European Commission

Background Report

Peer Review of the Danish R&I System

Horizon 2020 Policy Support Facility

Research and Innovation

Background Report - Peer Review of the Danish R & I System

European Commission
Directorate-General for Research and Innovation
Directorate A — Policy Development and Coordination
Unit A4 — Analysis and monitoring of national research and innovation policies
Contact (H2020 PSF Peer Review Danish R&I system): Ana Correia, Ana.CORREIA@ec.europa.eu

Contact (H2020 PSF coordination team):

Román ARJONA, Chief Economist and Head of Unit A4 - Roman.ARJONA-GRACIA@ec.europa.eu
Stéphane VANKALCK, PSF Head of Sector, Unit A4 - Stéphane.VANKALCK@ec.europa.eu
Marta TRUCO, PSF Team Leader, Unit A4 - Marta.TRUCO-CALBET@ec.europa.eu
European Commission
B-1049 Brussels

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EUROPEAN COMMISSION

Background Report

Peer Review of the Danish R&I System

Danish Ministry of Higher Education and Science- Danish Agency for Science and Higher Education

Directorate-General for Research and Innovation

2019 EN

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Introduction

This report is the background report for the H2020 Peer Review of the Danish Research and Innovation (R&I) system. Its main purpose is to provide relevant context information on the Danish R&I system in support of the peer review panel.

The background report has been drafted by the Ministry of Higher Education and Science, Danish Agency for Science and Higher Education, and consists of two separate reports: a report presenting the key indicators of the Danish innovation system and a report setting the Danish innovation policy in the historical context.

The background report has two appendices (separate reports): Appendix A consists of a Self-assessment of the Danish knowledge-based innovation system, authored by the Danish Ministry of Higher Education and Science, Danish Agency for Science and Higher Education; Appendix B contains the report on the Literature review and assessment of the Danish knowledge-based innovation support system, provided to the Ministry by the IRIS Group.

KNOWLEDGE-BASED INNOVATION INDICATORS

1 INTRODUCTION

This report presents key indicators of the Danish innovation system. Denmark is considered among the innovation leaders according to the European Innovation Scoreboard (EIS). It is, however, hard to summarize a countries innovation performance in a single number. The figure below illustrates this aspect by highlighting Denmark's ranking on selected EIS indicators. Even though Denmark has an overall high EIS ranking there is also areas where Denmark could improve such as the sales of new-to-market firm innovations.

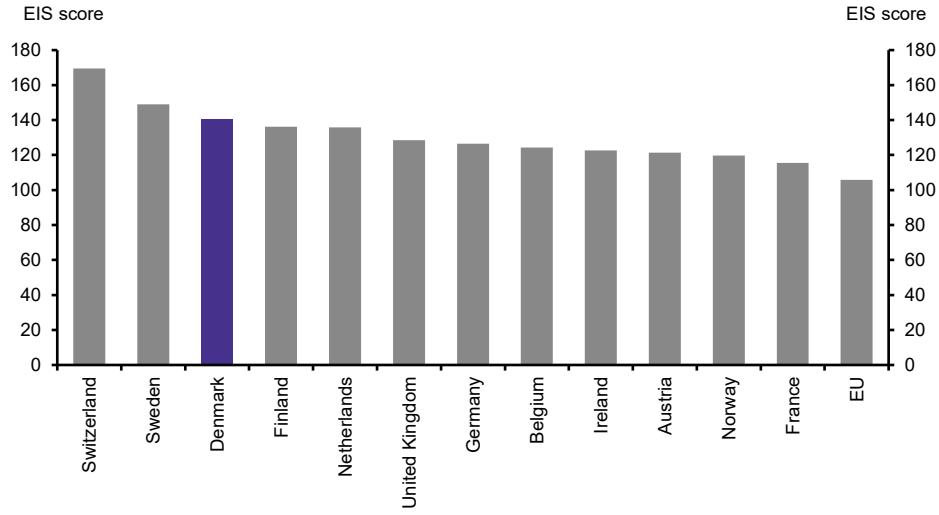
Figure 1: Denmark's' ranking relative to no. 1 on selected EIS indicators

Note: The relative placements are indexed in relation to the no. 1 placement being=100, *Orange=EU/OECD-average, Grey=no. 1, Purple=Denmark

Source:European Innovation Scoreboard

Since 2010, Denmark has attained overall high achievement in the European Innovation Scoreboard (EIS). The latest scoreboard showed Denmark in third place, cf. Figure 2.

Figure 2: European innovation scoreboard, 2018

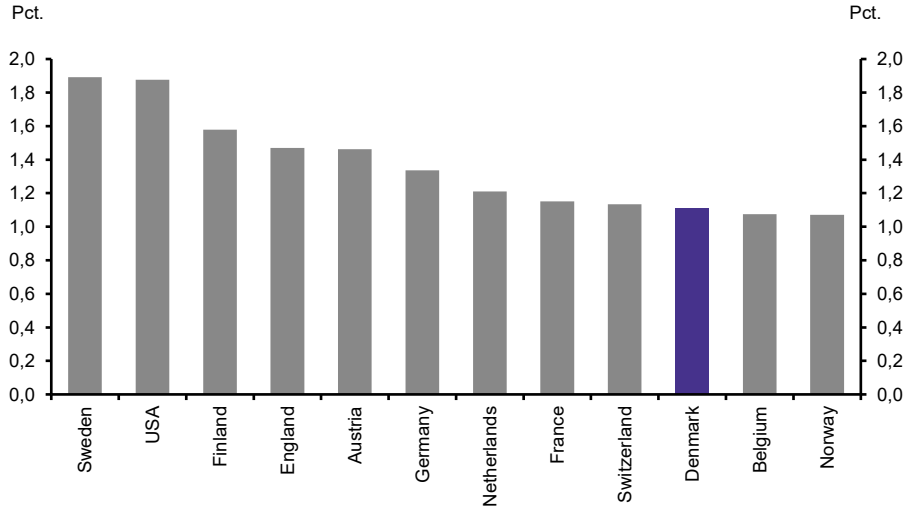


Note: Data are not available for the USA.

Source:European Innovation Scoreboard

Innovation performance is often correlated with economic growth. However, despite the fact that Denmark is one of the richest countries in the world, productivity growth in Denmark has been at a low level for two decades compared with that of similar countries, cf. **Error! Reference source not found.**3.

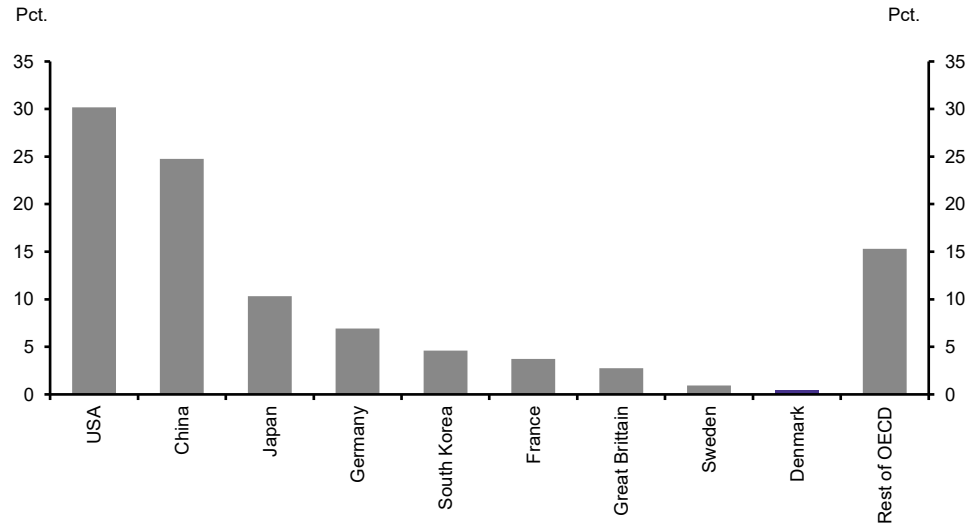
Figure 3 Average annual growth in hourly productivity, 1995-2015, pct



Source: OECD

The Danish economy is small and open. It is vital that Denmark absorb knowledge from other countries' research and development efforts because more than 99 percent of research is performed outside Denmark, cf. Figure 4. Some of the leading Western countries, the USA, Germany, Great Britain, and France, are also some of Denmark's most important trade partners.

Figure 4: Distribution of research and development expenditures across OECD countries and China, 2015, pct.



Note: Pct. of investment in OECD and China. The seven countries with the largest shares and Denmark and Sweden (12^{th}).

Source: OECD

Hence, the comparison throughout the report is between Denmark and similar countries: Austria, Belgium, Finland, Ireland, Netherlands, Norway, Sweden and Switzerland, which are all small, open economies. The US, the UK, Germany and France enter the comparison as well because they are some of the drivers of technological change in the world, and they are some of Denmark's most important trade partners.

The report is limited to quantitative indicators of the Danish innovation system. For an account of Danish instruments and institutions, the reader should consult the report by the IRIS Group (IRIS (2018)), which constitutes Appendix A to this report.

To summarize the indicators, Denmark is strong in public investment in R&D. The expenditures on public R&D relative to GDP are the highest in comparison with those of selected countries. The number of publications and citations is also among the highest in the comparison. The share of highly educated people in Denmark is at approximately the same level as in OECD countries and below that in many of the comparison countries. However, projections to 2040 show that the number of highly educated people in the labour force will increase by 50 percent.

