to the programme and 75 companies have completed all three funding phases. According to external evaluations, the results of the programme have been very promising. A key feature of the programme is its comprehensive approach for the company development: besides funding, the programme helps companies by providing non-financial support (e.g. mentoring).

Another important instrument for YICs is VIGO business accelerator programme, established in 2009. The purpose of VIGO is to bridge the gap between early stage technology firms and international venture funding by combining public and private funding. By 2014 the share of public funding was around 26 % of the total funding. The programme is implemented through independently run companies (currently 9), who act as "co-entrepreneurs" and invest in the companies they work with. Tekes is responsible for the implementation of the programme and it is coordinated by an independent contractor. According to an external mid-term evaluation, VIGO has been successful in achieving its early-stage goals. Science|Business Innovation Board assessment of the YIC and VIGO programmes

uncovered good evidence on their success (The impact of high-growth entrepreneurship policy in Finland).[9]

Tekes Venture Capital Ltd (established in July 2014) invests in VC funds, which invest in early stage Finnish companies. The purpose is to develop Finland's VC market by "fixing shortcomings that exist in the availability of funding for the initial stages of the operations of a company". In the new government Programme additional funds of 10 million euros will be allocated to Tekes Venture Capital Ltd.

Other instruments, not considered especially for start-ups but having a clear impact on the birth of new start-ups, have been established due to Nokia's restructuring. For example, within Nokia's new career support programme (the Bridge Programme) some 400 new firms were founded between 2011 and 2013, many of which classify as new innovative firms. Microsoft continued whit its own career support programme Polku. Similarly, the Innovation Mill, launched in 2009, is a concept for commercializing "non-core" corporate IPR from large companies by spinning off start-ups and new business lines in SME's. It is coordinated by a private service provider and funded by Tekes. Total funding of Innovation Mill in 2009-2014 has been 84 million euros of which 42 million has been public (Tekes) funding. In this case the research has already been executed - often by big companies and research organizations together - and patented, with Innovation Mill commercializing the results.

In parallel with public policy attraction to start-ups, there have been significant grassroots level initiatives to bolster start-ups. The most recognized initiatives are arguably those emerging around the Aalto University, e.g. the Start-up Sauna accelerator and especially Slush start-up event, which attracts more than 10,000 attendees (start-ups, international investors, executives and media) from all over the world. These initiatives have also received some public support, but they should be seen first and foremost as bottom-up initiatives.

Table 7. Innovation policies relating to entrepreneurial experimentation

Policy	Denmark	Finland
Market-neutral innovation policy	The innovation strategy highlights integration of innovative competences and entrepreneurship in education programmes and closer coordination of education, research and innovation policy A tax credit on R&D expenditures from 2012. The tax credit amounts to 25 percent and is applied to the busi-	The new Government programme in 2015: strengthening competitiveness by improving conditions for business and entrepreneurship by reforming key legislation and removing sectoral regulation that prevents competition

9 http://www.sciencebusiness.net/OurReports/ReportDetail.aspx?ReportId=84

	ness expenses that relate to R&D. A maximum of approximately €170,000 may be claimed per financial year.	
Policy support for risk taking	Denmark has developed a policy focus on turning knowledge into business by supporting the commercialization of public research results (proof of concept – to be phased out, venture capital and risk capital). The Growth Fund, a state investment fund, provides venture capital to entrepreneurial growth companies.	The focus of public RDI funding has been effectively shifted to growth companies: introduction by Tekes of a programme for funding young, innovative companies; establishment of Tekes Venture Capital Ltd fund of funds with the possible of asymmetric distribution of profits; the expansion of the Vigo Accelerator Programme The tax incentive for private investors targets business angels investing equity in SMEs University and polytechnics reforms stress more emphasis on entrepreneurial skills and innovation

2.2.5 Market formation

New technology often has difficulty to compete with embedded technologies. Rosenberg puts it like this: “Most inventions are relatively crude and inefficient at the date when they are first recognized as constituting a new innovation. They are, of necessity, badly adapted to many of the ultimate uses to which they will eventually be put; therefore, they may offer only very small advantages, or perhaps none at all, over previously existing techniques. Diffusion under these circumstances will necessarily be slow” (Rosenberg, 1976).

Market formation normally goes through three phases with quite distinct features. In the very early phase, “nursing markets” need to evolve (Erickson and Maitland, 1989) so that a “learning space” is opened up, in which the innovations can find a place to form (Kemp et al., 1998). The size of the market is often very limited. This nursing market may give way to a “bridging market” (Andersson and Jacobsson, 2000), which allows for volumes to increase and for an enlargement in the innovation system in terms of number of actors. Finally, in successful cases, mass markets (in terms of volume) may evolve, often several decades after the formation of the initial market.

Because of these difficulties in gaining market acceptance, it is important to create protected space for new technologies when they are deemed politically important. One possibility is the formation of temporary niche markets (Schot et al., 1994) for specific applications of a technology. Within such an environment stakeholders can learn about the new technology and expectation can be developed. Another possibility is to create a (temporary) competitive advantage by favourable tax regimes or minimal consumption quotes.

Public procurement of innovative solutions

An example of innovative public procurement that was established in 2011 in the Nordic region is a program on innovation in the health sector. Based on the observation that the health sector is by far the most important buyer and consumer of health care products, the program seeks to exploit the opportunity for demanding new and innovative products and services from the private sector. The program is one of the six so-called lighthouse projects that the Nordic Ministers of Trade and Industry agreed on for the Nordic cooperation program for innovation and industry policy.

Public procurement in Denmark has mainly been driven by efficiency and cost-effectiveness concerns. Until a few years ago, little consideration was given to innovative public procurement. However, this situation is currently changing due to several initiatives that aim at using public procurement as a means of stimulating innovation.[10] The purpose of *innovative public-sector purchases*[11] action area is to make it easier for public-sector institutions to obtain innovative new solutions. By specifying requirements in new ways, the public sector can help to target enterprise innovation, so enterprises develop better solutions that may even cost less. An innovative purchase could involve buying familiar products but combined with innovative new services to reduce operating costs and provide better service for citizens at the same time. It could also involve demanding brand-new solutions not yet available on the market or which require the public-sector partner to enter into public-private development cooperation.

Prior to 2009 the role of innovation oriented public procurement was modest in Finland. However, the Research and Innovation Policy Guidelines for 2011–2015[12] placed emphasis on public procurement by referring to it as one of the key tools of demand driven innovation policy. The development of public procurement is also one of the key themes in the action plan (Ministry of Employment & Economy, MEE) and policy framework for demand and user-driven innovation.[13] The aim of the smart procurement programme (2013 - 2016)[14] was to create smart demand, which will provide the prerequisites for new market creation and growth.

10 https://www.evm.dk/publikationer/2013/31-10-13-strategi-for-intelligent-offentligt-indkoeb
11 http://markedsmodningsfonden.dk/innovative_purchases
12 http://www.minedu.fi/export/sites/default/OPM/Tiede/tutkimus-_ja_innovaatio neuvosto/julkaisut/liitteet/Review2011-2015.pdf
13 https://www.tem.fi/files/27547/Framework_and_Action_Plan.pdf
14 http://www.tekes.fi/en/programmes-and-services/tekes-programmes/smart-procurement/

The main focus areas for the programme are those areas in which the public (or private) procurement has a major impact on the market: *energy and environment, ICT, health care, built environment, security and safety and private strategic procurement.* Furthermore, smart procurement is integrated as a theme in some other programmes, too. The programme budget is about 60 million euros of which TEKES covers half.

Up-scaling to international markets

Since innovation is about trial and error, failure needs to be recognized as an opportunity to learn and rebound, rather than being seen as the end of the game. Thus, the policy environment should enable successful firms to grow, but also let weak firms exit the market, so that scarce resources can be released to underpin the growth of the successful ones. In this regard, comparing countries with similar survival rates but significantly different post-entry growth patterns – e.g. Sweden vs. Italy and Finland vs. New Zealand – is instructive (Calvino, Criscuolo and Menon, 2015).

While trade can facilitate learning, firms must overcome a number of hurdles before they can trade. A key barrier is insufficient scale to the extent that international trade entails a number of fixed costs that must be met (Melitz, 2003). This is consistent with the finding that a relatively small share of large firms accounts for the lion's share of an economy's exports (Eaton, Kortum and Kramarz, 2011; Breinlich and Criscuolo, 2011).

Firm size tends to grow with the effective market size, implying that small and geographically isolated economies will be at a natural disadvantage in this regard. This disadvantage will be compounded by the fact that participation in trade results in larger market size, which in turn raises the returns to investments in R&D (Acemoglu and Linn, 2004; de Serres, Yashiro and Boulhol, 2014). Reaching sufficient scale takes on heightened importance given rising global integration. All else equal, tougher global competition implies that the minimum level of performance in terms of size (and productivity) at which firms are able to compete on global markets may have risen over time (Altomonte, et al., 2011).

The Market Development Fund (see Chapter 2.2.4) has since 2013 been concerned with assisting firms to bring their new products to the market faster. An amount of about 24 million euros was allocated for the Market Development Fund each year from 2013 up to and including 2016. The fund provides grants and guarantees to business projects which need support for market maturation. To be eligible for support these solutions must be ready to be launched in the market, but encounter barriers to reach the market. Funding is provided to test whether a prototype or concept works in a realistic environment or at a prospective customer's site and to adapt the prototype/concept to strengthen the solution's commercial market potential.[15] Moreover, companies with innovative products can be assisted by the Market Development Fund's guarantee to mitigate buyers' uncer-

15 http://markedsmodningsfonden.dk/faster_to_market

tainty about investing in new technology. The buyer has a 20% own risk, which means that if the buyer chooses to redeem the guarantee, the maximum refund will be 80% of the purchase price.

In Finland, Tekes introduced a "Planning for Global Growth" instrument (KKS) in 2013. The purpose of the instrument is to help companies examine their readiness for achieving rapid international growth. The maximum funding for companies less than 5 years old is 50,000 and for other growth-oriented companies 100,000 euros. Moreover, Finnvera provides financing for the start, growth and internationalization of enterprises and guarantees against risks arising from exports. Finnvera offers loans, domestic guarantees, venture capital investments, export credit guarantees and other services associated with the financing of exports. Finnvera's SME financing issued in 2014 was 1 billion euros and Export credit guarantees and special guarantees 5 billion euros. Even though the share of Tekes customers among Finnvera customers is only 10 %, the share of Finnvera customers among Tekes customers is 60 % in a longer time span.[16]

Table 8. Innovation policies relating to market formation

Policy	Denmark	Finland
Public procurement	The development of an intelligent public procurement strategy in order to foster innovation: Denmark has implemented initiatives related to public procurement of green innovations and in the health sector	The reform of the Act on Public Procurement, so that public procurements pay greater attention to innovation and creating a culture of experimentation in 2015: encourage businesses to develop new innovations, renew public services, increase productivity, and to create new markets The Smart Procurement Programme (2013–16)
Up-scaling to international markets	Restructuring of the Market Development Fund in 2013: test whether a prototype or concept works in a realistic environment, and guarantee to mitigate buyers' uncertainty about investing in new technology	Planning for Global Growth instrument in 2013

16 https://www.finnvera.fi/eng/Finnvera/News/(newsid)/3641

2.2.6 Knowledge diffusion

Support R&D collaboration between private firms and public research entities

R&D collaboration between private firms and public research entities has become increasingly common. OECD evidence suggests that more intensive collaboration between firms and universities – as proxied by the share of higher education R&D financed by industry – is associated with more diffusion of foreign advanced technologies and may also facilitate the mobility of skills. Accordingly, the productivity gap between national and global frontier firms tends to be lower in countries where there is more intensive R&D collaboration (Andrews, Criscuolo and Gal, 2015). This may reflect the fact that university researchers might be more connected to the global knowledge frontier, which increases the speed of technological diffusion, while financial support from industry might increase research possibilities and scope for international collaboration (by increasing the mobility of human talent), further enhancing knowledge spillovers.

R&D collaboration can also facilitate the diffusion of existing technologies from the national frontier to laggard firms. Closer collaboration between firms and universities is also needed to allow firms, especially smaller ones, to benefit from university connections with the global knowledge frontier and to provide them with access to research labs, knowledge and human talent. Greater R&D collaboration between firms and universities might also facilitate the technological diffusion to laggards by providing smaller and less productive firms with access to sources of knowledge – e.g. the necessary set of advanced machinery and skilled scientists and personnel – that typically require large upfront investments. Nevertheless, the Danish business sector invests in R&D conducted at universities only to a small extent (Universities Denmark, 2012). Similarly, the TrendChart report for 2011 identified improving cooperation between public science and the business sector as one of the challenges for innovation policy in Denmark in the next two years (Klitkou 2011).

In Denmark, many university researchers have been found to collaborate with industry and to engage in knowledge and technology transfer activities, which is why the overall knowledge and technology transfer framework has been suggested to function well (DASTI, 2014). Difficulties in collaboration nevertheless exist, particularly due to different institutional logics, i.e. university scientists are primarily rewarded for publication output and peer recognition which is not necessarily an outcome of industry-science collaboration since industry will likely have rather an interest in keeping research results secret in order to commercialize them. Technology transfer has been strengthened and possible conflicts of interests have been addressed in standard agreements on IPR and in strategic collaboration agreements between universities and industry partners.

The main framework for knowledge transfer is provided in the innovation strategy "Denmark – Nation of solutions".[17] It contains 27 individual policy initiatives implemented since 2013 and that target knowledge transfer and open innovation activities of Danish scientific institutions and companies. Within this framework, public-private collaboration occurs mainly between firms and the eight Danish universities as well as the nine public research institutes. While the universities are the main research performers, the research institutes are the main collaboration partners of the private sector. The strategy stresses the importance of increased cooperation between knowledge institutions, companies and other stakeholders to foster growth and employment; a higher focus on utilizing research results, commercialization and market maturation; and an active participation in the global knowledge and innovation network.

The main measures to support R&D collaboration between the public and the business sector are administered by the Innovation Fund Denmark, established in April 2014. These policy measures are the Industrial PhD and Industrial PostDoc programmes, InnoBooster, as well as public-private partnerships on innovation and strategic R&D projects.

The Industrial PhD Programme was established in Denmark in 1970 and it combines industrial experience with academic research. The Industrial PostDoc programme focuses on creating career paths in the private sector for personnel who have already accomplished their doctoral degree in public research activities. Until August 2014 the knowledge pilot regulation was in effect. A grant could be given to SMEs with limited experiences in hiring highly educated employees to cover some of the salary of a new employee with a higher education and who was to execute a development or innovation project in the enterprise. The new Innovation Fund has taken over this measure and integrated it into a new programme called InnoBooster.

InnoBooster now also includes a measure that was known as innovation voucher. The measure consists of a 40% co-funding of development projects applied for by SMEs who wishes to use the funding for knowledge acquisition from a public research organization or a member of the research institute network. The voucher could fund a maximum amount of about 14,000 euros. The Innovation Fund also offers support for problem-oriented strategic research projects, which are high-technology projects involving firms and public research institutions, and innovation partnerships.

The nine research institutes furthermore provide support through so-called innovation agents. The agents offer SMEs a free "innovation check-up", which is meant to identify innovation opportunities and challenges, and provides specific action proposals for ways of realizing such potentials. Moreover, the program shall help firms with the establishment of contact with the right scientific institution or advisory expert, or to apply to a public pool for a grant for such innovation activities co-funded by DASTI.

17 http://ufm.dk/en/publications/2012/denmark-a-nation-of-solutions

In Finland, public-private-partnerships are typical in cases when Tekes is funding universities, research institutes or large companies. Indeed, the partnerships are prerequisites for funding. There is an indirect incentive for cooperation also as the funding model of universities rewards for outside funding, such as Tekes project funding. Tekes programmes include projects, which are led by, and involve, public and private sector participants, and there is also cooperation between the projects. Tekes funding includes concepts like *Public research networked with companies* and *New knowledge and business from research ideas* where companies are involved in research projects. About half of the cooperation between universities, research institutes and companies in Finland is partly funded by Tekes. Indeed, Finland was ranked #1 in university-industry collaboration in R&D by the WEF Global Competitiveness Report 2015–2016[18] and the Global Innovation Index 2015.[19]

The introduction of the new University law (2010) made a fundamental change with regard to organization of knowledge transfer in Finnish universities. The new law gave the mandate and responsibility of organizing the knowledge transfer and business collaboration to the universities. The legal status of many universities also changed, as well as their approach to IPR incentives. Since then, universities have strengthened their knowledge transfer services and overall interest in these issues. At the same time, the role of technology parks and various other (semi-public) knowledge transfer intermediaries have lessened, and many of those have been closed down.[20]

Attracting foreign RDI investments

Trade and foreign direct investment enhance knowledge flows from global customers and suppliers (Crespi, Criscuolo and Haskel, 2008; Duguet and MacGarvie, 2005) and from the activities of multinational firms. Firms that make it to the global market, via trade and foreign direct investment, are a group of "selected" companies that are larger, more innovative and more skill-intensive, i.e. they belong to the national frontier (see Eaton, Kortum and Kramarz, 2011 for evidence on goods traders and Breinlich and Criscuolo, 2011 on services traders).