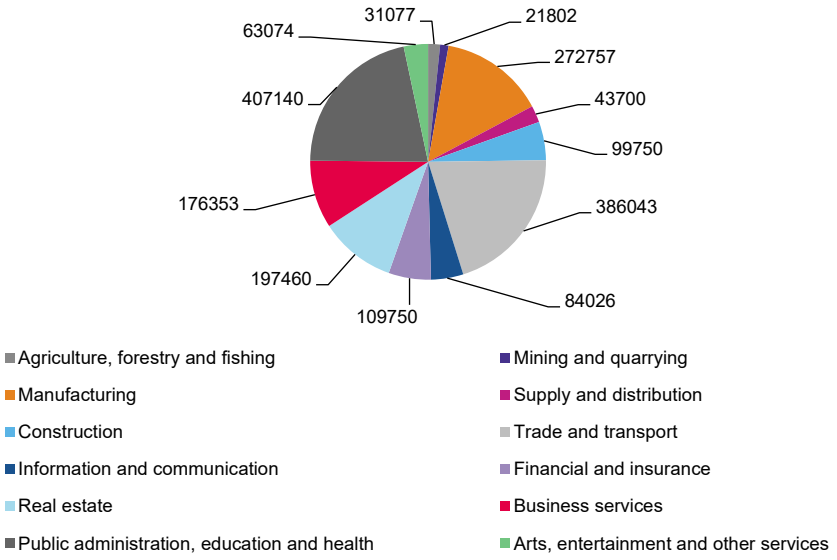
Private investment in R&D is highly concentrated both in the number of firms and geographically. Public and private R&D is biased towards the health and pharmaceutical industries. Indicators of product and process innovation place Denmark closer to the bottom of the comparison countries. In line with this result, activities in Denmark related to cooperation between innovative firms and universities and venture capital expenditures in Danish firms are not among the highest in the comparison. Moreover, surviving entrepreneurs stop growing after only three years, which indicates that Danish firms have problems scaling up.

2 DANISH INDUSTRIES

The following section gives a flash overview of the Danish business sectors. The purpose of the chapter is to offer a short description of the Danish industry structure and the knowledge intensive industries.

The Danish economy is to a high degree a service economy, when looking at the size of different sectors in terms of gross value added. The manufacturing sector compromises around 14.4 pct. of total value added which is below the EU-28 average of 16.4 pct. The biggest exports markets are in order DEU, SWE, USA, GRB and NOR.

Figure 5: Gross value added across different sectors in Denmark, 2017

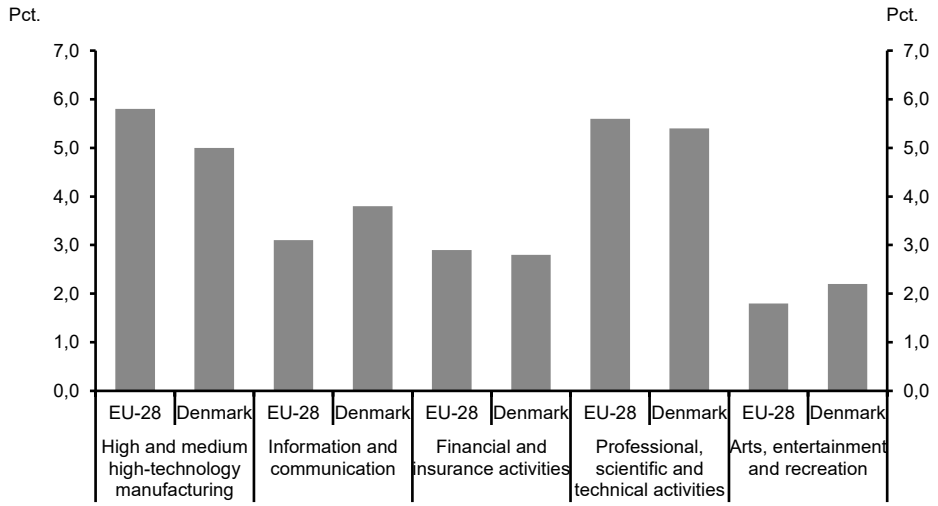


Source: The Danish National Account

2.1 Employment in knowledge intense industries

Of particular importance to the knowledge economy are high tech manufacturing and knowledge intensive service industry. The share of employment in the high and medium-high technology manufacturing in Denmark is below the EU-28 average by 0.8 percentage points. The share of employment in knowledge intensive services such as 'information and communication' and 'arts, entertainment and recreation' is slightly above the EU-28 average.

Figure 6: The share of total employment in 'high and medium-high technology manufacturing' and selected 'knowledge intensive services' in EU-28 and Denmark, pct., 2017

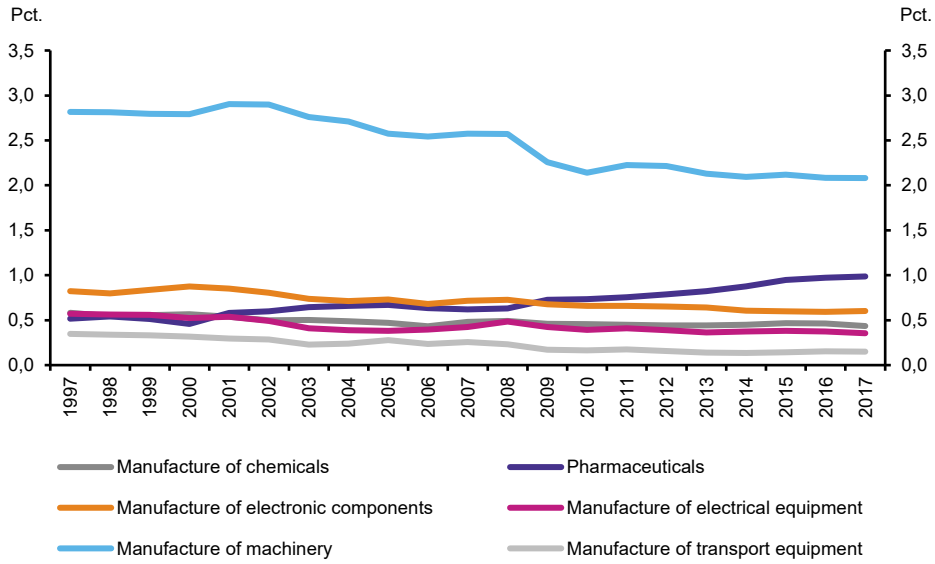


Notes: "High and medium high-technology manufacturing" is derived from the NACE codes at 2-digit level. Please refer to the appendix for a definition of the included industries.

Source: Eurostat - technology and knowledge-intensive sectors

Approximately two percent of the Danish labour force is employed within the manufacture of machinery, which is the largest high technology industry in Denmark measured as the share of total employment, cf. figure below. Over the last twenty years employment within the manufacture of machinery has been declining while employment within the pharmaceutical industry has been rising.

Figure 7: The share of total employment in high and medium-high technology manufacturing in Denmark, pct., 1997-2017



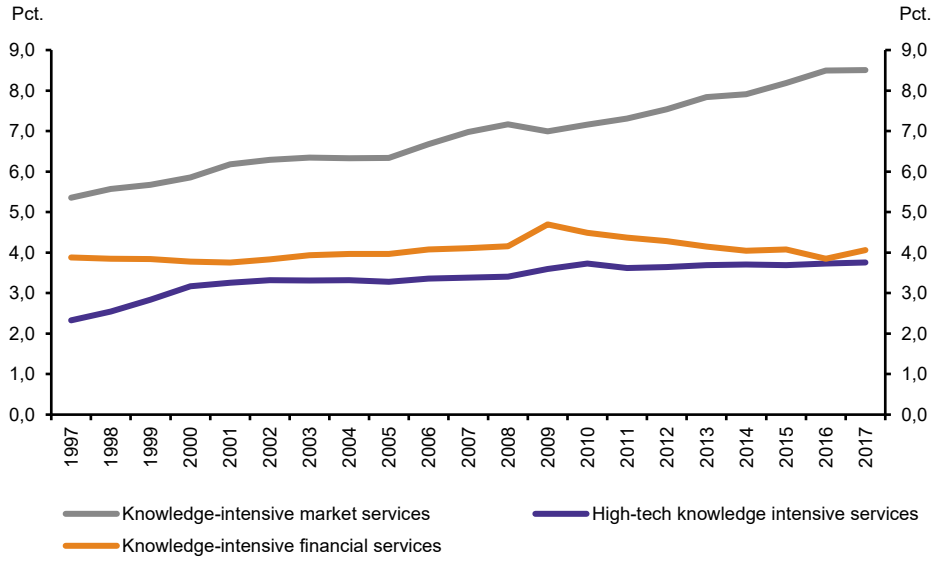
Note: *"High and medium high-technology manufacturing"* is derived from the NACE codes at 2-digit level. *Please refer to the appendix for a definition of the included industries.*

Source: The Danish National Account and Eurostat

Over the last twenty years employment within in the knowledge intensive market services has been increasing in Denmark and in 2017 it constitutes almost nine percent of total employment, cf. figure below.

The employment level within knowledge intensive financial services have been more or less stable around 4 percent in the period from 1997 to 2017. Employment within high-tech knowledge intensive services have increased from around 2 percent in 1997 to just less than 4 percent in 2017.