Domestic firms that trade are put in touch with the most efficient foreign and domestic producers that are able to compete on international markets and thus get them closer to the global frontier (Alvarez, Buera and Lucas, 2013). Global value chain (GVC) participation may boost productivity via a number of channels, including stronger competitive pressures that reduce the cost of intermediate inputs and access to a wider variety of foreign inputs that embody more productive technologies. Indeed, productivity grew more quickly in those industries that experienced larger increases in GVC participation (Saia, Andrews and Albrizio, 2015) and suggests that raising GVC participation to higher levels would be associated with

18 http://reports.weforum.org/global-competitiveness-report-2015-2016/
19 https://www.globalinnovationindex.org/userfiles/file/reportpdf/GII-2015-v5.pdf
20 http://www.tekel.fi/in_english/

significant productivity gains in a number of OECD countries. These potential gains to productivity come on top of the more effective learning from the frontier that is also associated with higher GVC participation. Of course, the likelihood that more productive firms self-select into GVC participation makes causality difficult to establish.

The diffusion of ideas from the global frontier firms to home frontier firms also requires complementary investments in knowledge-based capital, to facilitate the absorption and implementation of new ideas. In this regard, a strong domestic R&D sector is important for countries' ability to benefit from new discoveries by facilitating the adoption of foreign technologies (Griffith, Redding and Van Reenen, 2004). Some aspects of new technologies are difficult to codify and require practical investigation before they can be properly incorporated into production processes and thus the availability of researchers that can de-mystify "tacit" knowledge plays a crucial role.

In an analysis of foreign direct investment (FDI) inflows to Denmark from 2012 to 2014, the business investment authority concludes that investors locate in Denmark because they would like to leverage unique local knowledge and specialized competencies. These investors are typically interested in the Danish industrial strongholds like renewable energy, pharmaceutical development and the maritime industry. One third of the investors indicated that they would set up either an R&D department, a centre of excellence or a research collaboration with a Danish university (Invest in Denmark, 2015).

To measure the value of an FDI project, IBM has created an FDI Value Indicator which evaluates the added value and knowledge intensity of the jobs created during the course of an investment project. Based on this indicator, Denmark achieves a fifth rank in the world, behind Ireland, Singapore, Switzerland and Sweden (IBM, 2016).[21] This suggests that Denmark is well positioned to attract these jobs in high-value, knowledge-intensive sectors.

Lately Invest in Finland has started to keep more detailed records of corporate investments in Finland. According to them, in 2014 the FDI increased slightly. During that year, 229 new foreign owned companies were registered in Finland during 2014 (213 previous year). Most of them came from Sweden, UK and USA. The investments made focused on the ICT sector, business services, healthcare, retail and environmental technologies. The availability of a competent work force is one of the key factors influencing investment decisions. The structural reforms in the Finnish ICT sector have increased the availability of skilled workforce and attracted foreign companies to locate, with significant investments. Most potential investment areas in Finnish ICT are for example, vehicles, smart traffic, health, gaming industry, wireless technologies, industrial internet and cyber security (Finpro, 2015).

21 IBM, 2016. Global Location Trends 2016 Annual Report https://www-935.ibm.com/ services/us/gbs/thoughtleadership/gltr2016/

Table 9. Innovation policies relating to knowledge development

Policy	Denmark	Finland
Supporting R&D collaboration between private firms and public research entities	The innovation strategy stresses: a) increased cooperation between knowledge institutions, companies and other stakeholders and b) active participation in the global knowledge and innovation network: several funding instruments target these aims Standard agreements on IPR and in strategic collaboration agreements between universities and industry partners	Collaboration between research and business has been actively promoted since 1980s especially by Tekes programmes Establishing long-lasting partnerships have been considered important for RDI
Attracting investments by multinational enterprises	Foreign participation and cooperation is encouraged: priority will be given to the networks and partnerships where Danish universities gain access to cooperation with foreign universities that are among the world's leading universities	Action plan for research and innovation policy states the allocation of annual funding for research infrastructures

2.2.7 Counteract resistance to change

Support functional dynamics and legitimacy

Entry of new firms into the emerging technological innovation system is central to the development of positive externalities. New entrants may resolve at least some of the initial uncertainties with respect to technologies and markets (Lieberman and Montgomery, 1988). They may by their very entry legitimate the new innovation system (Carroll, 1997). Legitimacy is a matter of social acceptance and compliance with relevant institutions: The new technology and its proponents need to be considered appropriate and desirable by relevant actors in order for resources to be mobilized, for demand to form and for actors in the new innovation system to acquire political strength.

Legitimacy also influences expectations among managers and, by implication, their strategy. The greater the number and variety of actors in the system, the greater are the chances for new combinations to arise, often in a way which is unpredictable (Carlsson, 2003). An enlargement of the actor base in the innovation system enhances not only the opportunities for each participating firm in the system to contribute to knowledge development and diffusion but also for the firms to participate in entrepreneurial experimentation (Hekkert et al, 2007).

These dynamics may be enhanced by the co-location of firms. Marshall (1920) discussed economies that were external to firms but internal to location, and outlined three sources of such economies:

- *Emergence of pooled labor markets*, which strengthen the knowledge development and diffusion, in that subsequent entrants can access the knowledge of early entrants by recruiting their staff (and vice versa as time goes by).
- *Emergence of specialized intermediate goods and service providers*; as a division of labor unfolds, costs are reduced and further knowledge development and diffusion is stimulated by specialization and accumulated experience.
- *Information flows and knowledge spill-overs*, contributing to the dynamics of knowledge development and diffusion.

An illustrative example is that of the emerging technological innovation system for solar cells in Germany (Jacobsson et al., 2004). Initially, the type of knowledge development was limited to the scientific/technological field and the source was R&D on various competing designs for solar cells. The knowledge base was subsequently broadened as the system expanded along the entire value chain. First, application-specific knowledge was developed downstream as firms experimented with solar cells as a building element. Part of the knowledge development took place in schools of architecture where “solar architects” developed new design concepts. Second, upstream technological knowledge was enhanced through R&D performed by the capital goods industry. A significant aspect of that knowledge development was, however, also a very practical and problematic learning process to build automated production lines for the manufacturing of solar cells.

In Denmark, a group of 22 national Innovation Networks provides matchmaking and facilitates joint innovation projects in professional clusters of enterprises and research organizations within specific fields of technology or industrial branches. Approximately 7,000 enterprises participate in the 22 networks, of which two thirds are small enterprises with less than 50 employees. Six of the 22 networks have achieved the so called Gold Label for Cluster Excellence Management, which is given by the EU to cluster organizations that are able to document excellence on 31 quality and performance indicators. The networks are co-funded by DASTI.

In Finland, Minister of Economic Affairs set up the ICT 2015 working group in April 2012. The working group was tasked with preparing a strategy to alleviate the impacts of the sudden structural change experienced in the ICT industry, alongside reforming the information and communications technology industry and increasing its competitiveness. As illustrated in the report, the “21 paths to a friction-free Finland” establish a roadmap for long-term efforts to make Finland a leader in information technology applications over the next 10 years. One of the former Strategic Centres for Science, Technology and Innovation, DIGILE aims to

increase the pace of development of Finnish ICT and digital business by creating both business ecosystems and business concepts.

Efficient public services

Models of structural transformation suggest that while most countries have experienced substantial productivity catch-up in agriculture and industry relative to the United States, the productivity gap in most services has remained high (Duarte and Restuccia, 2010). A key risk is that low productivity in some domestic services sectors indirectly constrains productivity growth in more dynamic downstream sectors, and this may also carry direct consequences for future productivity.

Indeed, governments should find and develop practices that support dynamism in the society and do not unnecessarily hinder it with unjustified regulation. The Danish government has a strong interest in the promotion of better regulation. New initiatives have been taken over the past years in the areas of administrative simplification and the development of new regulation (OECD, 2009). Particularly the de-bureaucratization initiatives of the government have been helpful in freeing up time that can be spent on innovative activities. Moreover, most regulation with an innovation impact has been implemented in the form of R&D subsidy programs, like for example the energy technology, development and demonstration program (EDDP, launched in 2008) under the Ministry of Climate, Energy and Building, or the Green Development and Demonstration Programme (GDDP) under the Ministry of Food, Agriculture and Fisheries (launched in December 2009).

Improvement of the regulatory framework for business is among the top priorities in the Finnish government programme, also. The programme acknowledges that “due to excessive regulation and administration, Finland has lost its agility and competitiveness”. The government programme further states that “The government will assess all EU regulation from the perspective of economic growth, competitiveness and jobs, and will also require a corresponding approach by EU institutions.” The implementation plan of the government programme identifies several actions that will reduce the regulatory burden of companies. Much of this deregulation focuses on labor market issues or promoting open markets and competition environment. However, these actions have not yet been identified in detail.

Table 10. Innovation policies counteracting resistance to change

Policy	Denmark	Finland
Supporting functional dynamics	22 national Innovation Networks: provide matchmaking and facilitate joint innovation projects in professional clusters of enterprises and research organizations within specific fields of technology or	ICT 2015 working group’s (2012) strategy to mitigate the effects of the sudden structural change In 2012, RIC set a measure that supports the programme on the opening of public data and measures to promote business

	industrial branches	use of public sector information, education and training, advisory, networking and other support services
Efficient public services	An increased focus on easing the bureaucratic burden of the private sector by further digi-talization of public services	The new government programme (2015) aiming at deregulation and the reduction of the administrative burden

3. Critical competences for industrial renewal

3.1 Globalization, grand challenges and responses to these

Globalization, changes in working life, as well as demographic changes in population affect the importance of education. Investment in education is particularly important to ensure that the personnel have the capacity to learn new skills and adapt to changing technologies and working conditions. Globalization is changing the nature and ways of organizing work, as well as the professional structures, job descriptions and skill requirements. Changes in expertise requirements, together with changes in economic structure and population demographics may cause problems in the availability of skilled labor, making the conditions for skills-based entrepreneurship and innovation difficult. The availability of skilled labor may also be complicated by the conditions of the organization of welfare services (Ministry of Education and Culture, Finland, 2011).

Digitalization is one response to globalization and grand societal challenges. Digitalization changes the society, economy and innovation activities. Innovation will be more multifaceted together with open innovation platforms, demand and user orientation and social media (Ministry of Education and Culture, Finland, 2015). This will challenge the existing business knowledge. Companies have a need to continuously update their *innovation capabilities*, and innovations often grow out of mobile skilled persons having a lot of experience outside the company. *Recruitment and hiring* may then become a single critical competence in a company, being even more crucial than the development of a new digital technology inside the company as R&D, for example.

Current business environment is turbulent requiring companies to adapt to changes. There are pressures from low cost countries, and there are needs for rapid development. *Servitization* has been regarded as a beneficial strategy in manufacturing, because it helps the companies to create new value to clients and consequently provides competitive advantage in the markets where traditional business has become matured. *Knowledge-based services* that include optimization and consultancy – not only installation and maintenance – have been regarded important in particular. As main drivers of servitization, researchers have identified escaping the problems of matured business, increasing the customer orientation, and stabilizing the revenues with service-product combinations against eco-

nomic cycles (Wise and Baumgartner, 1999; Davies et al., 2006; Martinez et al., 2010).

Service offerings in the industrial context have generally been divided into services supporting the products, services supporting the use of products in customers' processes, and services supporting customers' business (Mathieu, 2001; Paloheimo et al., 2004; Turunen, 2011). The most typical service offerings in manufacturing companies are *systems, solutions, design and development* (Neely et al., 2011). Servitization starts from after sale services – repair, maintenance and supply of spare parts – and then proceeds to process optimization and finally to business consultancy. In the newest contributions, the linear view about servitization has been questioned and the circumstances in which servitization takes place have been highlighted as a factor that should lead to careful considerations about the specific way in which services are linked to products – not only at the level of offerings, but also at the level of organization (Turunen, 2011; Finne, 2014). In services linked to products, preventive maintenance can be made a routine and in services linked to processes, optimization data can be used for both managerial and planning purposes (Toivonen et al., 2014).

In addition of servitization, companies may focus on niche markets through focused efforts on different businesses. They may focus on innovation through individual customer solutions and products in a close contact and cooperation with customers, and involve customers in the process from early development to delivery. On the other hand, companies can focus on system solutions by combining services with products (e.g. maintenance, monitoring, data management) or by developing new business models based on continuous services. A lean service creation, lean start-up or networking may be the way to do it. Often alliances and big companies are in decisive roles here.

3.2 Digitalization and new industrialization

Today, an important factor influencing the further servitization and, on the other hand, the insourcing of a job earlier contracted out is *the new stage of digitalization*, within which big data and the *Internet of Things* (IoT) are particularly influential phenomena: equipment and sensors produce huge masses of data automatically and human activities are diminishingly needed for its accumulation, transfer and storage. In the context of manufacturing, these new phenomena are usually analyzed under the title of *industrial internet*. However, the data as such does not benefit companies, but analysis and interpretation are necessary before the data can be capitalized in a context-specific way. This raises knowledge-based services into a new position in the optimization and lifespan management of production as well as in the organization of business in value chains and value networks. Today, Internet of Things and industrial internet are central drivers for further servitization (Toivonen et al., 2014).

Internet of Things can be defined as a world where physical objects are seamlessly integrated into an information network, and where these objects can be-

come active participants in business processes (Haller et al., 2009). Industrial internet is a more comprehensive concept and refers to integration of complex physical machinery with networked sensors and software to run processes (Leber, 2012). It can also refer to information obtained from analytics, as well as the effective integration of the businesses. The increasing number of objects with sensors and networking capabilities enable data collection from all kinds of industrial machines to automate their optimal performance. In addition to data analytics systems, the use of human resources is essential. The data collected should be used – not only for monitoring and adjusting the machines in industrial procedures, but also for facilitating the performance and quality control by the shop floor workers. Further, the data should be used for management purposes at different levels to secure client benefit and productivity improvement.

Until now the discussions in the contexts of IoT and industrial internet have been strongly technologically oriented. However, in order to function adequately IoT-based solutions require increasing networking and *the development of new business models* that pursue stakeholder value and motivate participation in the entire IoT ecosystem (Leminen et al., 2014). The adoption of service thinking for experimenting and developing applications is crucial. The new stage of digitalization makes services as an essential part of the business and economic infrastructure, and all categories of industrial services can essentially benefit from it (Toivonen et al., 2014).

Five theses about digitalization have been presented:

- It is one of our time megatrends
- It changes the ways of working by moving traditional work to work of higher value added
- It is not only about technology: simultaneous changes in practices, processes and leadership are needed
- Speed, agility and experimentation are important in the digital economy
- Digitalization needs new types of knowledge: digital skills comprise *understanding of technology, visions on opportunities and courage to pilot new things* (modified from Setälä, 2015).

According to General Electric (2012), there are three dimensions of the industrial internet:

- *Intelligent machines*: machines, installations, equipment and networks connected to each other in new ways, using advanced sensors, controllers and software applications
- *Advanced analytics*: materials science and electrical engineering from the operation of machines and systems analysis focuses on effective, proactive algorithms, automation and in-depth expertise
- *People at this new type of work:* people have access to each other anytime and anywhere, such as in industrial plants, offices, or on the move.

In Denmark as well as in Finland, industrial production is largely based on *knowledge and customer orientation*. Automation, customization and flexibility are central factors that affect total production costs. Speed, agility, knowledge and insight significantly influence the company performance in the global market, and digitalization enables the development of new business models and services business. The latest development is that digitalization of both design and production processes makes it possible to take the client's wishes in terms of individuality and aesthetics into consideration without affecting the project price. Nowadays *customized design, advanced functionality, low energy consumption and minimal maintenance* can be associated with a product of a higher quality. As mentioned before, not only products or outcomes will be delivered but also processes or projects. A company can assist the client by ensuring that the building process will be short and within the original budget or by supporting client's strategic partnership.

Business strategies and value chains can also be under a process of change. In value chains, a system supplier is typically responsible for projecting, production and installation of the system product on the construction. Often, it is carried out as co-operation with other companies. A system solution may consist of a number of components, which combined makes it possible to incorporate the component in the construction.

A system supplier may also work with:

- Sustainable and energy optimized concepts, which are optimized across the projects.
- A digital infrastructure which reuses data from sales, quotations, project start-ups, projecting, execution/production and delivery. Often object-oriented information modelling is used for visualization and simulation of system solutions.
- A trimming/automation of the installation process (Lean).
- A more simple supply chain regarding system delivery (Supply Chain Management).
- Continuous improvement across projects (Continuous improvement).

Digitalization does not mean outsourcing this work into an information management unit, rather all key personnel should be there on a top of this transformation process. In addition, in a digital economy traditional industrial sectors and industrial services sectors are intertwined.

3.3 New skills are needed

Productivity improvement

Skills and productivity are the real sources of strong, inclusive and sustainable growth. Productivity is about working smarter rather than working harder. It reflects

our ability to produce more output by better combining inputs, owing to new ideas, technological innovations and business models. A better use of talent could translate into significant labor productivity gains in many countries (OECD, 2015). For increasing productivity, investments in research and development (R&D) and skills and organizational know-how are needed. They enable economies to absorb, adapt and reap the full benefits of new technologies. Servitization enters here as well: instead of routine-type add-ons in the total offering, each service – be it maintenance or consultancy – should be considered in terms of the new value it generates. One of the key questions is: What kinds of characteristics in organizational strategies, practices, cultures etc. foster or hinder *innovative capability* in servitizing industrial companies (Dosi, 1999; Lundvall, 1992) or in adopting new technologies (Toivonen et al. 2014).