Figure 8: The share of total employment in knowledge intensive services in Denmark, pct., 1997-2017



Note: "Knowledge intensive services" is derived from the NACE codes at 2-digit level. Please refer to the appendix for a definition of the included industries.

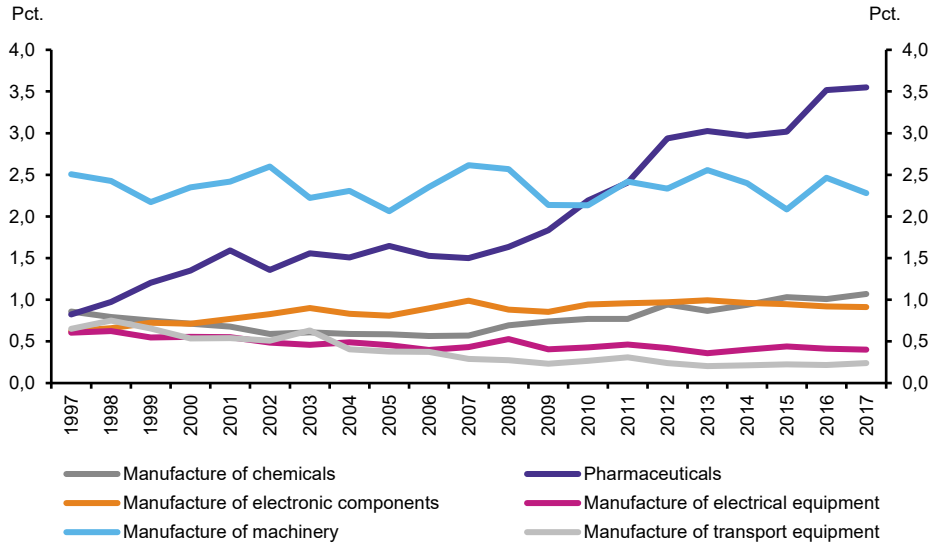
Source: The Danish National Account and Eurostat

2.2 Gross value added in knowledge intense industries

Focusing on gross value added (GVA) from high and medium-high technology manufacturing it is clear that pharmaceutical industry have increased its share of GVA in the economy, whereas the other industries have slightly fallen or remained at the same level. Particularly from 2008 the pharmaceutical industry have increased its share of GVA, cf. Figure 9.

Following the pharmaceutical industry the manufacturing of machinery comprises the second largest share of GVA in 2017 with nearly 2.5 percent. The share of GVA comprised from manufacturing of machinery has been somewhat stable from 1997 to 2017 between 2 percent and 2.5 percent.

Figure 9: The share of total value added of high and medium-high technology manufacturing, pct., 1997-2017



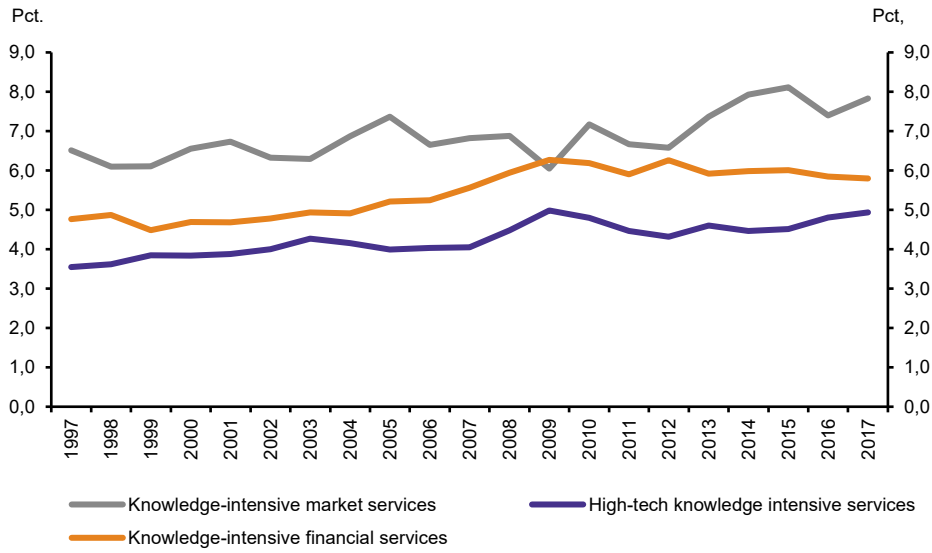
Note: *"High and medium high-technology manufacturing"* is derived from the NACE codes at 2-digit level. *Please refer to the appendix for a definition of the included industries.*

Source: The Danish National Account and Eurostat

Looking at knowledge intensive services, market services compromises the largest share of GVA over time. In 2017 the market services industry constitutes almost 8 percent of the total GVA, cf. Figure 10.

The GVA stemming from both financial services and high-tech knowledge intensive services have also increased from 1997 to 2017 and constitutes 6 percent and 5 percent of total GVA in 2017, respectively.

Figure 10 The share of total value added from knowledge intensive services, pct., 1997-2017



Note: *"Knowledge intensive services"* is derived from the NACE codes at 2-digit level*. Please refer to the appendix for a definition of the included industries.*

Source: The Danish National Account and Eurostat

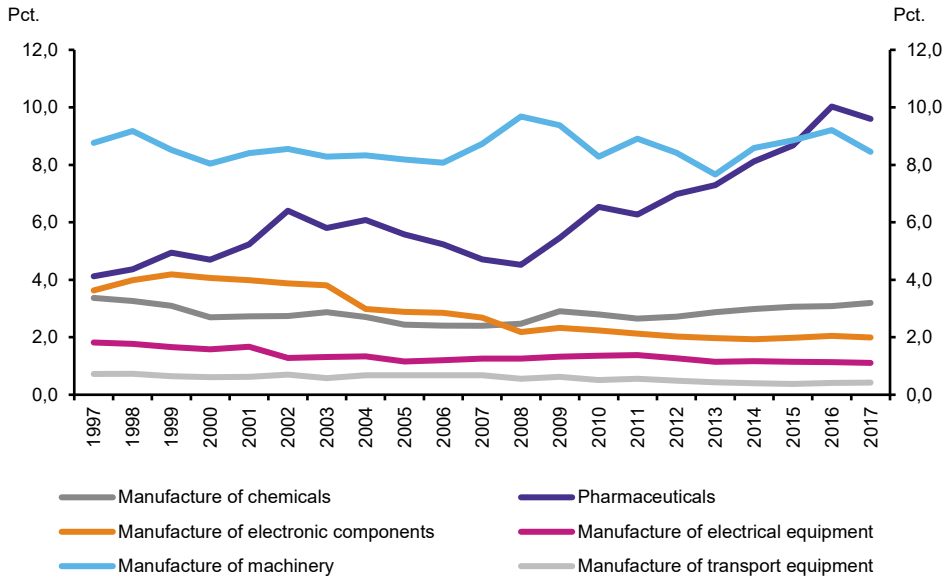
2.3 Exports in knowledge intense industries

Since the financial crisis in 2008 the exports from pharmaceutical industry have increased from approximately 4.5 pct. to 9.5 pct. of total exports, cf. Figure 11. Exports from the pharmaceutical industry rose particularly from 2008 to 2016 before dropping slightly in 2017.

The second largest exports of high and medium-high technology manufacturing in Denmark is the manufacture of machinery, which constituted around 8 percent of total export in 2017.

The share of exports has been relative stable for most of the other manufacturing industries since 2017. However the share of exports from the manufacture of electronic components have halved since the start of the 2000's.

Figure 11: The share of total exports from high and medium-high technology manufacturing, pct., 1997-2017



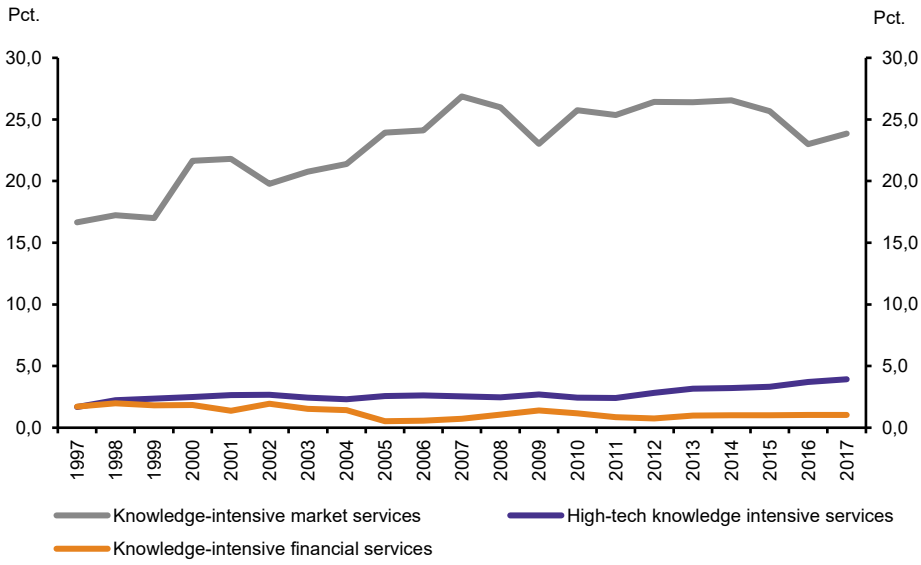
Note: *"High and medium high-technology manufacturing"* is derived from the NACE codes at 2-digit level. *Please refer to the appendix for a definition of the included industries.*

Source: The Danish National Account and Eurostat

The share of total exports from market services compromises almost 25 percent of the total Danish exports, cf. Figure 12. The share of export from this industry has been steadily increasing in the period from 1997 to 2017. This is almost entirely derived from the large shipping industry in Denmark, as water transport compromises around 1/5 of total Danish exports.