The ingredients of new growth are often created through *specialization*. Along with specialization, growth can be based on *exploiting intangible value creation.* Investments in intangible capital and the exploitation of intangibility have already turned out to be the key sources for economic growth. Investments in R&D constitute the main part of investments in intangible capital. Other intangible investments include investments in human capital, organizational structures, computer software, digitized information, brands, business models, intellectual property rights (IPR) and design. Management, marketing, ICT and R&D personnel together build up the (intellectual) knowledge capital of a company and they typically account for about 15 percent of personnel resources.

According to the quantitative studies conducted in this project non-R&D activities of companies are equal important as R&D activities in building up intangible assets contributing positively to firm level productivity (Eklund et al., 2017). Findings also imply that organizational competences have been higher in Denmark but the benefits from them are now growing in Finland. This suggests that Danish firms have greater focus on managerial, organizational and non-technical aspects of innovation than Finnish firms. The results also suggest that ICT assets have an important role in firms' efforts to adapt and compete especially after the financial crisis in 2008.

Here, non-R&D activities are classified into organizational (management and marketing) activities and ICT activities (i.e. activities of managing, developing and implementing ICT). The corresponding assets are measured as cumulative sums of intangible investments in organizational structures, brands, business models and ICT. The measurements of intangible investments are based on occupational data on the sums of wages and salaries in these groups. For R&D these measurements are broader than measurements based on the Frascati definition, but exclude tangible investments.

System transformations

Intangible value creation, environment and energy as well as digital technologies have opened up new growth opportunities for both Denmark and Finland. Bio,

circular and digital economies are, however, much more than technologies. To reach the target, changes will be needed in working methods, processes and management: old things have to be executed in a new way or totally new things have to be executed. (Setälä 2015).

The adoption of new technologies and digital (and green) transformations need new types of knowledge. For example, *digitalization necessitates product and system development thinking.* By using the innovation terminology defined in the Oslo Manual (OECD, Eurostat, 2010), we can claim that digitalization especially necessitates organizational and managerial innovations. M. Wunram, Corporate Head of Competence Development at company *Konecranes*, believes that in today's digitalization era, every company should ask where it would like to position itself within the context of the industrial internet (Wunram 2014). Based on their selection they should then develop the *core competencies* the company needs in order to succeed. He advises companies to pay attention to the following core competences:

- Data analytics
- Systemic thinking
- Virtual Enterprising & digitalization
- Innovation management
- Automation.

Data analytics: "Companies need to learn how to search, aggregate, analyse and, most importantly, utilize the data they have available regarding their customers, themselves as well as their suppliers and partners. It's not enough to collect data; you also need to know how to interpret the data and what to do with it once you've collected it."

Systemic thinking: "Systemic thinking is often underestimated by many companies today. Linear thinking may have worked in the past, but it will definitely reach its limit in the future. The industrial internet will enable interconnectedness between machines, customers, suppliers and partners on a data and process level, leading to an increased level of complexity in all interactions. As a result, any decision made or action taken in any part of the network will impact all elements in the systems we belong to, but at a higher speed and often with unpredictable results. Companies must develop their *capability to understand broader contexts*, to quickly interpret and understand the events within these contexts. Thinking in terms of customer service, companies will have to offer a whole range of services: from end-to-end solutions to mass customized products and services. This requires the ability to e.g. *integrate several departments or eventually change the entire structure and business model of a company*. IT, engineering, sales, marketing and the supply-chain will have to work much closer together in order to quickly react to changing circumstances and customer demands."

Virtual enterprising & digitalization: "Today, companies need to be capable of quickly building lasting or temporary alliances and partnerships with other companies. The increased digitalization of commercial and social interactions is a key

factor in satisfying customers' needs, and companies will have to search for additional core competences outside their own traditional environment and eventually build temporary or even lasting coalitions. In addition, more and more customers are online. The increased use of social media to gather information and news impacts the way we buy goods and services." Digitalization of manufacturing, machine industry and process industry means that the value of digital or virtual engineering exceeds the value of actual or physical engineering.

Innovation management: "Digitalization makes everything subject to much faster changes. Companies need to continuously scan for small signals in their environment. This ensures that they are not caught by surprise by any disruptive developments or miss any new opportunities. The ability to sense and interpret these signals is one side of the story. Developing the right ideas, concepts, products and services and introducing them to the market is the other side. There are several examples of companies that have gone bankrupt because they didn't pay attention to the small signals and trends in their market. There are dramatic examples from the mobile phone industry and photography market. A great example of success stories are the low-cost airlines. By reducing the amount of services to a minimum and investing in digital customer transactions, these companies have managed to drive down prices for flights. As a result, every aviation company is more or less obliged to adapt to similar business models, lowering their prices and the level of service, just because of this rebellious concept, even though well-known operators did not believe that flying would be attractive enough if offered that way."

Automation: "Although automation is a well-known discipline, its importance will remain and even increase as the prices of automation components are going down and developments in the field are progressing fast. The biggest benefit of automation is that it saves labor, energy and materials and helps to improve safety, quality, accuracy and precision."

M. Porter and J. Heppelmann (2014) identify the following strategies and competences that advanced manufacturing firms utilize to adapt and create value:

- Monitoring product's condition, environment, operation & usage
- Control product functions and user experience
- Optimization of product performance, predictive diagnostics, service & repair reduction of waste, energy and resource consumption
- Autonomy product operation, self-coordination, self-diagnosis & service.

4. Critical competences - findings based on case studies in Denmark

4.1 Methodology

This chapter reviews the findings based on case studies in Denmark. The purpose of these studies was to examine how changes in manufacturing strategies and business models are implemented in practice and, in particular, what competences were needed in order to succeed in putting these changes in place. We have conducted five case studies among Danish manufacturing companies within what can broadly be considered as clean technologies. In each case, we have examined their development in recent years and thereafter conducted semi-structured interviews with key managers involved in innovation or development activities.

For Denmark, the interviews were conducted by CFA. Firms were selected that were within manufacturing and characterized by a high level of technological development and within a sector or sectors that where important for Danish export. Firms were chosen from a cluster organization within the areas of energy, electronics and clean technology. In all, five companies were interviewed, two large, two medium and one small firm. Interviews in Denmark and Finland covered the same overall topics, though interviews in Denmark had a somewhat more general focus with less specific emphasis on IT based solutions.

The main question addressed in the Danish study was how changes in manufacturing strategies and business models are implemented in practice and, in particular, what competences were needed in order to succeed in implementing these strategies. Competences are understood broadly in the study, to include employee competences, organizational capabilities, R&D and technological knowhow, products and solutions, processes, and customer relations.

Selection of interviewees

After selecting the five cases, we identified the employees in charge of management, R&D or innovation activities. We wanted to interview employees who had knowledge about the company in general and also specific to activities related to innovation. The reason for not targeting CEOs was to get a ground floor view. We

wanted a participant who had experience with both the day-to-day activities and knowledge of and influence on the implementation of strategic changes. Furthermore, we aimed at interviewing an employee who had a history at the company in order for the interviewee to be able to reflect on changes over time.

In three cases, there was one interview participant while in two cases there were two participants. In the two cases the reason for having two interview participants was mainly because the operations where so comprehensive that the two would be able to cover most of the activities of the company. Moreover, this allowed different perspectives on the same questions.

Interview methodology

Semi-structured interviews were conducted revolving around central themes. The goal was to get through these themes through examples of projects or actions taken within the organization. What we often got was a mixture of specific and general histories. We began by introducing the project and explaining what we wished to accomplish, and thereafter asking the interviewee to open with a short description of himself and the company. In order to focus the interview on concrete cases, we allowed the interviewee to decide where to begin by giving examples of projects, products or strategies. Thus, the amount of time used on particular themes differed in each interview, reflecting that some aspects were more important than others in different companies. The interviews lasted approximately an hour.

Coding of transcribed interviews

The coding was performed in Nvivo to which the transcribed interviews where uploaded. Initially we identified empirical themes that revolved around a specific theme (e.g. Flexibility). The sentences and paragraphs that revolved around these themes received one or more thematic codes. When no new themes could be identified, they were horizontally aggregated into broader themes. The process led to a series of themes (e.g. Flexibility, speed and agility). The analysis reported below describes the main themes and how they relate to each other.

4.2 Interviewed companies

Company 1 (C1)

C1 produces industrial purpose refrigeration and freezing products. The firm has a turnover between DKK 400-500 million a year of which more than 90 % is exports. C1 has existed since the mid-sixties. In the lifetime of the C1, there have been considerable changes. C1 has moved from selling household appliances onto selling industrial purpose products. The products have gone from standardized to specialized and customer specific solutions. The number of employees has de-

creased from a peak of 1900 employees in the nineties to 350 employees at present. C1 has had production in Denmark since its beginning and recently bought a company in a Central European country where they now also have production.

Company 2 (C2)

C2 develops and produces electronic climate control solutions and software applications for industrial refrigeration and ventilation systems and heat pumps. C2 is owned by and supplies solutions to a large foreign manufacturer of compressors. Roughly, 75 % of the company's turnover of approximately DKK 50 MN stems from export. The two largest export markets are Asia and Europe.

The company is knowledge intensive employing mainly engineers; two-thirds of the 100 employees work within development, while the company only has three employees in the actual production. C2 has production facilities in Denmark, mainly for maturing and developing products, and optimizing the production process before moving production to one of its partners who produce the majority of the physical products. C2 has outsourced production to producers in eastern and southern Europe, with whom they have a very close relationship. In order to control the quality of production C2 has access to live monitoring of the test equipment at the sites.

Company 3 (C3)

C3 manufactures products services for measuring energy and water consumption. They sell products alone and deliver so-called turn-key solutions. Thus, customers can buy tailor-made products where they can control the systems or they can choose a turn-key solution where C3 also takes control of the system for the customer.

C3 has the production facilities, R&D department and administration in Denmark while it has sales offices in 24 countries. The company is physically present in sixteen European, three Asian, one African, one North American, and one South American country.

The production facilities are characterized by a high level of automatization. Of the 874 employees worldwide, roughly 25 % are employed in a technological development position. 80 % of turnover stems from export to sixty countries. While only 5 % of the company´s turnover is from services, the interviewees express a transition over the last 10-12 years where the company has moved from being a component supplier to being a service provider as well.

Company 4 (C4)

C4 develops, produces, sells and installs solar panel systems. The main segment is systems integrated in large public and private buildings and domestic houses. The systems are integrated into and adapted to the buildings often in collaboration

with architects and engineers. Besides the main segment C4 also sells standard solar panels.

C4 is 20 years old and presently employs 25 but in earlier years has employed 30. The turnover of the company is roughly DKK 100 M. There is focus on participating in large R&D projects with other companies and universities in order to create new products and solutions.

Company 5 (C5)

C5 is part of a large international concern within mechanical and electronic components. The concern, which is headquartered in Denmark, is highly global with sales in over 100 countries. Production and development activities are conducted in 19 countries. Development and production activities are interconnected across factories and countries, making communication and coordination critical.

C5 concerns a specific division of the concern, which specializes in electronic solutions for a range of industries. The majority of their business is in the form of custom solutions, entailing ongoing relationships with customers and often collaboration with them in the course of product development.

4.3 Summary

4.3.1 Pressures and drivers of change

It became apparent through the interviews that the case companies to some degree experienced the same general pressures that ignited strategic and operational changes. Some of the interviewees expressed these pressures as a feeling of being on a burning platform during the recent years. This burning platform included increased competitive pressures especially from large companies based in low-wage countries. These large companies were able to compete at the same level of quality and differentiation, but at a lower price because of a larger production capacity and lower wages. This development was also perceived as being rapid rather than incremental.

The Quote below represents the story quite well:

"CX actually grew for many years based on household products, first xxx then later based on xxx and xxx and was actually the main priority these products for the household and in the end of the 90's and in the beginning of the 00's, well at that time we really began being pressured on the prices, we can see it when we look at these catalogues still that it is incredible that anyone can earn money on it. We began to get really, really pressured on our margins up through the 00's and we really made an effort to see if we could lift ourselves out of the what can you call it

these cheap products and made some design updates and new innovative household products, but it wasn't a task that could be solved. We simply did not have the volume compared to some of the big guys that also had the advantage of being located in a low-income country. So we increasingly turned our focus towards niche products, what we today make a living off, being innovative, being creative, developing products, where we kind of get away from the red ocean and into the blue ocean and it is here we use all of our energy today. The process began for real in 2008, we chose to sell off the household division and focus intensely on the other legs and that are the legs we have today."

Another case company experienced a similar situation when new legislation concerning their product was implemented, which opened up the market to low-cost competitors.

(…) of course we can do standard, if we can do all these complex stuff, and that is what you could see in 2012 when the legislation was altered in 2012, where a lot of people turned they key, because the market nearly disappeared over night, and also when it exploded in 2011 or 2010 well at that point there wasn't a week without at least five new players arriving on the field, that had just received containers with xxx from china and then it just ran. And then they began selling xxx in xxx [Danish shopping malls and Hardware stores] and that kind of thing, well it just became a commodity, it wasn't serious.

4.3.2 Identified themes and strategies

The interviewees express a number of ways in which they have attempted to solve the challenges they have faced in the recent years. They have attempted to be innovative and competitive in a global marketplace by following various strategies that will be extended below. For each theme quotes will be presented and discussed in order to give a picture of the ideas and thoughts surrounding the strategic choices and also how it is practically enforced and implemented in the organizations and how they perceive the strategies work. Finally, the interviewees mention competences and supporting organizational aspects that are needed to maintain and improve the outcomes of the strategies.

Targeting niche markets and segmentation

One of the responses to the increased price-competition was to a higher degree than earlier to focus on segmentation; some of the companies changed from competing broadly in many market segments to focusing on a few segments in the market and attempting to tailor the products to the segment or to the single customers. The interviewees express that the focus on few segments allows for a level of specialization that shields them from direct competition with the large broad-based companies in the market. This allowed for a lesser focus on the price of the product and a higher focus on the application value and other parameters where the case-companies could compete with the large companies situated in a low-wage country.

CX moved from a broad focus on consumer appliances to a narrow focus within three industrial segments. These segments are, according to the interviewee, not relevant to the large competitors they were fleeing from as is it too small a scale for the compactors, but for CX the size and specialization is appropriate.

CY has two large clients and many smaller clients, they focus one delivering solutions that are tailored to specific targeted segments and even to the single customer.

"We want to be the specialists, we do not want to be the mass-producing company, we want to deliver solutions and understand what the customer's needs are, that is what is our core and then we have to be able to translate the knowledge we have; the hard-core competences with hardware, software and mechanics and make a product from it."

CZ differs from this strategy as they focus on a large array of markets and segments and attempt to create products that can fit into any system, such as a driver that can be used in any motor. In contrast, most of their competitors deliver entire systems.

CV concentrates on custom-built xxx solutions to xxx; however, they still sell standard products to the market in broad terms. Thus, they have not entirely focused on a particular segment. Even though they recognize that, the competition in this area is high.

CT has also adopted a focus segmentation strategy, as they focus on the customers who want a very high level of sophistication and not just simple measures of water and energy consumption.

Intelligent products and solutions

The companies all, to some extent, have focused on providing 'solutions' rather than stand-alone products. *Intelligent products and solutions* were words that very often were used to explain the companies' value-proposition.

Solutions means that the product serves a specific function of solving a problem and is adjusted or tailored to this end. This may include customizing the actual product or creating an entirely new product so it fits into the customers systems or fits better its need. It may also entail changing the software or creating data.

The primary reason the interviewees point to, is that they cannot compete in a commodity-like market that is undifferentiated and focused entirely on price.

"So, we make customer specific solutions, we do not want to make standard products, shelf products, because it quite quickly becomes a commodity, if it is not already."

"We have come a step further than just delivering the product, we also supply a common how to say five years in the future solution for the customer and his segment. "

"We only make smart instruments, we do not make cheap mechanical instruments, we make intelligent instruments that can communicate (…) we have succeeded in getting the price down so this transformation happens from the old way of doing things, from mechanical instruments to electronic instruments, which leads to new possibilities"

"It is tailor-made to the specific customer, so yes it is primarily what we do, so we get, we have the whole dialogue with the client and we only enter into this dialogue if we know something about the customer's application."

CX entered into a large development project in collaboration with a Danish university and a number of companies. The project attempted to create an intelligent control system for xxx. While the interviewee expressed that the particular project did not lead to a result that was useful for commercialization it shows the intent on creating intelligent products.

Close customer relationships and customer involvement in all aspects of the value chain

Close customer relationships can be seen as a prerequisite of the above-mentioned strategies or a strategy in its own right. The case-companies focus on integrating the customer into the entire value chain and include them early on in the product development process.

The advantage is an ability to create products that are tailored to the customer and thereby superior to off-the-shelf solution the relationship also creates some co-dependence and long-term revenue from customers.

(…) I know that our executive group here at C2 invite different actors to our yearly strategy process, it can be anything from (branch organizations) to large customers domestic and foreign. Where they can come and inspire us in light of how we understand their world. So we let ourselves inspire. There have also been situations where we have been part of our customer's strategy process and where we have attempted to inspire them.

"I think actually we're going to see more that it will be more like partnerships than customer-supplier relationships because then it becomes much so what do you say on specifications, not so much on the understanding that if we can understand the customer's situation. …So we can make just as much technology, but if we do not fit into any business models so it is not that interesting."

"We have always said; if one of our large customers calls their R&D department the phone should ring here"

Speed, flexibility and adaptation in terms of timely development, delivery and service

Speed, flexibility and adaptation are terms that where expressed often in each of the interviews and was a primary focus. The interviewees expressed a desire to be flexible in terms of both upstream activities and downstream activities. It was often expressed in combination with customer involvement. There was a need to include customers early in the process and be flexible and adaptable in terms of changing the specifications. Just-in-time considerations where also mentioned such as being able to deliver solutions in a very short timeframe to anywhere in the world.

"This idea with blue ocean … that's where we want to be, we need to understand our customers' needs, have the level of innovation, speed, flexibility, and flexibility throughout. Whether we are doing product development, making production plans, we just need to be changing in a changing world and with (focus) on quality, environment and design."

"We make to order, that is, we have not any finished goods lying, we produce only when we have a customer order and we will deliver within 2-5 days depending on where it is along in the world…It is designed for the customer and is being delivered to the customer directly from the factory."

Physically proximate production and R&D

Related to the customer focus and flexibility is the emphasis of R&D and Production being able to communicate quickly and effectively. For this to be possible, a number of the cases point to the importance of the two being co-located and integrated.

"that we have production close by means that we are quite flexible and we can also respond quite quickly to new markets where we encounter some things that we need to change."

Outsourcing and movement of production facilities

Even though production is consistently kept to some degree in Denmark where main R&D activities are, some of the production is outsourced or placed in a low-wage country. The main reasons are to be closer to the market in terms of delivery and market knowledge. However, the interviewees express concern about being able to control quality when production is outsourced and that there are considerable risks associated with the outsourcing of production. One of the interviewees expressed the importance of having real-time access to the foreign production in order to have quality-assurance in place.

Competences and innovative strategies

"So in my world there is innovation, … solutions we can invoice, but they must address customer's real needs and it may well be the customer is not fully aware

of what the real needs are, but then we will see if we can figure out together how we can do this even better and how we can jump in and say 'hey', listen to these possibilities that we can bring to the table and then we have come full circle."

"Innovation for us is to try and do it simple. There are many that can do it complicated, but to do it simple is extremely difficult and that is when knowledge of application really becomes relevant."

The competences and activities described above comprise key elements in broader innovative strategies or business models that the case companies have developed and applied in recent years. In particular, three strategies emerge from our interviews that are either employed individually or in combination.

The first is *niche markets***.** The companies gear their operations towards tailored products for a narrow market. Products are made to order, often involving incremental improvements in design or functionality. This also requires both close coordination between marketing, innovation and production activities, all of which need to be flexible and agile in adjusting and producing new products with short lead times.

The second is *solutions in product development*. Close, long-term relations are established with customers from idea to R&D to product/solution. Companies work with customers to determine their needs and thereafter gear their innovation and R&D to provide solutions to those needs. Essentially, the development and manufacture of physical goods becomes a service solution that the company offers its companies.

The third is *systems solutions*, where a number of services (maintenance, monitoring, data management) are combined with products. This is of course a trend that is very widespread, where manufacturing firms increasingly rely on service provision to create value for their manufacturing goods. However, the inclusion of R&D and product development with these other services increases the complexity of solutions, and also the demands on the company in terms of knowhow, flexibility and coordination. ICT-related solutions are a key element that often links ongoing service provision with new product development, where many new advances are taking place in the measurement and collection of data on firm operations and thereafter use and management of that data.

Table 11. Key findings among Danish companies.

Theme	Key findings among Danish companies
New Business Models and Strategies	• Targeting niche markets and segmentation: one of the responses to the increased price-competition was to a higher degree than earlier to focus on segmentation. • Intelligent products and solutions were words that very often were used to explain the companies' value-proposition. • Close customer relationships: companies focus on integrating the customer into the entire value chain and include them early on in the product development process. • Speed, flexibility and adaptation in terms of timely development, delivery and service were often mentioned by companies as their primary focus. • Physically proximate production and R&D: companies often pointed to the importance of the two being co-located and integrated. • Outsourcing and movement of production facilities: the main reason for this is to be closer to the market in terms of delivery and market knowledge.
Leadership and Competences	• *Niche markets* requires both close coordination between marketing, innovation and production activities, all of which need to be flexible and agile in adjusting and producing new products with short lead times. • Companies work with customers to determine their needs and thereafter gear their innovation and R&D to provide *solutions in product development* to those needs. • *Systems solutions*, where a number of services (maintenance, monitoring, data management) are combined with products is a trend that is very widespread. Like in Finland, these processes are not often in the phase of autonomy, where remote devices use self-coordination and self-diagnosis, for example. • ICT-related solutions are a key element that often links ongoing service provision with new product development.
Boosting industrial	• Denmark employs market-oriented approaches

internet or other eco-systems	for achieving its competitive advantages. The national innovation strategy stresses increased co-operation between knowledge institutions, companies and other stakeholders and active participation in a global knowledge and innovation network. There are several funding instruments targeting these aims.

5. Critical competences - findings based on case studies in Finland

5.1 Methodology

VTT was responsible for making the case studies and interviews in Finland. Seven companies were interviewed. Three of them were large companies in machinery industries, two small or medium sized technology providers and two medium sized software and service providers active in using industrial internet, Internet of Things. The focus of interviews was on new industrial internet solutions and energy saving technologies through digitalization. Companies were asked about their views on the advance of industrial internet solutions and new business models as factors renewing manufacturing industry.

The focus in our case studies is on new kinds of innovative practices and their implementation in the manufacturing industry and IT and consulting companies serving manufacturing companies, as well as capabilities in this area. For Finland, we have chosen to focus especially on industrial internet in the machinery industry. The focus is especially on the advance of industrial internet applications and new business models as factors renewing manufacturing industry. Targets of Interviews are:

- Big engineering companies which are known to have taken in use new digital or industrial internet solutions
- Technology or service providers which are known to have provided new digital or industrial internet solutions to Finnish engineering companies.

The method is the same as in Denmark, except that we also asked technology and service providers about their views on the situation and needs of their principals in manufacturing with regard to our research questions. An semi-structured interview guide was sent to the interviewees beforehand. In Denmark and Finland, we did not pick up exactly the same industries but the most promising ones for both countries.

We grouped the topics of case studies under three broad headings:

- New Business Models and Practices
- Leadership and Competences and
- Boosting industrial internet or other ecosystems

As mentioned in Chapter 1 we are interested in broadly defined innovation capabilities and want to look at different levels and types of capabilities, for example, for creating or adopting industrial internet or some sustainable technologies, new designs and brands, or new business models and management systems. These activities can be called with the name of *broad-based innovation activities*. In quantitative studies we are focusing on the corresponding knowledge items: e.g. what is the impact of R&D, ICT, marketing and organizational knowledge on companies' total factor productivity.

The focus is on new kinds of innovative practices and their implementation as well as capabilities in this area. In Finland, our focus lies especially in the advance of industrial internet applications and new business models. Our question is: what can we learn from Denmark and Finland, from their experiences, in the field of science, technology and innovation policy in promoting renewal in manufacturing, in promoting the advance of digitalization or clean and energy saving solutions in the manufacturing.

5.2 Interviewed companies

In Finland, we interviewed those big engineering companies which are known to have developed and taken in use industrial internet solutions as well as smaller technology and service providers which are known to have provided new digital or industrial internet solutions to Finnish engineering companies. We asked the above mentioned key companies for their views on *new business models and practices* related to the industrial internet, in developing the value creation, management and competences as well as in promoting the introduction of IoT solutions. In company interviews also *new drivers for renewing manufacturing industries* were enquired.

5.2.1 Metal product manufacturer 1

This big company is serving the marine and oil and gas industries.

Energy efficient solutions

Oil and gas industries are at the center of converging megatrends, namely at a transition towards a more diverse and cleaner energy mix, increased transparency and accountability with regards to environmental performance, and a need to improve economic performance.

The case company believes that digitalization will create new growth and opportunities for industries. There are a number of megatrends that drive digitalization:

growing amount of data, universal connectivity, globalization of value chains, intelligent solutions and services, exploratory analytics and visualization, and growing focus on the environment. Digital transformation will affect all the elements on how business is done, and finally, human behavior:

- *Technology*. Digitalization is driven by technological developments and the changes they enable.
- *User experience*. Growing user expectations create demand for seamless and effortless solutions, with a focus on e.g. data visualization.
- *New business models*. Digitalization is changing customer value creation, as new business models become available.
- *Human behavior*. Ultimately, digitalization is a cultural change with a net positive effect on our lives on many levels.

Digital value creation

The case company wants to be part of the digital transformation, and invests in developing new solutions and services that create value for its customers and enable it to grow together with them. It believes that new opportunities emerge at all stages from design to operations support, creating new business models and making old ones more efficient. Moreover, digitalization will enhance customer engagement, enabling a seamless and rewarding customer experience. Digitalized services can improve performance throughout the installation lifespan.

The decision-making process of its customers is typically affected by product prices, delivery times and reliability, project management, ease of installation, and the supplier's ability to manage large delivery scopes. Owners, on the other hand, require safe and efficient operations, reliability and support, as well as the availability of services. Their decision-making is also impacted by the capital and operating costs. Furthermore, both owners and operators are increasingly considering factors such as environmental compliance and fuel flexibility in their decision-making.

The manufacturer is committed to meeting the needs of all its customer groups. The company succeeds through its in-depth understanding of their businesses, operating models and requirements, which are backed by its extensive network, broad product portfolio, and ability to be involved in the life of the vessel as early as the design process. This enables the company to support its customers throughout the whole lifespan of their installations with products and solutions that best serve their business interests. The company supports its customers by offering the most comprehensive portfolio of services in the industry, thereby optimizing their operations and the lifespan performance of their installations. The company’s service network is the most extensive in the industry.

There are five focus areas for the digital value creation:

- Customer engagement

- Intelligent engines and components
- Digital maintenance services
- Virtual concepts and
- Asset performance optimization.

These are elaborated in a greater detail below.

Customer engagement

Company tailors its service agreements to enable customers to choose from different levels of partnership. Technical management agreements include regular inspections, monthly reporting, and exchange programmes for spare parts. The company's operations and maintenance agreements can cover complete operational, management and maintenance services, as well as installation performance guarantees.

Digitalization enables new forms of customer engagement. Increasingly sophisticated digital services offer value and empowerment. User experience is expected to be seamless and intuitive. Company believes that within the next two years condition based maintenance results create online dynamic maintenance schedules for customers; that remote centres are available for running diagnoses, making adjustments and operating the assets remotely, and customer online spare part ordering is one of the biggest sales channels and includes proactive offering.

Vessel operators are facing constant challenges to comply with current and future regulatory requirements related to safety, the environment and operational efficiency. The multifunction displays present, e.g., radar, automated and advanced route planning, power management tool, fast and easy access to navigation and automation data, optimizer for fleet management, vessel performance monitoring and data collection for later analysis and feedback, and common user interface with multiple options for further integration, such as cargo monitoring.

Breakthrough innovations emerge from exploiting intelligent technologies. Key components will be equipped with track and trace features enabling them to alert when issues arise. In intelligent engines, components communicate with each other and self-optimize based on this communication.

Intelligent engines and components

Company believes that within the next two years a new ecosystem with suppliers is in place, smart or intelligent components are embedded, enabling remote identification of condition, machine-to-machine (M2M) communication is improved, and interaction between machine data and external conditions will optimize the business.

Digital maintenance services

Reliable, continuous performance is essential. A modern approach to maintenance and improving an installation´s performance includes the planning of opera-

tions and maintenance based on actual real-time equipment data. This way performance can be optimized effectively to minimize downtime, balance cost structure and improve overall efficiency and safety. A system of condition based maintenance that relies on continuous monitoring makes it possible to accurately predict the actual condition of the engines, thrusters, motors, pumps, electrical equipment etc. and adapt servicing schedules accordingly. Furthermore, digital technologies make it possible for service providers to provide an increasingly analytical perspective into their customers' operations. With today´s technology, it is already possible to collect and analyze installation data and remotely monitor performance. This allows conducting maintenance in a dynamic way, based on the equipment's actual condition.

When the condition and wear of the installation is monitored and always known, trends and changes in operating parameters can be identified well before they might compromise the performance of the installation. Maintenance planning can then be dynamically based on actual need rather than a set schedule. This dramatically improves cost-effectiveness as maintenance intervals can be extended and spare parts consumption reduced. Correctly timed service will ensure optimum engine performance and fuel consumption. The constant monitoring and analysis of engine information also means that approaching premature failures can be discovered at an early stage before they occur, and the worse can be avoided.

Company believes that within the next two years digital and mobile concepts and tools, like virtual engineering, make interaction with customers transparent and collaborative throughout the maintenance process, an accurate, more user-friendly guidance at customers' locations is taking place, and real-time services from online diagnostics to remote operation from remote centres exist.

Virtual concepts

By focusing on the initial stages of the development process and by utilizing simulation, virtual testing and validation, company is able to reduce the lead time for new solutions without compromising reliability and safety aspects. Solutions based on 3D design can offer new ways to benefit from real-time information and knowledge to enhance technical assistance, support maintenance and servicing, enable new types of virtual training concepts from video training to holograms and augmented reality, and increase the availability of selected components through 3D printing. Company believes that within the next two years holograms and augmented reality are used for training and supporting customers remotely, live direct or indirect view of physical real-world environment is augmented with sound, video, graphics or other data, external developers will be utilized to create virtual mobile apps to support customer business and operations, and 3D printing will optimize the local availability of selected components.

Asset performance optimization

Focus is shifting from maintenance and servicing to more comprehensive optimization of customer business. Company's asset performance optimization concepts are designed to optimize e.g. an installation's energy efficiency, or even the management of an entire fleet. This will be done by integrating advanced dynamic voyage planning, ship efficiency advisory services and energy analysis, as well as extensive condition monitoring of the main equipment into one consolidated solution.

By knowing and fully understanding the operating equipment and its condition, it is possible to improve efficiency and lower fuel and maintenance costs, while also extending the time between stops for maintenance. Engine performance can be optimized by upgrading the engine and propulsion components to newer technology that can offer efficiency and performance benefits that easily justify the investment. Fuel quality and flow are also factors that have a significant effect on efficiency. The project management capabilities enable the optimization of the performance of its customers' installations through upgrades, modernizations, fuel conversions and safety solutions. Sometimes a conversion to another fuel type altogether or to a multifuel solution can be performed to improve the engine's fuel efficiency and flexibility.

Optimization is the keyword when improving lifespan efficiency. By knowing and fully understanding the operating equipment and procedures, it is possible to optimize performance in all areas for increased output, lower costs, and reduced maintenance requirements. When performance is optimized in all phases of an asset's lifespan, the total cost of ownership can be optimized. Longer-term efficiency-increasing strategies reduce operational expenses and improve business efficiency by increasing availability.

Company believes that within the next two years fleet management information is available in company's online services portal, asset performance optimization services can help define the optimal performance of the ship or power plant, as well as help customers optimize business performance, and all equipment or installation-based condition and performance data are in the same data cloud.

Digitalization creates business benefits

To conclude, digitalization is changing industrial services and enabling efficiency improvements through new types of real-time and knowledge-based solutions. Efficiency improvement refers to everything from planning, building and commissioning to operation and finally decommissioning. It starts with a good design, the operation of which is then managed in a way that minimizes its operational costs and maximizes its operational lifetime and, consequently, its profitability over the entire lifespan. There are three main areas to consider: preventing the unexpected, performance optimization and environmental efficiency. These are all business critical issues that companies have to solve in order to get the most

value out of their assets over the lifespan. A lifespan approach enhances business by minimizing risks and improving reliability and cost predictability through efficient operation and optimal asset management. Looking at the three dimensions above, it can be seen that preventing the unexpected is about minimizing operational and economic risks, and performance optimization focuses on getting the most out of the asset with optimal cost structure. Environmental efficiency has a direct connection to operational efficiency through e.g. more efficient use of fuel, and with ever more stringent environmental legislation, regulation compliance has also become a key lifespan efficiency issue.

When it comes to the development of new digital services and the technologies that enable them, there are two logical locations to do that: either close to customers or close to company research and development operations. For the company, the customer base is extremely scattered and hence linking digital business creation with R&D looks for a more viable alternative. In this case, Finland can get its share of the development work. However, in a multinational corporation, operations are placed where the management deems there are the best chances to get remarkable results. It then goes down to it, how the Finnish industrial internet ecosystem can serve the corporation in its business areas and business needs better than the competing industrial internet ecosystems.

Capabilities and competences

The manufacturer is continuously developing its existing competences while also building *new skills in strategic growth areas, such as oil & gas, asset optimization, and environmental solutions*. Expanding its offering by developing its portfolio through innovations connected to the overall digitalization of the industry will continue to be its focus in the future. Further growth is sought by strengthening its service offering in response to its customers' increased interest in partnerships, thereby providing them with both lower costs and improved operational efficiency.