Exports from financial services and high-tech knowledge services constitute a much smaller share of the Danish exports. The high-tech knowledge intensive services constitute almost 5 percent of the total export whereas the financial services only constitutes around 2 percent.

Figure 12: The share of total exports from knowledge intensive services, pct., 1997-2017



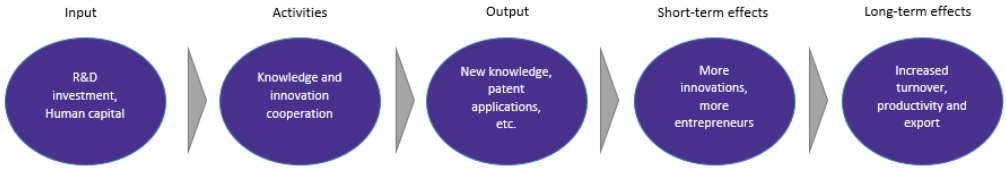
Note: *"Knowledge intensive services"* is derived from the NACE codes at 2-digit level*. Please refer to the appendix for a definition of the included industries.*

Source: The Danish National Account and Eurostat

3 CENTRAL INDICATORS

The analysis is structured around an innovation process approach: *input, activities, output and effects*. On the input side we have government and private firm activities to increase knowledge base (mainly R&D investment and education). The input supports activities such as knowledge and innovation cooperation, which in turn leads to new products and processes, entrepreneurship, and cooperation in the short run and ultimately to productivity improvement and economic growth in the long run. **Error! Reference source not found.**3 presents the highly simplified process of innovation.

Figure 13: Innovation process



Source: UFM (2018)

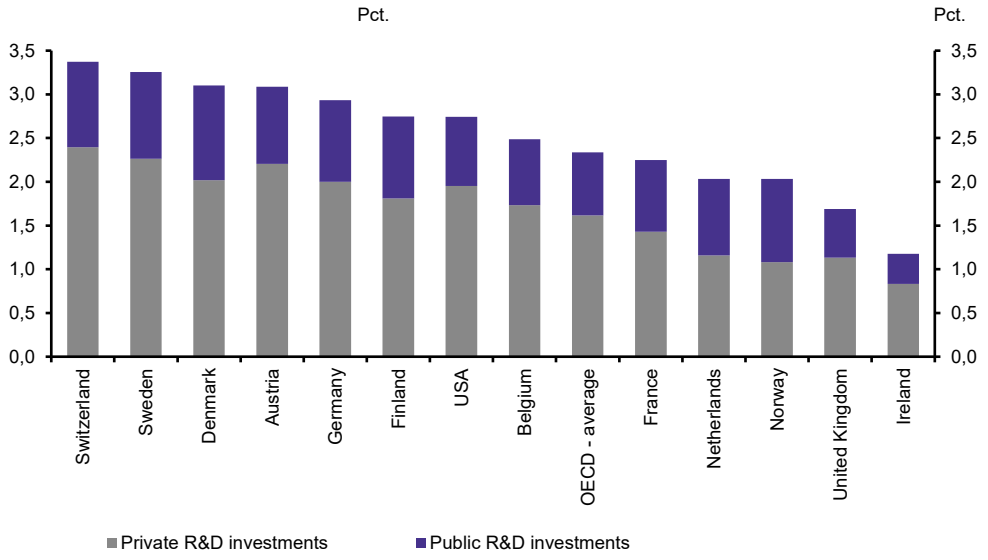
It is tempting to look at the innovation process as an organizational model. The actors associated with research, development and innovation could be mapped out along the process. On the input side, the government plays a fundamental role, but the government also plays a role at later stages in terms of framework conditions for private firms. Innovation mainly occurs in private and public firms, as do short- and long-term effects.

Private firms also contribute input, mainly in the form of development, and, to a lesser extent, with research. The measurement of effects in the public sector is not sufficiently advanced in the statistics, so it is not part of the analysis. Therefore, only private sector innovation behaviour is covered below.

3.1 Innovation input

In 2016, total R&D investments in Denmark accounted for approximately 66 billion DKK, which is equivalent to 3.2 percent of GDP and is one of the highest among similar countries, cf. Figure 1414.

Figure 14: Total R&D investments in the public and private sectors, pct., 2016



Note: Data for Switzerland is from 2015. Pct. of GDP.

Source: OECD (2018), "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database), "BERD as a percentage of GDP", "GERD as a percentage of GDP" and Statistics Denmark

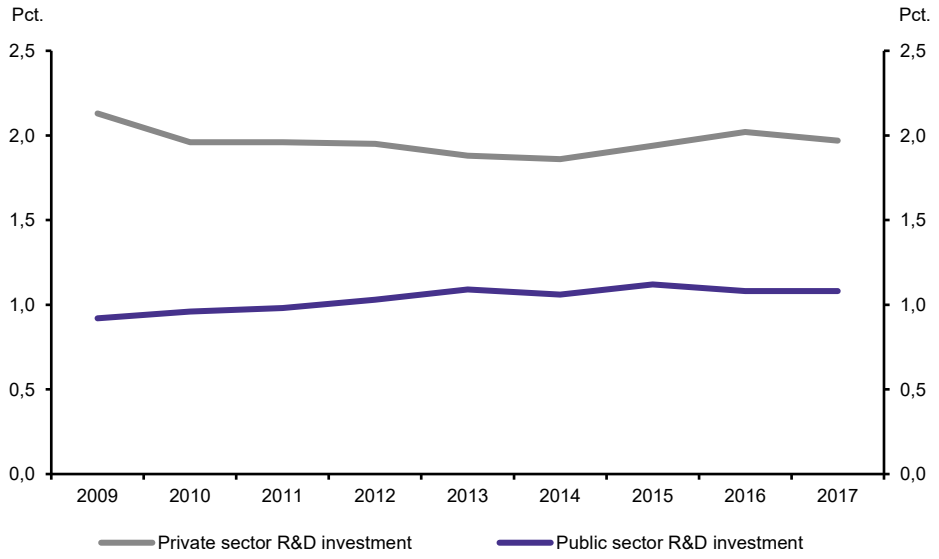
The R&D investments, by percent of GDP, in Sweden and Switzerland are slightly higher than that in Denmark, which is mostly due to higher private R&D investments in these countries.

Denmark has the highest level of public R&D investments among the OECD countries, which is equivalent to 1.1 percent of GDP. Denmark has a target of spending 1 percent of GDP on public R&D investment. On top of government R&D investments, regional and EU R&D investments are allocated under the target. The 1 percent and the regional and EU funds have implications for the government budget.

Denmark has increased public R&D investment over the last decade. Over the last 8 years, public R&D investments have risen from 0.9 percent of GDP to 1.1 percent of GDP in Denmark. There is no clear consensus about the consequences of overachieving the target. At the moment, there is a potential for cutting back public R&D investment.

In private R&D, investments have not risen at the same rate, which is partly due to the financial crisis in 2008 that led to a decrease in business R&D investments. Over the last few years, private R&D investments have been rising again and have risen from 1.8 percent of GDP in 2014 to 2 percent of GDP in 2017, cf. **Error! Reference source not found.**.

Figure 15: Business enterprise and public R&D investment, pct. of GDP, 2009-2017

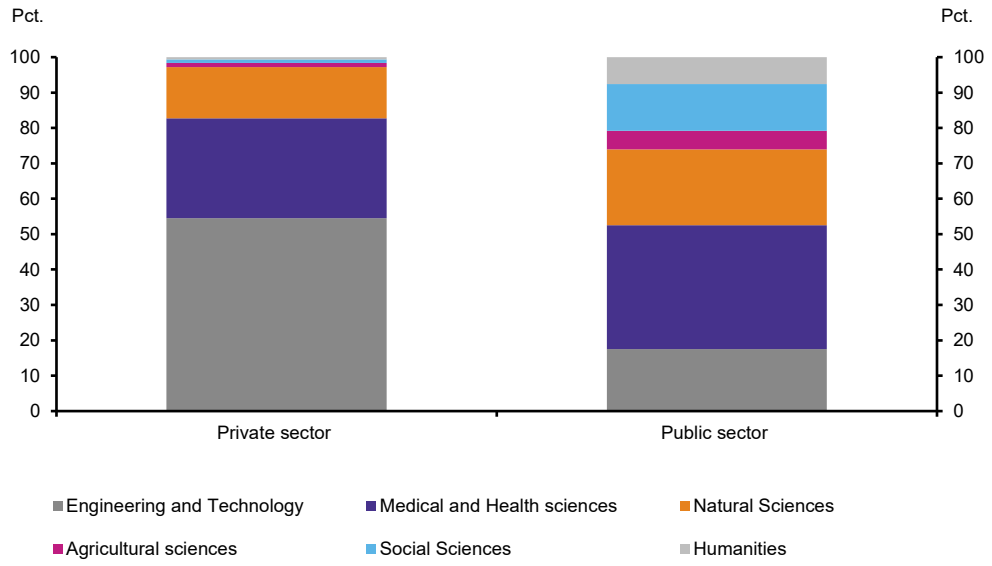


Source: Statistic Denmark

The private sector and the public sector prioritize R&D expenditures different, cf. Figure 4. Approximately 54 percent of the private R&D expenditure is performed within engineering and technology followed by medical and health sciences that account for nearly 30 percent of the private R&D expenditures. Private R&D expenditures within agricultural sciences, social sciences and humanities only account for approximately 3 percent of the total private R&D expenditure.