In company's vision, customer value creation is a partnership in which digital technology and analytical skills of human experts are combined to achieve a common goal. Interactive and real-time data helps secure and optimize the operation of power plants and vessels. Utilizing this data can help predict maintenance and competence needs well in advance, enabling better planning. It provides transparency of real-time data from order to invoicing.

Table 12. Innovative practices and their implementation in metal product manufacturer 1.

Theme	Key findings
New Business Models and Practices	• Digitalization enables new forms of customer engagement: e.g. by integrating advanced dynamic voyage planning, ship efficiency advisory services and energy analysis, it is possible to op-

	timize an installation's energy efficiency, or even the management of an entire fleet • Correctly timed service will ensure optimum engine performance and fuel consumption: the actual condition of the engines can be predicted accurately and servicing schedules adapted accordingly • Solutions based on 3D design enable new types of virtual training concepts from video training to holograms and augmented reality
Leadership and Competences	• Key components need to be equipped with track and trace features enabling them to alert when issues arise: planning of operations and maintenance is based on actual real-time equipment data • Interaction between machine data and external conditions will be used to optimize the business • More user-friendly guidance at customers' locations is taking place, and real-time services from online diagnostics to remote operation from remote centres exist • Solutions based on 3D design offer new ways to benefit from real-time information and knowledge to enhance technical assistance, support maintenance and servicing • The optimization of performance in all areas for increased output, lower costs and reduced maintenance requirements requires knowing and fully understanding the operating equipment and its procedures • Knowledge of environmental legislation and regulation compliance are key lifespan efficiency issues
Boosting industrial internet or other ecosystems	• New digital services and the technologies that enable them need to be developed either close to customers or close to company research and development operations: for national RDI policy the key question is whether the Finnish industrial internet ecosystem can serve the businesses' needs better than the competing ecosystems

5.2.2 Metal product manufacturer 2

This big company is serving the building and real estate industries.

In the exploitation of industrial internet, the most essential thing is the utilization of the collected information. The starting point is the company's customers and products. For example, industrial companies must consider what could be known more about their products and what would be the value of that knowledge to the firm, to its clients, or to some third party. Traditional partnerships and value chains are subject to change. There are two general themes within which a manufacturer will exploit Internet of Things. First, for managing customer experience, and second, making its own manufacturing and service processes more efficient.

Managing customer experience

A key aspect of providing intelligent solutions to customers is to integrate advanced technology into different systems. The driving principles of system design nowadays are that they can communicate with intelligence portfolio solutions, including e.g. destination guidance, access control and equipment monitoring solutions. For a manufacturer, system intelligence is about integrating advanced technology and different systems into one cohesive whole. For example, transportation devices or their access control systems may already be intelligent on their own. However, to ensure the best possible experience for customers, these devices and systems must also communicate with each other. Integration is about using existing technology in new ways, and improving security and the user experience.

Smart equipment is required for a location to be intelligent but having excellent systems and related solutions is not enough: servicing individual needs is also needed. Clients need help in selecting the right type of transportation devices for their specific needs in the planning stage. The challenge here is that the final type of use of the space may not be known at this point in time. For example, for an office space, the strictness of the access control depends on the lessee and her requirements. Allocation algorithms may be used to search for the optimum routes for the vehicles to serve a destination call. Optimal call allocation decisions guarantee short passenger waiting and journey times. There are five steps in this optimization procedure:

- Learning daily traffic
- Allocating calls to vehicles
- Measuring people flow and vehicle parameters
- Forecasting traffic patterns
- Minimizing passenger waiting times

Destination solutions can be programmed according to individual needs. In the future, locations can recognize regular users through a wireless connection with a device such as the phone in their pocket, and automatically guide them to their destination. Even today, a remote call allows users to call a vehicle or an elevator using a mobile application installed on their phone.

Energy efficient solutions

For the manufacturer, environmental responsibility is a combination of offering its customers innovative and eco-efficient solutions and reducing the environmental impact of its own operations. The biggest environmental impacts of the solutions relate to the amount of electricity machines and devices use over their lifetime. This underlines the importance of continuing to innovate and improve energy efficient innovations. Typically, the assignment of an environmental strategy is to provide safe, environmentally efficient and responsible high-performance solutions and services. In addition to complying with or exceeding applicable laws, rules and regulations, the company works with its suppliers and customers to prevent or reduce business operations-related emissions and waste. A company's environmental responsibility can cover the full lifespan of its products, from design and manufacturing to maintenance, modernization, and end-of-life treatment.

Maintenance and monitoring

The manufacturer typically offers maintenance and monitoring solutions that maximize reliability and safety while minimizing downtime and costs. For that purpose, it tracks operation information, service records and technical data of the equipment by using a machine to machine (M2M) remote monitoring technology to create a new diagnostics service to schedule proactive maintenance tasks. This capability for predictive maintenance provides a basis customer offering. In this service, the condition of a device is analyzed thoroughly. The service then helps to plan the modernization of it. Modernization solutions range from small upgrades to the full replacement of the equipment. They improve the equipment's safety, accessibility, performance, aesthetic appeal and eco-efficiency.

Business model renewal

Another important issue is the monitoring of the markets and a certain kind of alertness: Is there a new way to serve our customers better? Are there new ways to add values to the data equipment are producing? In the first area, a manufacturer is following their competitor's approach to bring technologies from across their brands to combine Central Heating Ventilation and Air-Conditioning Systems with intuitive software, advanced technology with security solutions; and merge entry control solutions with automation systems. The customer promise may be to minimize energy consumption, maximize comfort and enhance productivity. However, the drawback of this strategy is that if one aims to provide all of the aforementioned services, it must compete with a number of specialized third-party vendors, who in many cases can be valuable collaborators. Even more, the customer may opt for not ordering all the equipment, software and system integration from one source.

Even so, there is a promise in being able to provide smooth operation and inter-operability between the different components in modern locations. A manufacturer's strategy may be to call for collaborators from SMEs to innovate and develop value add products and services on top of its own products and services. *Unfortunately, in Finland the ecosystem of capable collaborators is pretty thin and the potential suppliers have to be looked for from overseas areas*.

Capabilities and competences

In a quickly changing business environment, capabilities and competencies are evaluated continuously and one needs to stay ahead of the competition in order to survive. A company can also harness an "intrapreneur" system where ideas are rated, commented on and promoted. The best ones are given a few weeks to be designed and expressed in more detail. The purpose is to make the beginning of the process as agile as possible. The new concept must work in a practical context and fit into the company's strategy. Common sense and questions relating to possible users or clients usually provide enough information to decide whether to continue or not. Therefore, the nature of these decisions demands *visionary and managerial skills* concerning uncertainty and possible failures. For managers, this calls for managing the whole value creation process instead of just organizational management.

Table 13. Innovative practices and their implementation in metal product manufacturer 2.

Theme	Key findings
New Business Models and Practices	• Companies must consider what could be known more about their products and what would be the value of that knowledge to the firm, to its clients, or to some third party • Promise in being able to provide smooth operation and inter-operability between the different components in modern locations
Leadership and Competences	• System intelligence is about integrating advanced technology and different systems into one cohesive whole: integration is about using existing technology in new ways, and improving security and the user experience • Important continuously innovate and improve energy efficient innovations; also, the environmental impact of company's own operations need to be reduced • Need to cover environmental responsibility for the full lifespan of products, from design and

	manufacturing to maintenance, modernization, and end-of-life treatment • servicing individual needs is also needed. Clients need help in selecting the right type of transportation devices for their specific needs in the planning stage. The challenge here is that the final type of use of the space may not be known at this point in time • In an "intrapreneur" system ideas can be rated, commented on and promoted: demands visionary and managerial skills concerning uncertainty and calls for managing the whole value creation process
Boosting industrial internet or other ecosystems	• Traditional partnerships and value chains are subject to change • Call for collaborators from SMEs to innovate and develop value add products and services on top of its own products and services: however, the Finnish ecosystem of capable collaborators is pretty thin

5.2.3 Metal product manufacturer 3

This big company is serving many clients in engineering, process and marine industries.

Company develops equipment to the next generation of application platforms and architecture, activates a variety of industrial internet co-operation networks and applies the principles of rapid prototyping and customer-oriented development. Internet of things refers to the integration of networked machines to the sensors and software, information obtained from analytics, as well as the effective integration of the businesses. The core of the industrial internet is based on a series of sensors which cooperatively collect and analyze data for certain purposes.

Relevant information and new kinds of work

When intelligent equipment, plant & equipment and networks will be linked with the workers both at the workplace and when moving, processes can be optimized in new ways, and productivity and efficiency can be improved. In addition, it will change the competitive advantage and force the other players in the sector to adapt quickly in order to survive. The process speed varies by industry, but the spread of the effects on the whole economy will increase.

Companies have a lot of opportunities to take advantage of the features of the industrial internet, but not all the benefits have seen yet. In the implementation,

one has not yet discerned, how much it will ultimately influence the business models and how to get add value out of it. From the manufacturer's point of view, the ideal situation would be a new relationship model with the customer, where the customer's processes and their improvement are in the focus. It would provide a competitive advantage for both parties.

Value chain

All the traditional Porterian elements of value chain can be found inside the case company. R&D activities are in own hands, as well as IT activities, and the development of managing systems and administration. Not a single business area is fully in the hands of suppliers or partners. On the other hand, some parts of each business area have been outsourced. In some areas, strategic long-term partnerships are very important, in some other areas more subcontracting is used. The products of the company are long lifespan products based very much on technologies of earlier product families. Only data services have been outsourced.

When planning services, one aims to take into account that their user experience, layout and presentation is uniform with and supports the company's main brand. Brand design, the image of the company and user experience reflects well off the product design, as well as the productization of services when presenting them to the customers. Brand applies to the interface of the final user, and turnkey contracts have a higher role than service supply. User experience and outward appearance are central parts in the services company is offering.

Need for new capabilities

The most import needs for new capabilities are there when entering new business areas. In that case it would be natural that the company needs to acquire more capabilities partly in-house, partly via innovative partners. These needs relate to industrial internet. However, the competition is still based on the basic technology and the associated development work. There are a lot of opportunities to take advantage of new materials and new technologies e.g. when substantially changing the construction of the basic product in order to make it more competitive in terms of prices. This is the way how to maintain the knowledge and development work in basic technology, in production and methods. After this there is lot of needs of *system thinking and system engineering* by which different elements can be linked to a workable wholeness, and of *ability to search for workable partnerships*. Data analytics, understanding of the data collected is also needed. It, for its part, needs the feedback with other objectives.

When talking about opportunities around the basic process company is offering to its customers, there is lot of needs for integration with other things and actors. This development is still in its early phases, and it is too early to say, which the systems to rely and build on are.

Company has a lot of environment and energy saving solutions that do not immediately relate to the industrial internet technologies. A huge, so far largely unused potential can be found there how devices could be linked with the surrounding wholeness. Here many things could still be conducted and activities developed. Many ways to increase the value added, to control better for the wholeness and material flow could be seen, or ways to support the operation of existing devices, to transmit information to them or forward from them. This is a field where quite a few things have taken place so far. In manufacturing industries or logistics no such common standards or platforms exist that could be used. Existing solutions are still vertical solutions.

What comes to the customer relation management (CRM) and enterprise resource planning (ERP) systems, company has been in a good position: the development of these basic systems has been on the move at the same time, and they have started to integrate to each other. Company's portal, the data on machines and devices are visible to its customers. Customers will see, how the device is working, how it has been used and maintained or will be maintained. Customer can itself activate certain maintenance events and order different types of transactions. Invoicing from the company can also be seen as well as the management system and device data. When this system planning was started, the user experience was the standpoint, and different types of customer touch points and services were looked at and their functioning planned. There are, however, still a lot to be developed in these fields. Customers have been co-developers in these.

Challenges

Mergers and acquisitions and other events in the history of the company constitute quite a big challenge. The largest asset in the industry may be the knowledge and understanding on what has been delivered and to whom. And because the lifespan of the products is long, the main part of the sales turnover comes from products delivered by the company and others quite a long time ago. It follows that when new solutions are constructed and developed for products of today, they can be a great thing just ten years from now. In addition, there are customers of many levels, some of them more demanding than others.

When talking about an integrated window into how customers are using products on the basis of system data, this window has to be mastered. This is really a big challenge. Company has started a project to integrate all the data and all the data management from the beginning of the early phases of the product lifespan until its end in a harmonic way into one and the same platform. Perhaps the biggest single implementation relates to the harmonization of the information. Information on customers, devices and their maintenance is still in many different systems. This also relates to the products' security of information. For this purpose, the remote steering of products may be restricted. The amount of customer information transferred outwards is relative minor and processed. The major part of analytics will take place on the device level.

In the phase when some de facto standards for platforms are entering the market, a new jump forward can be reached. However, an overall package solution from measuring to data transfer, storage and analysis may not be a working solution in the B2B context in manufacturing. If very short term returns are striven for then it may be challenging to get a new product off to a flying start. In addition, because of the long lifespan of products, the change cannot be a fast one. Ensuring the working conditions for the change, fixed wired network should be improved and fiber capacity and cloud services constructed. In the Nordic Countries, there is quite a lot of knowledge in these fields. We should have workable models how to engage small and large companies in this development and through different open interfaces provide them new solutions that first could benefit the products developed by big companies but also provide value added to all. There is huge potential in this.

Where is the development heading to?

ICT competence in Finland is quite a unique opportunity in this area: there is an awful amount of potential in this area. The company regards the shutdown of the SHOK financial instrument pretty annoying. The platform of SHOK activities had big companies involved, as well as small businesses as subcontractors, and research institutes. It was very much a piloting activity and now there is a great danger that when the funding is shutting down, even though it was not the most important element for a large company, it will break up networks. It's really been a platform that has provided opportunity for the company to take other, smaller companies to experimental development and to share that knowledge and strive to develop the ecosystem. If we cannot develop this ecosystem in the same way as currently, it will lead our own development activities towards a more closed development so that it does not become general knowledge and development, and then it will focus more on a limited part of the area. The fact is that it slows down such a general development.

In Finland, on technology side there is a rather credited talent and an active start-up landscape at the moment. Public funding has made it possible that industrial internet was worth a try. But if the development has to be done with client funding, it will limit actors' innovativeness to think about the existing methods.

Table 14. Innovative practices and their implementation in metal product manufacturer 3.

Theme	Key findings
New Business Models and Practices	• The objective is a new relationship model with the customer, where the customer's processes and their improvement are in the focus • Integrating customer relation management (CRM) and enterprise resource planning (ERP)

	systems, helps customers to see, how the device is working, how it has been used and maintained or will be maintained; customer can itself activate certain maintenance events and order different types of transactions
Leadership and Competences	• Intelligent equipment, plant & equipment and networks will need to be linked with the workers both at the workplace and when moving; then processes can be optimized in new ways, and productivity and efficiency can be improved • Lots of needs of system thinking and system engineering by which different elements can be linked to a workable wholeness; analysis and understanding of the collected data is needed • One needs to manage and integrate all the data from the beginning of the early phases of the product lifespan until its end in a harmonic way into one and the same platform • Unused potential can be found on how devices could be linked with the surrounding wholeness, to control better for the wholeness and material flow, or ways to support the operation of existing devices, to transmit information to them or forward from them; in manufacturing industries or logistics no such common standards or platforms exist that could be used • Need to take advantage of new materials and new technologies e.g. when substantially changing the construction of the basic product to make it more competitive • Principles of rapid prototyping and customer-oriented development are applied
Boosting industrial internet or other ecosystems	• Strategic long-term partnerships are very important: some parts of each business area have been outsourced, in some areas more subcontracting is used, company needs to acquire more capabilities partly in-house, partly via innovative partners • The SHOK was a platform that provided opportunity for the company to take other, smaller companies to experimental development and to share knowledge and strive to develop the ecosystem; now there is a danger for more closed and slower development

5.2.4 Technology provider 1

This medium sized company provides technology for cities and industries. It has its background in electronics and telecommunication.

The case company produces intelligent electronic devices and systems and provides cloud services for clients and their partners. It has a vast cooperation network of subcontractors producing mechanics and electronics, which the company then assemblers. Devices go to final users or contractors directly from the company or through a wholesaler. Contractors make the installation services. Company operates cloud services for steering the electronic devices on behalf of the contractors but the target is that contractors could provide this steering system for final users. Company provides software and platforms in the cloud but buys cloud services for its own use, too.

Company manages its brand and produces electronic devices, technology and software in practice by itself. It used outside industrial designers but concluded, that it benefits the company to design the devices itself in order to control better for their modularization and expenses. Cloud and mobile phone software is bought from partners. In materials management it uses an enterprise resource planning (ERP) system. It buys accounting services as well as personnel management and logistics from a network of companies. Company is responsible for developing and selling the system.

Needs for new capabilities and business models

Company is using commercially available sensors or develops its own sensors integrated in its own systems. It tries to increase business networks around it and sells technology and technology platform to others. Finland is good in technology developing, there is knowledge in this, but are we good in production? As long as machines are responsible for production, it does not matter in which country the production is located, the cost level is about the same. Manual production is more expensive in Finland, but its share in total production is small. This relates especially to research and product development. Productization is just going on for a smart module so that it can be produced on an automatic line. Company is focused on technically advanced products with a high output capacity. Internet is integrated in these modules so that each system has its own IP address. If a device is out of order, it will generate an email. It will tell which device is broken down and what its physical address is. At the moment this information is gathered for easy maintenance but soon all the sensor data will be gathered up. Company has expertise for this but not for robotizing the production.

In the company, it has been a surprise that recruited persons may not understand the connection of business strategy of where to go with their own everyday work. In other words, the meaning of own work from the viewpoint of business strategy may not be understood. People should be capable to learn away from the old to the new, e.g. from selling devices to selling energy efficiency. Technicians are not good in selling contents. In addition, the Finnish culture of action is rather

based on long and thorough planning than a fast and agile piloting and testing. Thorough planning has, however, its good sides, too. But we should rather be fast and look then at whether the product has a market or not.

It has been said that system thinking is a bit lost in Finland, as well as knowledge for making business. On the other hand, there may be knowledge, but one does not know how to use it. In the company, personnel have been taught to think comprehensively at the level of systems. It is, however, not easy to learn to think strategic, outline things and turn service products into processes that would be workable and selling.

Challenges

It is possible to move upwards in the value chain if company reaches the status of a plausible producer. This is why it now collaborates with a national level contractor. Moving upwards in the value chain would also mean scaling the production up. However, investing in smart products will typically pay more than investing in basic products. The prise of investment can prevent clients of using smart products; instead they may use basic products with lower lifespan productivity. A smart solution is always a high-priced solution at the moment of purchasing. It is also a risky solution even though the risk level can be made lower over time. The smart solution company is providing is open to other systems, it uses open interfaces. It will also bring energy savings over time because it allows for an automatic single or group steering of devices through sensor information. This cost saving can be remarkable.

Table 15. Innovative practices and their implementation in technology provider 1.

Theme	Key findings
New Business Models and Practices	• People should be capable of learning away from the old to the new, e.g. from selling devices to selling energy efficiency
Leadership and Competences	• Be able to manage a vast cooperation network of subcontractors producing mechanics and electronics, which the company then assemblers • Be able to provide software and platforms in the cloud but also buy cloud services for own use
Boosting industrial internet or other ecosystems	• Manages its brand and produces electronic devices, technology and software itself, used outside industrial designers but internalized the activity to control better for their modularization and expenses; sells technology and technology platform to others

5.2.5 Technology provider 2

This small company provides technology for digitalization e.g. in process industries and engineering.

The case company will digitalize devices, old and new ones, not earlier digitalized. It also provides data management services through its own cloud. It can connect devices to different channels and sensors, and has developed communication technology.

Value chain

Contractors produce smart components (mechanics and electronics), and company then provides analytics algorithms or they will be developed together with the client. Clients include industrial machine manufacturers, e.g. wind mill manufacturers. Company collaborates with information and telecommunication companies. Clients will use the solutions company has produced either as a fixed element of a product or as an extra service. These companies try to understand what phenomena happen in their devices, e.g. in gearbox. The biggest competitor of the case company is the R&D department of the client.

Knowledge and competences

Knowledge is basically in engineering, but manifold knowledge is needed both in back end (server data bases) and in front end (applications, software). In addition, there is need for Internet of Things experts who know industries. Finding technology competences is not a challenge. Analytics is nowadays based on monitoring of single variables and limit values, but it is heading towards optimization and autonomy. It seems that there is no demand for more complicated analytics.

The clients should understand service business. There is need for a change in mental picture. Finnish companies are slow to try new things; companies in Sweden and Germany are faster. Companies do not have development resources. In addition, there should be someone who is responsible for a new service business.

Table 16. Innovative practices and their implementation in technology provider 2.

Theme	Key findings
New Business Models and Practices	• Provide data management services through its own cloud: connect devices to different channels and sensors, and has developed communication technology for that purpose • There seems to be no demand for complicated analytics
Leadership and Competences	• Provides analytics algorithms or develop them together with the client

	• Analytics is based on monitoring of single variables and limit values, but it is heading towards optimization and autonomy: knowledge is needed both in back end (server data bases) and in front end (applications, software); there is need for Internet of Things experts who know industries
Boosting industrial internet or other ecosystems	• Manages its brand and produces electronic devices, technology and software itself, used outside industrial designers but internalized the activity to control better for their modularization and expenses; sells technology and technology platform to others

5.2.6 Service provider 1

This medium sized company is serving several companies in engineering and other industries.

The case company strives to create new innovative ways of working for maintenance, marketing and automation. Company is providing data warehouse solutions and analytics and reporting systems. It also helps customers to build their portals for their customers and take care of the business in these portals. These types of solutions are quite common in big data.

Value chain

Company is serving manufacturing companies in system planning and process industries in the fields of data, skills and management. Value creation comes from customerships and markets. Customer data relates to the operational level. Gathering this data will bring results. In practice, all the clients of the company are longstanding. All data servers have been outsourced. From the company's point of view it is better to propose to the customer more piloting type doing. Company would like to be a research and developing partner for forefront customers, pilot customers. This should be carried out cost efficiently in collaboration with research centres and universities, so that company wouldn't try to do everything by itself. Company should try to find efficient partners.

Changes in businesses

Company's business has changed a lot: earlier a project definition could take a whole year. After this it was implemented for a while. Nowadays, one should all the time discuss with the customer's business what to do, and perhaps we are not so certain to make the strategy beforehand. Instead we should be better in experimenting and testing ideas. We also should be good in searching for those fore-

front clients with whom we could start developing the ideas. We should find clients who know that there are no ready-made solutions. This is called information management or decision making based on facts where we also will process what kinds of customer experiences there will be. Customer experience originates from the whole service, information, targets and even from the leadership. The customer will get an experience that this bunch really served them and made this easy and produced them value. This is the brand of the company.

In the future, even a larger part of company's sales turnover should originate from fixed or certain services, not from working hours. Company should become a real value added producer for customers. Through agile ways of working, company has been heading from back-office level towards customer businesses, platform businesses and leadership consultancy.

Industrial internet in this change

It is important to understand what industrial internet means from the perspective of the whole business not only from the perspective of devices. Industrial internet is connected with customerships and sales management. For example, if a device needs maintenance, then the system can also trigger an extension contract for sale. Or it can trigger new sales, marketing and service processes. Industrial internet means a lot of new things for the whole business, not only for devices. Nowadays, sales, marketing and services are quite separated, and Internet of Things refers greatly to devices, big data and the use of that data. Data is used, for example, in sales and marketing. Company has not yet decided what will happen next when all these are working. Could they, for example, profile their customers and connect them with each other. Or could they find among other customers the same devices that generate different opportunities for these customers. Customers can also find that they do not have to develop all things themselves but make use of existing systems.

What does the digitalization of devices and interaction mean, from the viewpoint of customer experience, for example? It means that the company has to provide new solutions, operation models, management models and opportunities, not just technologies. Customers should understand this. It also means that the company could act as a value added partner in developing customer's business. Directed information services makes is easier for the company to activate customers, to present them a new thing and test whether it interests them. Only those will then be contacted who were interested in. This kind of system may imply that instead of making a separate customer management system (CRM), enterprise resource planning system (ERP) and equipment control system for the customer we could make a joint system. Anyway, when starting from customer's viewpoint, when we are looking at the whole business of information, service, interaction, understanding and maintenance, we may enter solutions that are totally different. industrial internet should be that of the customer, not that of the device seller.

Competences for value creation

Services should be productized into specified forms, in order to make them duplicable. This also concerns cloud services even though it may be difficult to get them into specified forms. There should be more concepts including semi-finished things, which could be easier to fit in with the same platform and get them to work together and this way bring customers more cost-effectiveness. More value to the customer should be created with the same work. The speeding up of the development cycles is our main challenge when serving large offshore customers.

We should look forward and think what role corporate management has in this transformation process, and owners and investors in company boards. To some extent, operative management seems to follow technological dimensions, but, in fact, competences among managers and company boards are quite different. *These competences could be categorized to technological, information, services and business competences*. Information management, decision making based on facts should be represented there, as well as developing of new technical or other innovations. There should be different competences in different levels, and these competences should also meet each other.

Many companies are thinking how internal entrepreneurship could be harnessed to benefit the whole company, so that new things should not be developed in start-ups but there could be certain rules, power and responsibility and enthusiasm inside the company in a similar way than in start-ups. Within certain rules a person could leave the company and even benefit from a discovery himself. This means that *there should be a competence of agile acquisition and buying in of something new, start-ups, fast things, or innovations.* A company shouldn't try to grow only internally. It follows from this that there should be a competence to manage development portfolios, to get into this development either by ownership arrangements, own R&D or buying it in. Buying from the market again needs competences of its own kind.

Needs for increasing value added

One way to increase value added is that the company converts from providing back office processes to operating customer's processes. In other words, companies should transform themselves from device producers to service providers and operators that run the customer processes. This change is already going on: companies are able to control for the environments of many service providers which solve customer problems in a controlled way. There could be such a way directed to small and medium sized engineering companies about how they could catch up what is possible in this developing and managing customership.

All new types of services do not necessarily generate value added for the vendor. The pricing and earnings logic can be totally different when running customer processes. Perhaps the increased profitability describes best the vendor's value added. In the early stages, when entering cloud services in the case of many

actors which all added a high margin on the top, the final service could have been extremely expensive. Nowadays the market works so that there is always someone who is capable to produce the service cost efficiently e.g. with a centralized data management capacity. On top of that, there can be actors who produce extra value for the customer, and develop new ways to combine different things and this way generates value added for them.

Research organizations should be better in making available of knowledge they have. It is difficult for companies to find from these things that really are workable and to modify them to serve their own business. The big mantras like “the digitalization” will come to Finland terrible late, when these have been going on already for 10-15 years elsewhere. We should attain a situation where “these things just are there” and we can fast get along and they become visible as a high wave when they are implemented. We should not allow that someone decides on what is the mantra we all should follow.

Where is the development heading to?

At least, there are portal services, which are now easier to build, and with which data can be delivered and customers can manage their own services. With these tools also some triggering and more complicated adjustments can be made and automatized. One can also monitor whether they work or not. For example, in directed marketing a company can monitor whether a customer opens the message or not. The same applies to other services. This is a way to identify new opportunities and develop companies’ activities and it is already in practice. We can also talk about customer activating, customer assisting and thinking business together. Big data should be understood rather as *rich data*. We can learn from customer’s device usage, this can then be used for customer guiding and business development. A new kind of business model description may be needed. The old distinction between equipment supply, maintenance, marketing, selling does not work anymore, it categorizes things too much. Technology can change the whole interaction process to become so different that these concepts should be rethought.

The case company works more and more with customer’s management and decision making systems. Together with the customer the company systematically and in a controlled way thinks over the customer’s value creation. It considers e.g. what is valuable when working in a chain. The customer would like to monitor and measure whether it can create value and where it comes from, and to discover things that do not work well or to cut them off. At the moment, management is seen more or less as the management of an organization. But now we should try to manage the whole value creation process and think whether or not to build an organization around it. This is an interesting change.

First appeared *e-commerce* and then appeared the *change in marketing and customership* through digitalization. It is possible that this change proceeds with *cost efficiency and optimization* of own devices on top, and someday one will

realize that, in fact, the customer value is there behind all this. The change may anyway start from the viewpoint of companies' technical opportunities to improve their cost efficiency or quality. Another question is how this modifies the activities of customers and their customers. There are also questions of what would happen if database and equipment producers would provide data to some other actors, would there be actors that would be better in thinking and making new services for their customers based on that data? Customers would take care of their own business and with minor research efforts provide an opportunity to use the data to their equipment producers. Another possibility is to make this together, e.g. in an open data ecosystem. An actor could try to make value itself or by first integrating a wide network of actors for this. An example could be the construction of the metro heading towards west in the capital area of Finland.

In Finland, there could be (Tekes) programs for small and medium-sized engineering companies targeted to catch up with what is possible in this industrial internet development. But we need a more systematic understanding of the customer's value creation process, what is valuable etc., and we should be able to monitor and measure this, that is, the capability to generate value and what it consists of, and develop it so that those things that do not really seem to be working, can be improved or left out.

Table 17. Innovative practices and their implementation in service provider 1.

Theme	Key findings
New Business Models and Practices	• Companies should transform themselves from device producers to service providers and operators that run customer processes: big data should be understood rather as rich data, we can learn from customer's device usage, this can then be used for customer guiding and business development • Act as a value adding partner in developing customer's business: the company systematically and in a controlled way thinks over the customer's value creation; we should try to manage the whole value creation process and think whether or not to build an organization around it
Leadership and Competences	• Need to be good in searching for forefront clients with whom to develop new business ideas: find clients who know that there are no ready-made solutions • Provides new solutions, operation models, management models and opportunities; when starting from customer's viewpoint, look at the whole business of information, service, interaction, un-

	derstanding and maintenance; helps customers to build their portals for their customers and take care of the business in these portals • Need a systematic understanding of the customer's value creation process, what is valuable etc., and how monitor and measure these • Need more semi-finished concepts, which could be fit in with the same platform and bring costs down • Must be able to manage development portfolios, organize development either by ownership arrangements, own R&D or buying it; buying from the market again needs competences of its own kind • Agile development: need to speed up of the development cycles when serving large offshore customers
Boosting industrial internet or other ecosystems	• Internal entrepreneurship requires certain rules, power and responsibility and enthusiasm inside the company in a similar way than in start-ups

5.2.7 Service provider 2

This medium sized company provides digital readiness evaluation that gives to the client a picture of how prepared it is to reap the benefits of the coming changes in its environment.

New business models

For the interviewee, the industrial internet means completely new business models, where data analytics and software applications, combined with intelligent machines, play a crucial role. The digital revolution means a change from a national and analogue economy to a global and digital one, since the new information technology enables global value chains. In a similar fashion, it is possible for Asset Builders that make, market, distribute and sell physical products to Technology Creators that develop and sell intellectual property and Network Orchestrators that create and manage networks of consumers, businesses or investors.

Growth through digital innovation

The case company starts by finding a problem worth solving. They then create concepts and test them to get immediate customer feedback on whether they fulfil the outlined needs. The customer's industry knowledge together with the case

company's expertise of service creation will bring innovation sprints. Long-term success comes from people understanding the opportunities digitalization provides and from giving them tools to successfully drive initiatives forward. There are always needs waiting to be filled, and seeing these opportunities requires deep customer understanding. Coordinated work by multidisciplinary teams that understand business drivers, customer experience and technology produce innovative solutions.

Knowledge

The work in the case company is based on teaching of several modern disciplines: agile software development, service design and user-centred design, lean, and analytics. These share many core principles such as autonomous, co-located, cross-functional teams and embracing change.

Key elements of the digital readiness include:

- A culture of experimentation
- Customer-centric business creation
- Leading with data
- Marketing as a dialogue
- Delivery clock speed
- Management system for speed and outcomes

On the basis of these elements clients' digital capabilities can be built on improved customer experience and personalization of the offering.

The case company prefers learning by doing. This is because things are changing too fast to afford meticulous planning beforehand. People's routines change fast, markets change fast, and competition emerges rapidly from unknown places. The only way to stay in the forefront of the competition is to continuously learn by doing. The best way to understand one's customers is to build something for them and experiment. The best way to figure out the market is to go out there and compete. The best way to change companies internally is to do things in a new way and get results; and all this in very fast cycles, so that every cycle is optimized for learning only the most important thing. *Getting things done requires a specific personal mentality, good understanding of tools and methods, and an organization supporting individuality and freedom of choice.*

Lean service creation or Lean Start-up as business development framework

When building successful businesses the case company favors lean service creation (LSC). LSC is a way of doing agile and user centred service design. Understanding user needs and market potential, rapid conception and quick validation of the concepts are all at the core of LSC. LSC is at its best when innovating new,

yet-to-be-proven services. LSC's primary goal is to learn as quickly as possible if the service is worth further investment.

Lean service creation or Lean Start-up framework can be applied anywhere where uncertainty of the right action is high. The framework was originally built to support start-ups (a domain that naturally has high uncertainty), but can be used by established businesses as well. For example, Lean Start-up is useful for developing new products or services, or expanding an existing business domain or customer base. Lean Start-up has also been used in process improvement and governmental initiatives.

The Lean Start-up framework highlights that a lot of our beliefs about a product are assumptions. Some are more likely to be true and others less likely, but they are still assumptions until they are validated or invalidated with appropriate feedback. If some critical assumption is invalidated, one needs to return to modify her business model in light of the new information. Lean Start-up also directs us to find out which of those assumptions are most critical to the success of the product, and test them as early as possible – before we invest too much of our time and resources in the wrong product.

Speculation and lab testing is rarely as useful as getting real-life feedback from actual users. Interviews, user observation and statistical approaches are all used to gather ideas for improvement. Early on, delivering the product can also include a lot of manual steps, so a lot can be learned in the delivery process itself. The primary question for this stage is “how many assumptions can we test before we run out of time or money?” At this stage, the typical customers are early adopters who are generally willing to accept missing features or less comfortable use in exchange for being at the forefront of new ideas or services.