The public R&D investments are more equally spread across the different field of sciences, where the largest is medical and health sciences, which account for 35 percent of the public expenditure. R&D expenditures within natural sciences and engineering and technology account for 21 and 18 percent of the total R&D expenditure, respectively.

Figure 16: R&D expenditure in the public and private sector by field of science, 2017, pct.



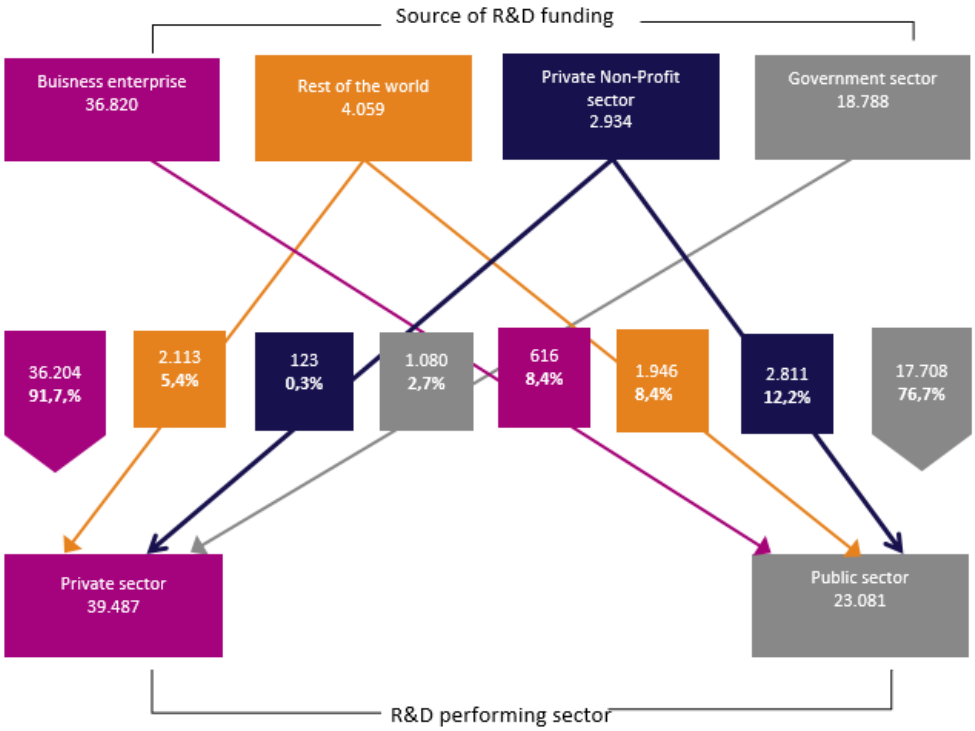
Note: The total R&D expenditure in the private sector in 2017 is 42.8 billion kr. and 23.5 billion kr. In the public sector. The R&D expenditure in the public and private sector for 2017 is preliminary.

Source: Statistics Denmark

The majority of the R&D performed in the public and private sector is financed by the sector itself, cf. **Error! Reference source not found.**17. For instance, in the public sector, R&D was performed for a total value of 23 billion DKK in 2016. Of this amount, 17.7 billion was financed by the government sector, which is equivalent to 77 percent.

The same pattern exists in the private sector, where companies themselves financed approximately 36 billion DKK of the total 39 billion DKK for which they performed R&D. In 2016, the government sector financed R&D activities worth approximately a billion DKK in the private sector.

Figure 17: Flow of funds from research funding sectors to research performing sectors, Denmark, 2016



Note: The percentages on the arrow describe how large a share the given research funding sector constitutes of the R&D performing sector. The percentages add up to 100 percent for each of the two R&D performing sectors. The calculation is based on preliminary data from 2016 for public R&D investments and data for 2015 for the business enterprise sector.

Source: Statistics Denmark

Innovation is more than investment in R&D. On the private side, we know very little about how much firms spends on non-R&D innovation activities. On the public side, the exact numbers do not exist either, but the Figure below illustrates the distribution of funds in the public research budget, which is target towards activities with a primary focus on either research or innovation.

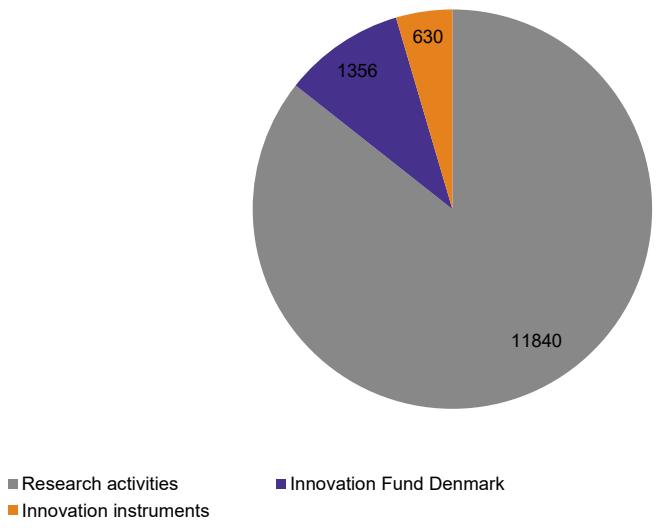
The Figure only accounts for activities organized within the Ministry of Higher Education and Science and are therefore not a complete picture of the public funds going towards innovation activities. In this respect, it is important to emphasize a lot of the activities are targeted private R&D.

In the research budget for 2018 approximately 2 billion DKK are allocated to activities that have a primary focus on innovation activities. The research funding organization Innovation Fund Denmark has a budget in 2018 around 1.4 billion DKK. The organization fund a variety of instruments with a primary focus on increasing the research and innovation activity among private companies.

Besides the Innovation Fund Denmark, funds are allocated to the innovation networks, innovation clusters and the RTO's (GTS-institutes). In the budget for 2018 a total of 630 million DKK are allocated to these three instruments.

The remaining funds on the public research budget is primarily targeted towards activities that focus on public research. The biggest funding is to the universities, that receive nearly 9 billion DKK in basic research funding.

Figure 18: Distribution of research and innovation funds in the public research budget for the Ministry of Higher Education and Science, 2018, million DKK.



Note: The Innovation instrument cover funds to the Innovation Networks (79 million DKK), Innovation clusters (224 million DKK) and RTO's (327 million DKK). Research activities covers a variety of funding such as basic research funding for the universities (8.902 million DKK) and research funding organisations (1.673 million DKK) as well as international instruments such as CERN and ESA (431 million DKK).

Source: Ministry of Higher Education and Science

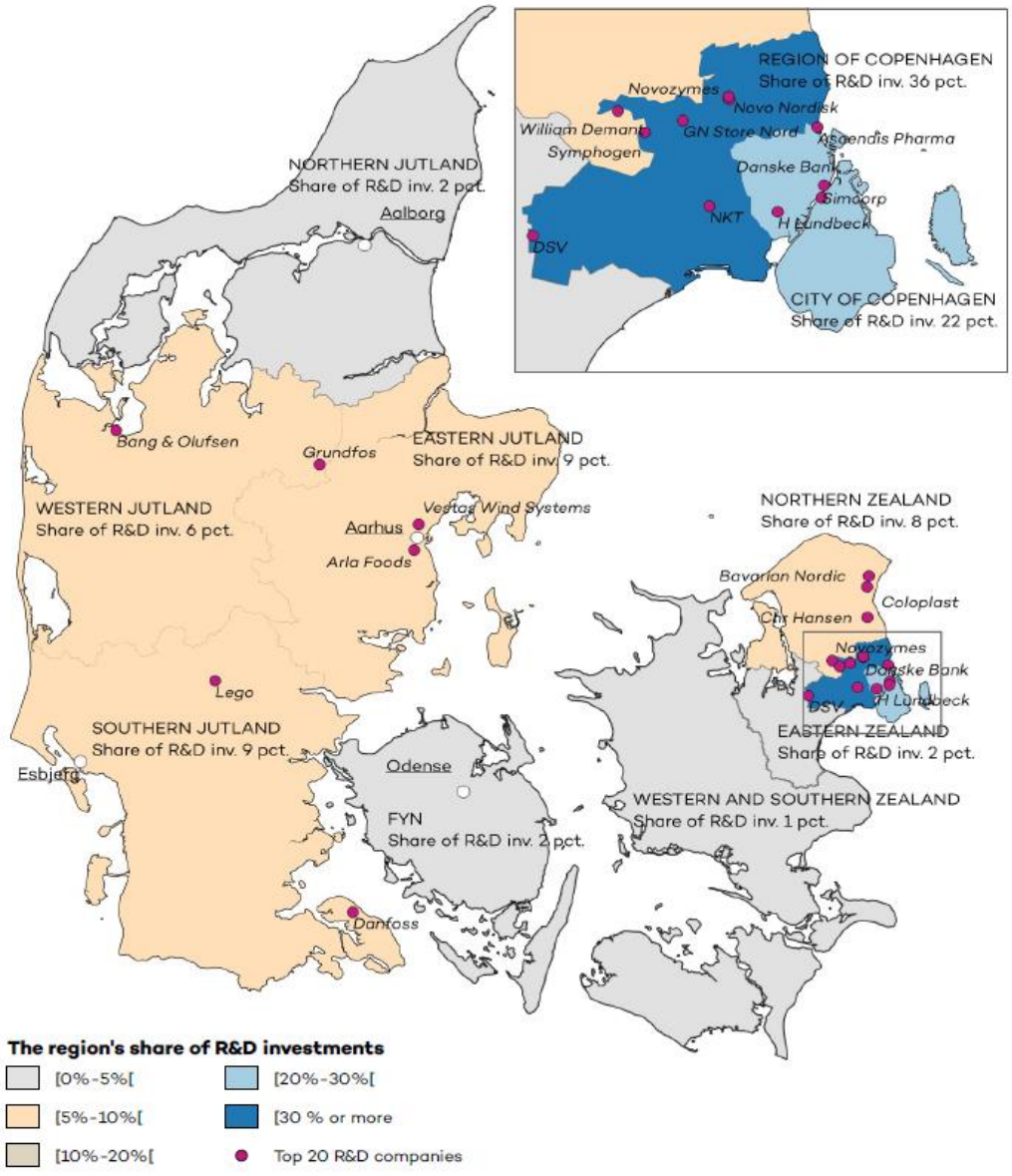
It's important to note that there is a variety of instruments aimed towards the innovation activities of private companies that are not included in the Figure above since it only includes instrument organized under the Ministry of Higher Education and Research.

Other ministries spend almost 3 billion DKK on instruments targeted towards innovation activities, where the Development and Demonstration programmes (UDP) are the most important. Additionally there is a range of tax support for business R&D in Denmark, that encourage companies to invest more in R&D activities.

3.1.1 Private R&D investment x

The majority of Danish private R&D investments are concentrated in and around the capital, Copenhagen, cf. **Error! Reference source not found.**19. Enterprises located in the Copenhagen area accounted for more than 50 percent of the total private R&D in 2016.

Figure 19: Regional distribution of private R&D investment, 2016



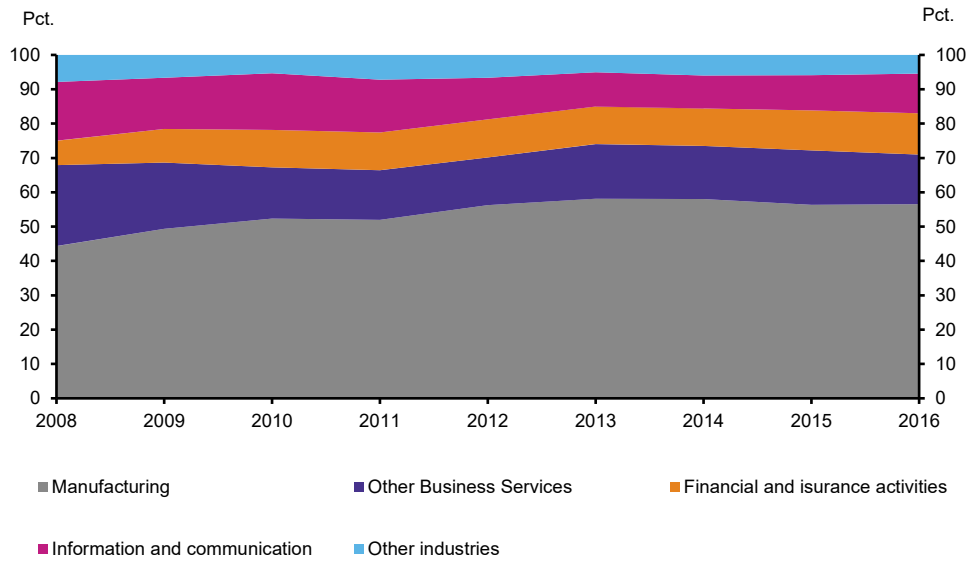
Note: The distribution of private R&D investments in the provinces is based on data from Denmark Statistics. The geographic location of the enterprises is based on the location of their headquarters. Data for the 20 largest R&D companies is based on data from the EU Industrial R&D Investment Scoreboard 2016/2017.

Source: Calculations based on data from Statistics Denmark and EU Commission EU Industrial R&D Investment Scoreboard.

The remaining private R&D investments are primarily located in the provinces of northern Zealand, south, west and east Jutland. There is a low level of private R&D investment in the remaining provinces, such as northern Jutland and western and southern Zealand, that each make up less than 2 percent of the total private R&D investments.

Enterprises within the manufacturing industry perform the majority of private R&D investments. Their share of the total private R&D investments increased by 12 percentage points from 2008 to 2016.

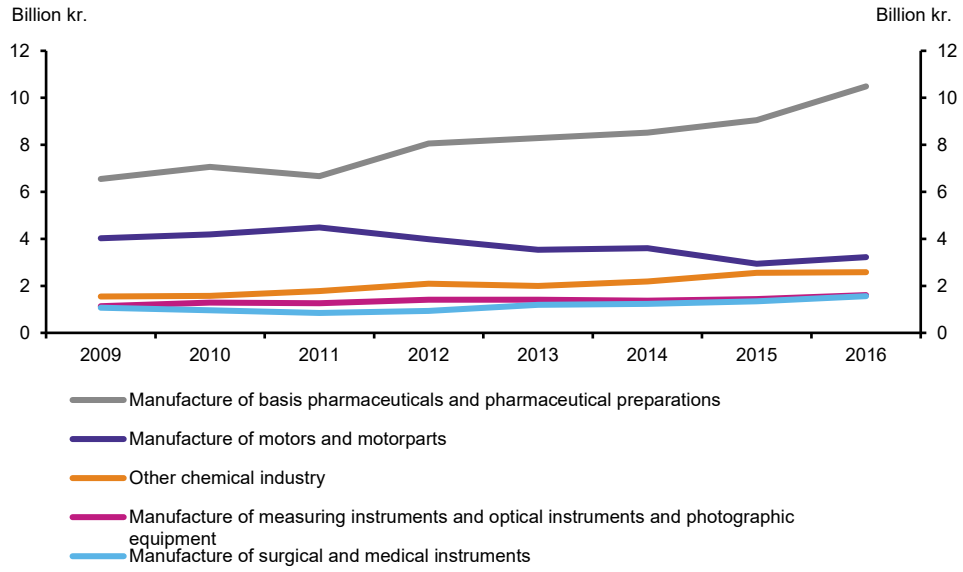
Figure 20: Private R&D expenditure by industry, 2008-2016.



Source: Statistics Denmark

The R&D expenditures for companies within the manufacturing industry are highly concentrated among enterprises engaged in the manufacturing of basic pharmaceuticals and pharmaceutical preparations, cf. Figure 21. These enterprises have increased their R&D investments from approximately 6 billion DKK in 2008 to 10.5 billion DKK in 2016. R&D investments from enterprises engaged in the manufacturing of basic pharmaceuticals and pharmaceutical preparations constitute 43 percent of the total R&D investments for enterprises in the manufacturing industry.

Figure 21: Private R&D expenditure by subindustries within manufacturing, 2009-2016

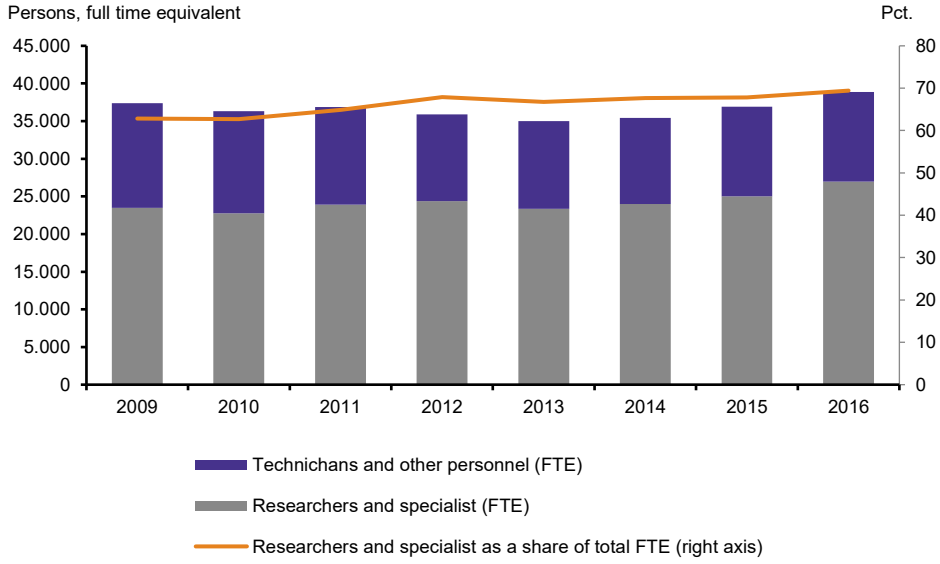


Note: The figure only contains the five subindustries within manufacturing with the largest R&D expenditure.