The “product” that Lean Start-up develops is not the company’s product or service, but rather the whole business around it. There are four distinct elements that must be considered and aligned with customers:

- *Problem*. Is the problem we perceive a genuine problem for the possible customers? Do they want it to be solved, and are they willing to pay to have it solved? Who, within all potential customers, suffer enough from this problem to pay for a solution?
- *Solution.* Does our envisioned service or product actually solve the problem? Does it solve the problem in a way the users want to use? Does the product or service meet the users’ unstated requirements? Is the solution financially feasible considering the cost and effort it takes to deliver it?
- *Business model.* How do we make the business financially viable? How and how much do we charge for the product or service? Are users willing to pay that much or that way?
- *Customer acquisition.* How do we connect with our customers? Do they understand our message? Do people understand the problem and how we solve it? Does our sales funnel work effectively?

Work on aligning all of these four areas should start early. For example, it can be wise to charge money for the service or product from a very early date – if people perceive the value and are willing to part with money for it (even when the product is still in its infancy), it validates a lot of assumptions related to the business model and can be used to test pricing.

Market fit

Market fit is the moment the four elements above are aligned. That moment marks the transition from learning focus to scaling focus. After market fit, the business has already proven its viability, and the focus switches to optimization. Automating the service (to reduce costs) and scaling the product (to be able to serve more customers) become important. The product still needs to be improved since new customers are much less willing to accept incompleteness or poor quality of service. The success of experiments is usually measured in how the statistical behavior of customers changes (with e.g. A/B testing) rather than asking or observing individual customers.

Change management and road mapping

An efficient way to disseminate information about digital is to bring in people with the desired knowledge. The case company recommends digital officers for hire for companies that want to understand what the right qualities for a person leading *digital initiatives* are before committing to a permanent recruitment. Chief Digital Officers for hire are senior consultants with an overview of all things digital and the ability to infuse the customer organization with new thinking and new approaches. For today's companies technology is often a commodity, but understanding the possibilities new technologies offer can be a source of competitive advantage. Moreover, the digital world moves fast and exploiting available opportunities before they pass can be a challenge for many companies. Chief Digital Officers for hire are also able to tap into the knowledge of the rest of case company's experts.

One tool for managing these digital initiatives is service and product roadmaps. Creating a service or product roadmap is a methodical way to discover what the core reasons your customers use it are. This knowledge allows one to develop her services in a way that fulfils both customer and business expectations. Creating a roadmap provides the organization with concrete plans for both building and scaling services.

Pivotal Labs follow a similar procedure to discover "what, why and how" and to prioritize the best features to help one meet her end goal: We need to know, not guess, what your user needs and wants from your product. Pivotal is a GE backed start-up with a broad research and development and commercial agreement aimed at accelerating GE's ability to create new analytic services and solutions for its customers. The investment in Pivotal and new business agreement align with GE's focus on the industrial internet.

To conclude, there are four categories of capabilities in digitalized business development. These capabilities each build on the preceding layers and include:

- *Transparency*. With real time monitoring there is visibility about where a product is, what it is doing, what environment the product is being used in, and the condition of the product. By monitoring a product it is possible to set acceptable ranges and trigger alerts and alarms.
- *Optimization*. In addition to monitoring a product, it is possible to embed software that enables bidirectional control over a product. It is then possible to add algorithms to optimize its operation and performance. This can include predictive maintenance to intervene before something bad happens. A number of Finnish manufacturing companies are on this stage.
- *Business model development*. The developed operations form a basis for new value added services. For example, a company may start to sell predictive maintenance as a service for a range of customers, not just to its own clients.
- *Value chain development*. Finally, a company may change the business logic of an entire business area. Well-known examples include Uber, Airbnb and Tesla Motors. This is an area that calls for visionary, entrepreneurial, and cross-company collaboration.

Table 18. Innovative practices and their implementation in service provider 2.

Theme	Key findings
New Business Models and Practices	• Start by finding a problem worth solving, then create concepts and test them to get immediate customer feedback, and tie the customer's industry knowledge together with own expertise of service creation to bring innovation sprints • Offer “Chief Digital Officers” for hire: senior consultants with an overview of digital opportunities and the ability to infuse the customer organization with new thinking and new approaches: the digital world moves fast and exploiting available opportunities before they pass can be a challenge for many companies, understanding the possibilities new technologies offer can be a source of competitive advantage
Leadership and Competences	• Coordinated work by multidisciplinary teams that understand business drivers, customer experience and technology produce innovative solutions • Relies on several modern disciplines - agile software development, service design and user-

	centred design, lean service creation and analytics - and an organization supporting individuality, co-located, cross-functional teams and freedom of choice • Understand customers by building something for them and experimenting; figure out whether there is a market by going out there and competing; change companies internally by doing things in a new way and getting results; all this in very fast cycles, so that every cycle is optimized for learning only the most important thing
Boosting industrial internet or other ecosystems	• New information technology enables global value chains: Asset Builders make, market, distribute and sell physical products; Technology Creators develop and sell intellectual property; Network Orchestrators create and manage networks of consumers, businesses or investors

5.3 Summary

We can sum up our case study findings by the main questions as follows:

New business models and practices

What could be the most important findings about companies' readiness to introduce new business models and practices? What types of strategies, technologies and new business practices are used and needed?

Many manufacturing companies told that they and most of the Finnish IoT active manufacturing companies are in the phase of optimization: they typically conduct predictive maintenance but are not yet in the phase where they really have started to introduce or adopt new industrial internet related business models or value chains. They also optimize processes in order to reduce waste, energy and resource consumption, but are not yet in the phase of autonomy, where remote devices use self-coordination and self-diagnosis, for example.

As a service provider told, in addition to monitoring a product, it is possible to embed software that enables the control over a product. It is then possible to add algorithms to optimize its operation and performance. This can include predictive maintenance to intervene before something bad happens. In addition, one service provider declared that "big companies with billions of turnover have entered IoT, also some smaller ones, but after them there is a huge black hole".

A new business model springs to life when a company starts to sell predictive maintenance as a service for a range of customers, not just to its own clients, for example. Finally, a company may change the business logic of an entire business area.

Leadership and competences

What competences are required to implement these strategies, technologies and practices? What would be the critical dynamic capabilities in advancing the introduction of IoT related business models or practices? What would be examples of new competences needed now?

We could claim that the most critical competences driving or blocking digital transformation are those ones locating in the state government and industrial federations. But this is not the whole truth. Critical competences can also be found in the boards of companies as some interviewees replied. For example, value chain development is an area that calls for visionary, entrepreneurial, and cross-company collaboration. The nature of these decisions demands *visionary and managerial skills* concerning uncertainty and possible failures.

There is lot of needs of *system thinking and system engineering* by which different elements can be linked to a workable wholeness. Companies must develop their capability to understand broader contexts, to quickly interpret and understand the events within these contexts. Thinking in terms of customer service, companies will have to offer a whole range of services from end-to-end solutions to mass customized products and services. This requires the ability to integrate several departments or eventually change the entire structure and business model of a company. For managers, this calls for managing the whole value creation process instead of just organizational management. Especially big manufacturers highlighted that *systemic skills* are needed, and that one needs the ability to search for workable partnerships.

In fact, *versatile competences* are needed and there should be different competences in different levels, and these competences should also meet each other. Service providers should be good in searching for those forefront clients with whom they could start developing their ideas, and there should be a competence for managing development portfolios to get into this development either by own R&D, agile acquisition or buying in something new, start-ups, fast things, or innovations. Buying from the market in turn needs competences of its own kind. Competences in agile software development, service design and user-centred design are also needed. In addition, *new skills in strategic growth areas*, such as asset optimization and environmental solutions, are needed.

Digital skills comprise understanding of technology, visions on opportunities and courage to pilot new things. There is need for Internet of Things experts who know industries. However, one service provider declared that “finding technology competences is not a challenge; these critical competences may rather lie among the *service and business competences*, or among attitudes.” “A mental change will be needed” told one of the service providers. Besides technological and analytical skills there is need for information, service and business competences. Information management, decision making based on facts should be represented there, as well as developing of new technical or other innovations. Especially there is need for those senior consultants with an overview of digital things and the ability to infuse the customer organization with new thinking and new approaches.

Boosting industrial internet and/or lean and energy saving ecosystems

Some service and electronics providers declared that “Finnish companies are slow to experiment new things, companies in Sweden and Germany are faster”, and “Finnish companies are afraid to do trial and error and they have limited resources for development work.” We can here only shortly touch the questions: *How can innovation policy foster the building of dynamic capabilities and their contribution to firms' innovation and performance?* We will come back to this question in Chapter 6.

We will start from the fact that the development of competences should *not* restrict on company's internal competences, as highlighted a service company providing knowledge management to its clients. Large companies may be seeking possibilities outside the company, often in start-ups. We discussed with some service companies that endless planning is outdated; we need a culture of fast assimilation and continuous integration.

One finding clearly emerged: *business model experimentation* has become popular in software companies in recent years. Continuous learning by doing is also important as well as the mobility of skilled persons. Especially there is need for persons good in processing large data blocks, systems and networks. Financing for piloting and experimenting is needed, and not only financing by loans. Agility is strongly called for: no big planning projects but rather agile and fast smaller projects. Innovative procurements were highlighted for ordering the first references.

Table 19. Key findings among Finnish companies.

Theme	Key findings
New Business Models and Practices	• Most of the Finnish IoT active manufacturing companies are in the phase of optimization: they typically conduct predictive maintenance but are not yet in the phase where they really have started to introduce or adopt new industrial internet related business models or value chains.
Leadership and Competences	• The most critical competences driving or blocking digital transformation are those ones locating in the state government and industrial federations. • Critical competences can also be found in the boards of companies: The nature of these decisions demands *visionary and managerial skills* concerning uncertainty and possible failures. There is lot of needs of *system thinking and system engineering* by which different elements can be linked to a workable wholeness. • For managers, this calls for managing the whole

	value creation process instead of just organizational management. There should be a competence for managing development portfolios. Especially big manufacturers highlighted that *systemic skills* are needed, and that one needs the ability to search for workable partnerships. • Competences in agile software development, service design and user-centred design are also needed as well as *digital skills* that comprise understanding of technology, visions on opportunities and courage to pilot new things. • However, critical competences may rather lie among the *service and business competences* than technology competences.
Boosting industrial internet or other ecosystems	• *Business model experimentation* has become popular in software companies in recent years. Continuous learning by doing is also important as well as the mobility of skilled persons. *Recruitment and hiring* has become one of the most critical competences in companies. • Financing for piloting and experimenting is needed, and not only financing by loans. • Agility is strongly called for: no big planning projects but rather agile and fast smaller projects.

6. Discussion and conclusions

6.1 Implementing lean start-up and co-creation methodologies

Finland and Denmark are small open countries with about the same size of population. Companies respond to globalization and grand challenges by searching increasingly for specialized products. Clearly in these both countries, there is an increasing focus on innovation through customer solutions. Close contact and cooperation with customers is a rule. Furthermore, combining services like maintenance, monitoring, and data management with products is a common trend. We can also talk about servitization: business models are based more and more on continuous services, not just on one-off delivery of products and services. In many cases, new solutions in product development are in use, like different models of open innovation. There is also discussion about new ways to allocate tasks between specialists and developers. For example, start-ups are utilized in designing user experience.

It is not a new finding that “you cannot do it alone”. Even the smallest companies are willing to reinforce their networking with other companies. On the other hand, with the advent of IT start-ups and their new funding schemes, a new business culture is about to coming ashore and penetrating the markets. This business culture deviates from that of grand old companies, being often family owned. Companies that have adopted a new business culture, IT services companies in the forefront, are typically lower in hierarchy, more transparent in their internal communication and flexible and faster in their operations. In the first place they are more creative, problem solving and disruptive innovation is being built-in in their business models, which often are hyper scalable.

In the manufacturing, the most decisive thing is, to what extent large companies can innovate like start-ups. During the past few years, large companies have started to implement lean start-up methodologies. But public companies are not architected to create start-ups or attract and retain entrepreneurs who have built successful businesses from just an idea. For this reason, most public companies grow and innovate by acquisition (Free 2013). In addition, *recruitment and hiring* has become one of the most critical competences in companies, being possibly

even more important than the development of a new digital technology inside the company as R&D.

6.2 Digitalization as an opportunity for renewal

There is a lot of discussion about new platforms, IoT or service platforms; which one is beating the other ones, what will be the role of open source platforms etc. Perhaps big companies are here in decisive roles. Furthermore, there is discussion about the locus of innovation, locating in value networks rather than in individual companies. In interviews, generally taken service providers were willing to change their business more towards operating their client's businesses. Service providers were experts in knowledge management and/or in cloud technologies. We can see that digitalization indeed affects the business ecosystems and business models.

These findings have also been mentioned in the report *Need for Speed* (DIMECC 2016, http://www.n4s.fi/publication/) and in that of Frost & Sullivan (2014). One finding mentioned in the report of DIMECC is that cloud technology is increasingly becoming the core of firms' business strategy. We observed this among the interviewed big manufacturing companies, too, and this is why we also focused on their technology and service providers. Companies providing cloud services are in the forefront, and leading with data is relevant, too. There is a need except for digitization, also for remote monitoring and collaborative supply chains (Frost & Sullivan, 2014).

Digitalization is an important opportunity for renewing manufacturing. This opportunity is firmly rooted in technological advancement in the area of intelligent technologies, but it does not realize itself via technology push. More than ever, the development requires analysis of the practices that result in customer and stakeholder value, and in these practices services play a major role (Toivonen et al., 2014). Digital transformation requires that innovation processes are agile and networked, which involves, for example, start-up co-operation and various partnerships.

6.3 Adopting new business models

It has been said that Finnish companies have indeed identified the trend of digitalization and there is even knowledge for designing intelligent solutions, but applications are still left unfinished. In practice, the development has meant that services have been placed in networks, or remote monitoring has been adopted in industrial uses. However, solutions have not been very ambitious or they do not create completely new businesses (Microsoft, 2015).

"I think the courage for combining innovation and digitalization has been lacking. No attempt has been made to do something completely new. I would encourage companies to experiment. The experiment itself does not necessarily revolutionize business, but may provide keys to solve the challenges ahead" says H.

Åkerman, Business Group Leader at Microsoft. "I think that digitalization should be understood as a product development matter. Experimentation and focusing on projects, that are not certain in their outcomes, belong to the product development paradigm. Digitalization projects should get the same position" K. Hagros, CIO in Kone Corporation, continues (Microsoft, 2015).

ICT understanding should nowadays be the basic competence in management. This could encourage companies to invest more not only in digital technologies but also in new designs and brands, new business models and management systems. In addition, one should remember that new innovations do not emerge if a company is searching for immediate business benefits only. Often, optimization of an existing process does not lead to the creation of a new business model, since in some cases the change may require the cannibalization of the existing business. Companies must continuously search for new ways in which new customers can be met, but the dilemma is, how to grow while still take care of the existing production. If you make a new business, you may have to ignore your old customers.

Companies should have people who can handle the task of creating new innovative solutions, not only to drive production, as it is now. “The question is about a change in mind-set; it is important to understand the market without being a part of it” (Innomitta II workshop in Aarhus, 2015). In addition, the question is about risk taking. In the short run creating new services may be a costly activity, but in the long run several initiatives may achieve success and be a good investment. ”Putting a price on everything you do is bad for innovation and competitiveness”.

6.4 The renewal of Finnish and Danish manufacturing, a comparison

Danish production companies are in several respects similar with Finnish. However, quite recently, a boom of IT start-ups has emerged in Finland. This is partly due to the high number of IT skilled persons released from Nokia and Microsoft. The same phenomenon can be seen in Sweden, but perhaps not in the same scale in Denmark. This boom affects manufacturing in many ways. Large and medium sized manufacturing companies are renewing their products and processes by creating new businesses inside the company or by utilizing established start-ups. Start-ups have been used e.g. for designing user experience, other vendors for providing tools for managing the complexity of business. Furthermore, we can conclude that the need for digitization, for remote monitoring and collaborative supply chains (i.e. for *process improvements*) has been and still is a key driver for the renewal of manufacturing in Finland. In Denmark ICT has possibly less served as a driver for innovation but the situation is now about changing. Many companies even in discrete manufacturing industries are beginning to invest in automation, but still in a small scale.

Both in Denmark and Finland, we are in the middle of a large industrial experiment where companies should be highly innovative. One problem is that most decisions and investments are made on the basis of cost, and production compa-

nies are not willing to sacrifice enough. They should be willing to invest more and take decisions based not only on costs and a positive bottom line. In the *Industry 4.0* hype wireless automation can be seen as a key driver for innovation. There is much technology in the field, but it can take about 10 years before companies can actually get positive return from it. Despite this, digitalization should be placed in the core of business, as a part of the business strategy and decision making (Tivia, 2016).

It has been discussed that Finland might be more focused on framework policies and ecosystems than Denmark. For example, it is important to see the maritime industry as an ecosystem: it is more a collection of interactions than institutions. When developing the industry we a need a platform for the development and networks of companies. We should concentrate on promoting intangible platforms. This kind of an intangible platform could be managed in a small country even though part of the operations, for example, the manufacturing would take place in a low cost country.