Source.: Statistics Denmark

In 2016, the private sector employed nearly 39.000 in full time positions (FTE) within R&D activities, cf. Figure 22. Researchers and specialist constitute 69 percent of the total R&D personal in the private sector. In the period from 2008 to 2016, the private sector have employed fewer technicians and instead increased the number of researchers and specialist among the R&D personal. Since 2008, there has been an increase of researchers and specialist employed in the private sector from 23.000 FTEs to nearly 27.000 FTEs.

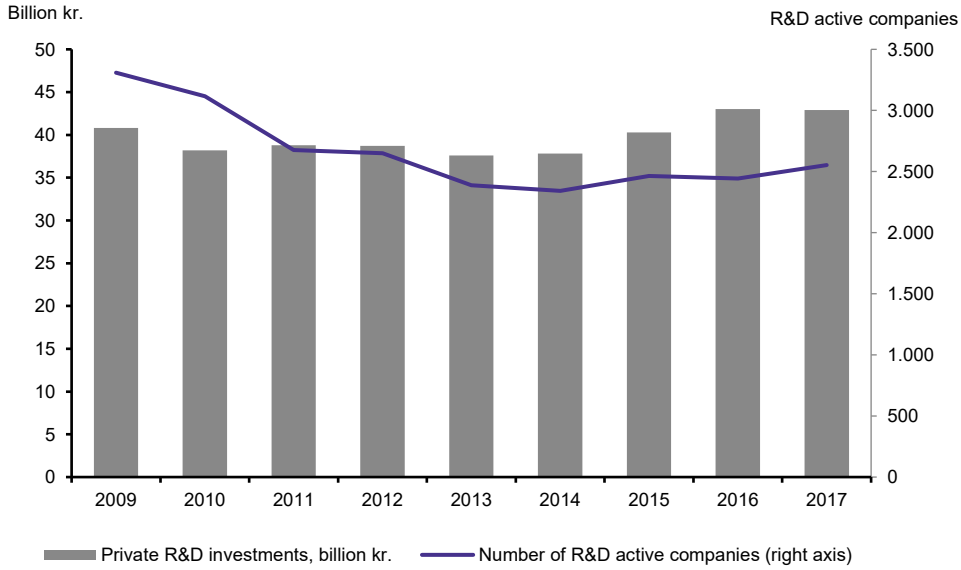
Figure 22: R&D personal in private sector by occupation and researchers as a share of total R&D personal, FTE and pct., 2009-2016



Source: Statistics Denmark.

In the years following the financial crisis the number of R&D active companies have declined in Denmark, cf. Figure 23. The number of R&D active companies have decreased by nearly one quarter from 3.300 companies in 2009 to 2.400 in 2013. Since then there has been a small increase in R&D active companies in 2017 to approximately 2.550, however the level of R&D active companies are still below the period before the financial crisis.

Figure 23: Private R&D investments, billion kr. number of R&D companies, 2009-2017.

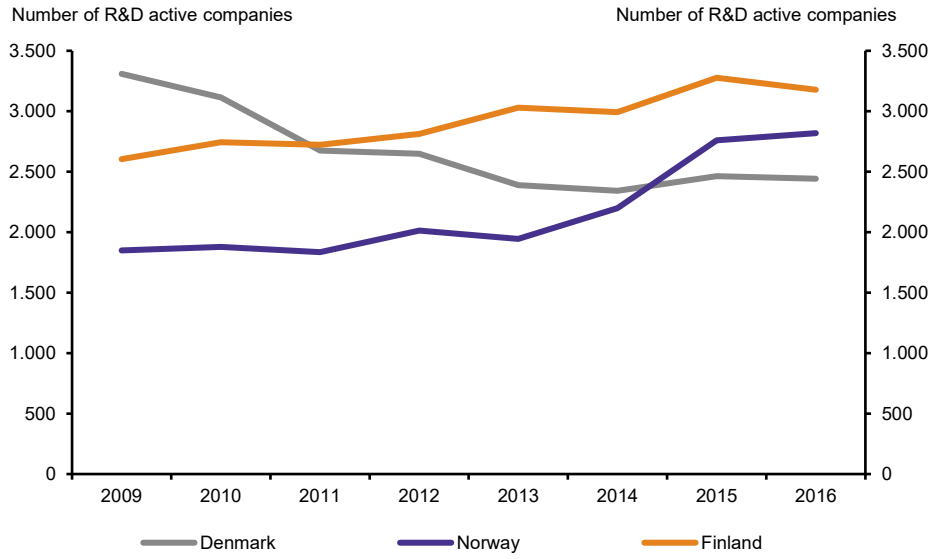


Note: Private R&D investments have been converted from regular to fixed prices using the Statistics Denmark's deflator.

Source: Ministry of Higher Education and Science based on data from Statistics Denmark.

A comparison with Norway and Finland shows a significantly different development in the number of R&D active companies in these countries, cf. Figure 24. These two countries have not experienced a similar decrease in the number of R&D active companies and both countries have more R&D-active companies than Denmark.

Figure 24: Number of R&D active companies, Denmark, Norway and Finland, 2009-2016

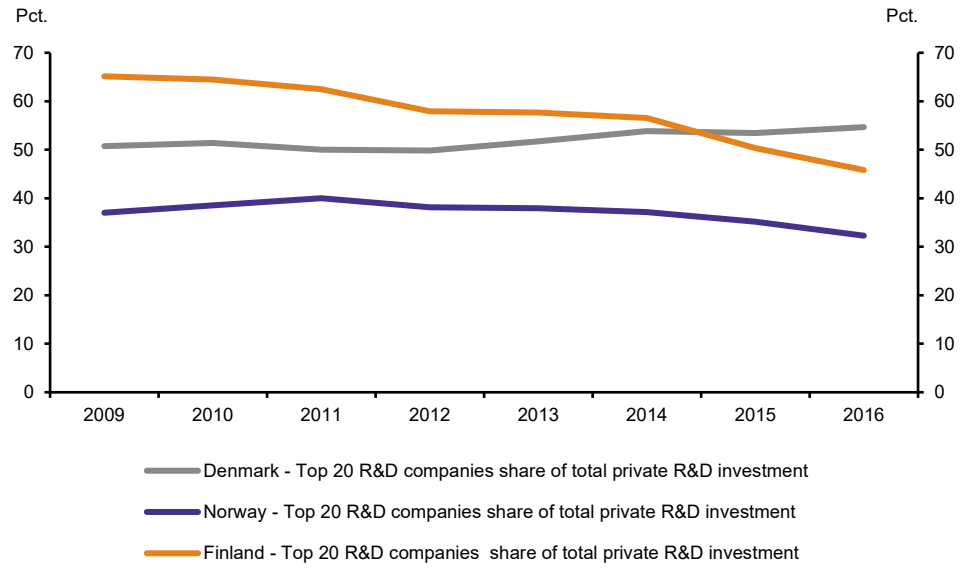


Note: Top 20 companies are measured each year as the 20 companies with the largest R&D investment.

Source: Statistics Denmark

In addition to the decrease in the number of R&D active companies in Denmark, there has been a concentration of R&D expenditure on fewer companies, cf. Figure 25. Since 2009 the 20 largest R&D companies have increased their share of the total private R&D investments in Denmark and constitute 55 percent of the total private R&D investment in 2016. The R&D investments of the 20 largest companies in Finland and Norway constitute 32 percent and 46 percent of the countries' total private R&D investments, respectively.

Figure 25: The 20 largest R&D companies share of total private R&D investment, percent., 2009-2016



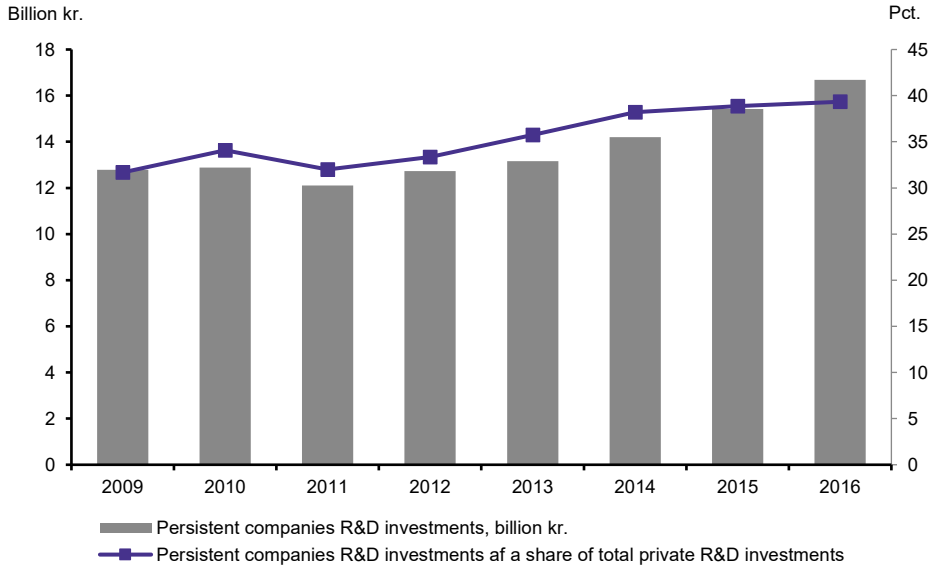
Note: The 20 largest R&D active companies are measured by their R&D investments.