Based on findings commonly known and emerged in this project we can conclude that the needs for promoting relevant platforms and ecosystems and building dynamic capabilities for these in small countries like Denmark and Finland are reasonable similar, and also the solution models are approaching each other. As a caricature, Finnish industries have traditionally followed a “technology first” or technology push model and Danish industries a “user-centred design first” or customer involvement model. Now, there are indications that Finland should take further steps especially in developing new business competences and Denmark in developing new digital competences.

Nowadays, both Denmark and Finland employ market-oriented approaches for achieving their competitive advantages. However, there is still place for state government to promote this development. In Denmark, the national innovation strategy stresses increased cooperation between knowledge institutions, companies and other stakeholders and active participation in a global knowledge and innovation network. There are several funding instruments targeting these aims. Furthermore, the innovation strategy highlights integration of innovative competences and entrepreneurship in education programmes and closer coordination of education, research and innovation policy. Universities mainly cooperate with larger companies, both in terms of value added and in terms of number of employees.

In Finland, establishing long-lasting partnerships have been considered important for RDI and there are several measures to promote business use of public sector information, education and training, advisory, networking and other support services. The new Government programme in 2015 strengthened competitiveness by improving conditions for business and entrepreneurship by reforming key legislation and removing sectoral regulation that prevents competition. Reform of research institutes and research funding (2013) as well as new funding model for universities are meant to drive for excellence.

Finally, organizational capital and organizational competences like taking advantage of IT advances, the capacity to deal with change, risk and uncertainty, and global connectivity, and linking capabilities where best and the ability to tailor

operations to specific markets are important and they should be understood as a product development matter or at least they should get the same position as product development in companies. This should encourage companies to invest more in new designs and brands, new business models and management systems, i.e. in *non-technological innovations*.

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APPENDIX

INTERVIEW GUIDE FOR THOSE BIG ENGINEERING COMPANIES WHICH ARE KNOWN TO HAVE TAKEN IN USE NEW DIGITAL OR INDUSTRIAL INTERNET SOLUTIONS /
INTERVIEW GUIDE FOR THOSE TECHNOLOGY OR SERVICE PROVIDERS WHICH ARE KNOWN TO HAVE PROVIDED NEW DIGITAL OR INDUSTRIAL INTERNET SOLUTIONS TO FINNISH ENGINEERING COMPANIES
THIS GUIDE WILL BE SENT TO COMPANIES ALREADY BEFORE THE INTERVIEW

INTRODUCTION
The interview is part of the Tekes and Dasti (Danish Agency for Science, Technology and Innovation) funded project on the *Renewal of manufacturing* in Finland and Denmark, as well as on the capabilities that are required in this renewal.
The interview places special attention to the new development phase of digitalisation, which is also called the third industrial revolution. Here, integrated digital technologies and Big Data such as *Internet connected sensor data, customer data, and social media* are used for improving business competitiveness, productivity and customer focus as well as for implementation of new industrial services and approaches.
According to the ETLA discussion paper "Finnish industrial internet - from challenge to opportunity", industrial enterprises are looking for three kinds of benefits from the industrial internet. The company may seek to improve its current business operations (evolution), develop an entirely new business (revolution) or increase the value of its products:

- **Improving the productivity of current business** by using more efficiently the data that can be collected from equipment, machinery or processes (Operations Management). The benefit may come from the predictive maintenance, energy savings (in particular in buildings and in transportation), or through more efficient use of labor. The focus is not in increasing revenue, but in obtaining better profits through savings.
- **New business development**: More and more, manufacturers are moving from equipment or systems sales to a service business, at first to the sales of maintenance and care, but later also to the sales of operation hours or productivity (we do not sell a gravel truck, but transferred sand tons). The benefits for the company are improved predictability of revenues and lower dependence on business fluctuations.
- **Increasing the value for the customer** by increasing the "intelligence" of the products (Customer Management): The buyer may benefit from more efficient operations and increased productivity. Equipment, machines and systems are rapidly becoming more intelligent, i.e. they include sensors, networking, software and devices that measure their op-

erations. Machine to machine co-operation, which requires smart features and intelligence from those machines, provide clear benefits at the system level. The manufacturer may benefit through a higher sales price (or lease payment).

industrial internet and new business infrastructures require significant amount of investments and new skills and capabilities, which companies need to take into account in human resource planning and IT systems development, among others. Also, change management itself requires a particular kind of expertise: structural changes lead to significant skills shortages and restructuring. Many beneficial changes are such that they do not belong to anyone's current tasks. On the other hand, management may not always perceive the extent of the possible improvements.

New IT operations, as well as the environmental and energy-saving techniques that link to them, are expected to affect corporate business and revenue models, products and services, production and distribution methods, marketing and sales activities, partnership and customer networks, as well as the administrative functions.

In this interview, the company's representative (e.g. CEO, CTO, CIO, Competence Manager) is asked for his/her view of the company's key focus areas to improve its operations and capabilities that the company needs to succeed in the face of growing international competition, in the development and uptake of new IT-based solutions, and in responding to the environmental challenges. This includes both internal capabilities and those that will be purchased from external parties.

The interviewee is also asked how important he/she considers industrial internet, Big Data, the environmental or energy-saving techniques or services based on these for the development of new products, value-added services or entirely new business. In addition, the interviewee is asked to characterize the most important structural needs for how to increase value added in the industry he/she represents.

1. PRESENT STATE

THE POSITION OF YOUR COMPANY IN THE VALUE CHAIN

How would you characterize your company’s position in the value chain? Which of the following functions the company performs mainly by itself, and in which you are using outside resources?

Production and services, supporting activities like distribution, design of products and brands, IT activities, design of administrative systems, research and development activity.

Do you use short-term contracting in a wider scale than strategic partnerships or long-term cooperation with other companies? In which activities you are using strategic partnerships or long-term cooperation? Have you outsourced some activities? Which activities?

Are parts of the above-mentioned supporting activities performed abroad?

How design, sales and marketing play a role in the company’ innovation activities?

2. FUTURE STATE

THE KEY RENEWAL AREAS OF THE COMPANY

Please characterize those key areas and capabilities, either internal or those that will be purchased from external parties, which your company needs in order to succeed in the growing international competition, in the development and uptake of new IT-based solutions, and in responding to environmental challenges.

Do these key renewal areas and capability needs lie in the first place in:

New business or business models e.g. in transition towards deeper partnerships in complex company networks or towards *Internet connected products and services* based operational model?

New products and production processes?

New research and development processes?

New sales and marketing methods like new aesthetic design, new brands, new sales channels or customer relationship management (CRM) systems?

New management and decision making methods or systems like supply chain solutions or (global) asset management (GAM) systems?

THE MOST IMPORTANT RENEWAL AREAS IN YOUR INDUSTRY OR IN THE WHOLE MANUFACTURING

Please characterize those key structural renewal areas your industry or the whole manufacturing would need *in order to increase its value added*./

Please characterize those key structural renewal areas your industry or your manufacturing customers' industry would need *in order to increase their value added*.

For start-up companies: what *challenges for growth* there are around start-ups?

3. USE OF NEW TECHNOLOGY, BIG DATA OR SERVICES BASED ON THESE

Has your company generated or taken in use industrial internet technologies like sensors integrated in products, or analytics of Big Data, or environmental or energy-saving techniques or services based on these? If it has, please describe them and reasons for implementing them. If not, do you intend to implement them in the future?

Have you implemented / do you intend to implement them in your company and/or in your manufacturing customer companies in:

New products, services, or production or distribution methods?

New sales and marketing methods or systems?

New management methods or systems, or *new business models*?

Somewhere else, please describe?

These technologies and services include, among others, the use of industrial internet in a production or material management system (ERP, MRP), in information management systems (IMS), quality management or decision making systems; analytics of sensor data, customer data or social media and visualization of results, and intangible value-added services (e.g. SaaS, PaaS, IaaS, Condition Based Maintenance CBM, Fleet Management, Remote Operations or Condition Monitoring, ROM, RCM, Business Intelligence).

How important do you see industrial internet, analytics of Big Data or environmental or energy-saving techniques or services based on these for the development of:
Internal business operations?
New products, services or *entirely new business*?
Value added for customers?
Something else, please describe?
BIG COMPANIES: What strategic goals you may have for these? Has your company digitalisation strategy, IT organization or IT manager (information manager)? Has your company environmental strategy? What about design strategy or design manager?

4. CHALLENGES IN THE INTEGRATION OF NEW TECHNOLOGY, BIG DATA OR SERVICES

What challenges do you see to appear in your company and/or in your manufacturing customer companies in integrating industrial internet, Big Data or environmental or energy-saving techniques or services or solutions based on these into:
New products, services, or production or distribution methods?
New sales and marketing methods or systems?
New management methods or systems, or *new business models*?
Somewhere else, please describe?
These challenges include, among others, technological compatibility challenges, information security and privacy challenges in networks and cloud services, challenges related to management systems and organization, to investment in new IT-based solutions, and challenges outside the company like funding of investment, high risks or weak availability of suitable technologies, capabilities or skills.

5. CAPABILITIES FOR THE ADOPTION OF NEW TECHNOLOGY, BIG DATA OR SERVICES

What kinds of capabilities do you foresee as important for reaching goals related to industrial internet, Big Data or environmental or energy-saving techniques or services or solutions based on these? What kinds of company-wide capabilities would your company /or your manufacturing customer companies need for the implementation and integration of these technologies or services into:
New products, services, or production or distribution methods?
New sales and marketing methods or systems?
New management methods or systems, or *new business models*?
Somewhere else, please describe?
Are there any shortages of these capabilities in Finland, overall?
In general, what kinds of (IT) technical solutions, platforms, piloting environments or other co-operation do you regard as important for reaching goals related to industrial internet or environmental or energy-saving technologies?

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Title	**Critical competences for industrial renewal in Denmark and Finland**
Author(s)	Olavi Lehtoranta, Mika Naumanen, Carter Bloch, Carita Eklund, Janne Huovari, Hannu Piekkola & Magnus Simons
Abstract	Denmark and Finland are small open economies with about the same size of population. Companies respond to globalization and grand challenges by searching increasingly for specialized products. This publication gives a short excursion into some technological and non-technological innovations and their competence requirements that support this specialization. Also, we describe recent developments in national innovation strategies in both countries. In both countries, there is clearly an increasing focus on innovation through customer solutions. Close contact and cooperation with customers is a rule. Furthermore, combining services like maintenance, monitoring, and data management with products is a common trend. In general, service providers are willing to change their business more towards operating their client's businesses. The development requires an analysis of the practices that result in customer and stakeholder value. We can see that digitalization indeed affects the business ecosystems and business models. ICT understanding should be the basic competence in management. The need for digitization, for remote monitoring and collaborative supply chains (i.e. for process improvements) has been and still is a key driver for the renewal of manufacturing in Finland. In Denmark ICT has possibly less served as a driver for innovation but the situation is now about changing. Profitability effects are positive for process innovations although these do not increase productivity, at least if not combined with product innovations. This suggest that process innovations are important for improving efficiency, but this may be because of the improvement of cost efficiency rather than an increase in output. Digitalization is an important opportunity for renewing manufacturing. This opportunity is firmly rooted in technological advancement in the area of intelligent technologies, but it does not realize itself via technology push. Innovation locates in value networks. Digital transformation requires that innovation processes are agile and networked. Even the smallest companies are willing to reinforce their networking with other companies. On the other hand, large companies have started to implement lean start-up methodologies. In addition, recruitment and hiring has become one of the most critical competences in companies, being possibly even more important than the development of a new digital technology inside the company. Companies should have people who can handle the task of creating new innovative solutions. With the advent of IT start-ups and their new funding schemes, a new business culture is coming ashore and penetrating the markets. Companies that have adopted a new business culture, IT services companies in the forefront, are typically lower in hierarchy, more transparent in their internal communication and flexible and faster in their operations. They are more creative, problem solving and disruptive innovation is being built-in in their business models, which often are hyper scalable. In these companies, organizational capital and organizational competences are key for business development. They invest more in new designs and brands, in developing new business models and management systems, i.e. in non-technological innovations.
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Nimeke	**Teollisen uudistumisen keskeiset kyvykkyydet Tanskassa ja Suomessa**
Tekijä(t)	Olavi Lehtoranta, Mika Naumanen, Carter Bloch, Carita Eklund, Janne Huovari, Hannu Piekkola & Magnus Simons
Tiivistelmä	Tanska ja Suomi ovat väestöltään suunnilleen samankokoisia pieniä avoimia talouksia. Molempien maiden yritykset vastaavat globalisaation ja talouden suuriin haasteisiin etsimällä omia erikoistumisen kohteitaan. Kuvaamme niitä teknologisia ja ei-teknologisia innovaatioita sekä niiden taustalla olevia kyvykkyyksiä, jotka tukevat tätä erikoistumista. Esittelemme myös kansallisten innovaatiostrategioiden viimeaikaisia kehityskulkuja molemmissa maissa. Asiakaslähtöisten innovaatioiden synnyttäminen on keskeinen fokusalue molemmissa maissa. Tiivis yhteys ja yhteistyö asiakkaiden kanssa on keskeistä. Tuotteisiin yhdistetään yhä enemmän lisäarvopalveluja kuten huoltoa, tarkkailua ja tiedonhallintaa. Palveluntarjoajat ovat halukkaita ottamaan yhä suuremman osan asiakkaittensa liiketoimintaprosessien hoitamisesta kontolleen. Kehitys vaatii niiden toimintojen tarkkaa analyysiä, jotka todella tuottavat arvoa asiakkaalle. Tapauskuvauksissa saatoimme nähdä, kuinka digitalisointi tosiaankin vaikuttaa liiketoimintaekosysteemeihin ja liiketoimintamalleihin. Tieto- ja viestintätekniikan mahdollisuuksien ymmärtämisen pitäisi olla yritysjohdon peruskyvykkyyksiä. Digitalisointi sekä kaukovalvonnan ja toimitusketjujen hallinnan kehittäminen (eli prosessien tehostaminen) ovat olleet ja ovat edelleen keskeisiä ajureita valmistavan teollisuuden uudistumiselle Suomessa. Tieto- ja viestintätekniikan rooli muutosajurina on mahdollisesti ollut vähäisempi Tanskassa, mutta tilanne on nyt muuttumassa. Prosessi-innovaatiot parantavat yritysten kannattavuutta, vaikkeivät ne lisääkään tuottavuutta, ainakaan jolleivät ne yhdisty tuoteinnovaatioiden kanssa. Voi olla, että prosessi-innovaatiot ovat tärkeitä tehokkuuden kasvattamisessa, mutta kasvu saattaa johtua tuotoksen kasvun sijasta kustannustehokkuuden parannuksesta. Digitalisointi avaa uusia mahdollisuuksia valmistuksen modernisointiin. Tämä mahdollisuus on seurausta älykkäiden teknologioiden kehityksestä, mutta se ei toteudu teknologiaa kehittämällä. Digitaalinen muunnos vaatii, että innovaatioprosessit ovat ketteriä ja verkottuneita. Pienimmätkin yritykset ovat halukkaita vahvistamaan verkostojaan toisten yritysten kanssa. Toisaalta suuryritykset ovat alkaneet seurata startup-yritysten pelkistettyjä keinoja haarukoida uutta liikeideaansa. Uusien työntekijöiden etsiminen ja palkkaaminen ovat muodostuneet yhdeksi yritysten kriittisimmistä kyvykkyyksistä, ollen mahdollisesti jopa tärkeämpiä kuin uuden digitaalitekniikan oma kehitystyö. Yrityksellä pitäisi olla palkkalistoillaan ihmisiä, jotka kykenevät luomaan uusia innovatiivisia ratkaisuja. Uudet ohjelmisto- ja tietotekniikan startup-yritykset ovat luomassa uutta yrityskulttuuria ja muuttamassa työmarkkinoita laajemminkin. Uuden yrityskulttuurin airuilla, tietotekniikkapalvelutyrityksillä etunenässä, on tyypillisesti matala hierarkia, ne ovat läpinäkyvämpiä sisäisessä viestinnässään sekä joustavia ja nopeampia toiminnoissaan. Ne ovat luovempia, ongelmanratkaisu ja uutta luovat innovaatiot ovat osa niiden liiketoimintamalleja. Liiketoimintamallit ovat myös usein äärimmäisen skaalautuvia. Näissä yrityksissä organisatorinen pääoma ja organisatoriset kyvykkyydet ovat avainasemassa liiketoiminnan kehityksessä. Ne investoivat enemmän muotoiluun, designiin ja brandin kehitykseen sekä uusien liiketoimintamallien ja johtamisjärjestelmien kehittämiseen eli ei-teknologisiin innovaatioihin.
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Critical competences for industrial...

Critical competences for industrial renewal in Denmark and Finland

This publication gives a short excursion into some technological and non-technological innovations and their competence requirements. In the context of industrial renewal, it compares Denmark and Finland in terms of innovation policies conducted in these countries. Digitalization is considered as an example of the most recent industrial transformations taking place in both of these small economies.

The publication emphasizes that ICT understanding should nowadays be the basic competence in management. This could encourage companies to invest more not only in digital technologies but also in new designs and brands, new business models and management systems, i.e. in non-technological innovations.

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