Source:Statistics Denmark

A few large companies primarily drive the concentration of private R&D expenditures in Denmark. In the period from 2009 to 2016 eight large R&D active companies have increased their R&D expenditures by 30 percent from 12.9 to 16.9 billion kr. (2017 prices), cf. Figure 14.

In 2009, the eight large R&D companies accounted for approximately 32 percent of the total private R&D expenditures while they in 2016 accounted for 39 percent.

Figure 26: 8 persistent companies R&D investments and their share of total private R&D investment, billion kr. Percent, 2009-2016.



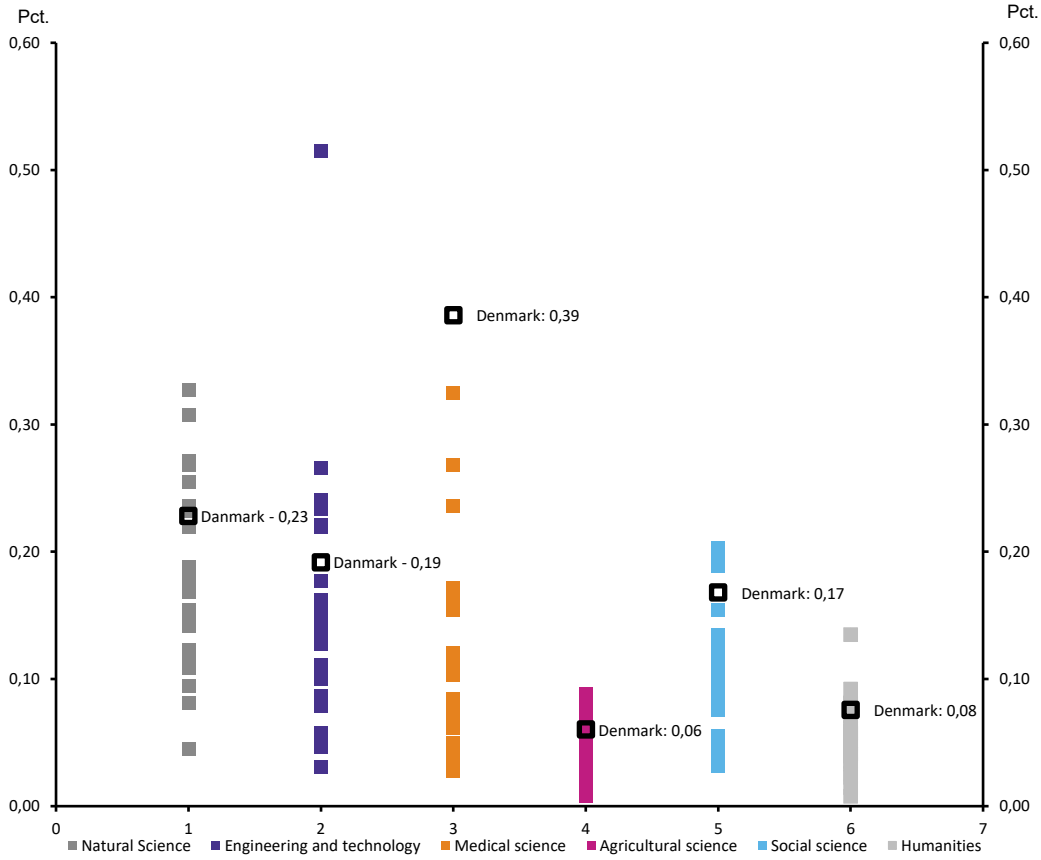
Note: Private R&D investments have been converted from regular to fixed prices using the Statistics Denmark's deflator.

Source: Ministry of Higher Education and Science based on data from Statistics Denmark

3.1.2 Public investment in R&D

A large share of public R&D investments are spent on research conducted within the medical and health sciences, where Denmark also has the highest level of R&D expenditure among the OECD countries by percent of GDP.

Figure 27: Gross domestic expenditure on R&D for the public sector by scientific field, pct., OECD, 2016.



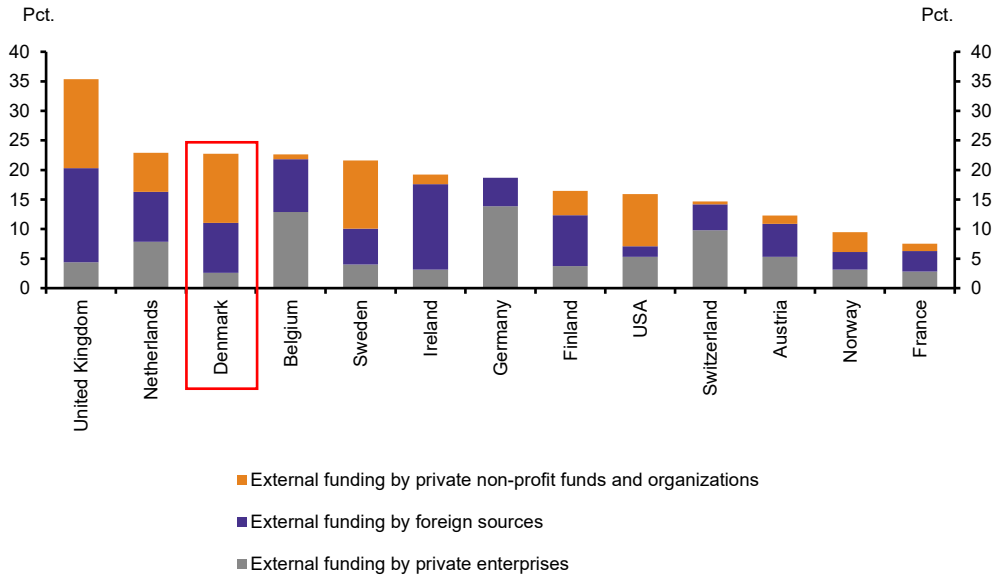
Note:Data are from 2016 or the most recent available year. Data are not available for Canada, France, Mexico, New Zealand, the USA and Australia. R&D investments include all research performed by public institutions, regardless of the source of the funding. Pct. of GDP.

Source: OECD - "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database).

Public research investments in the field of health and medical sciences have increased by nearly 3 million DKK over the last 8 years, corresponding to a 48 percent increase.

Approximately 12 percent of research conducted at Danish higher education institutions is financed by private non-profit funds and organizations, which is one of the highest levels among the OECD countries.

Figure 28: External funding of higher education institutions, pct., 2016



Note: Data are from 2016 or the most recent available year and include university hospitals. Data are not available for Australia. Pct. of total funding.

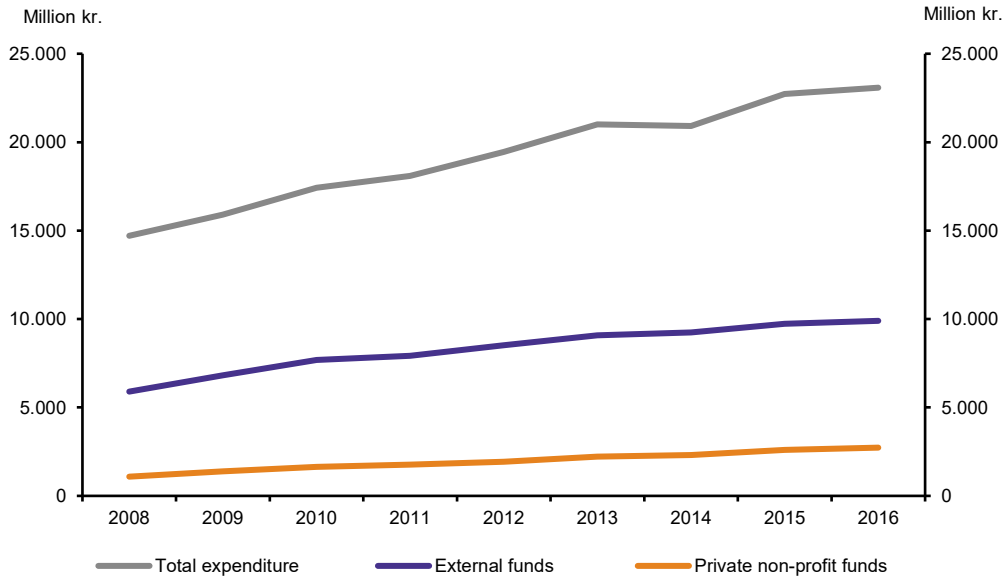
Source: OECD (2018), OECD Science, Technology and R&D Statistics (database), "Gross domestic expenditure on R&D by sector of performance and source of funds" and Statistics Denmark.

In terms of external funding from private enterprises, Denmark is at the lower end of the spectrum in comparison with the OECD countries. In this regard, it should be noted that private companies, in a number of cases, are owned by private non-profit funds in Denmark and that higher education institutions indirectly receive a great deal of funding that was originally derived from business through non-profit funds.

The majority of external funding from foreign sources in Denmark originates from the European Union Horizon 2020 framework programme.

External funds from private non-profit funds and organizations in Denmark rose from 1.1 billion DKK to 2.7 billion DKK from 2008 to 2016 (cf. **Error! Reference source not found.**29), which corresponds to an annual increase of 14.0 percent. In general, external funding increased from 5.9 billion DKK to 9.9 billion DKK, corresponding to an annual increase of 7.7 percent.

Figure 29: Selected sources of public research funding, 2008-2016

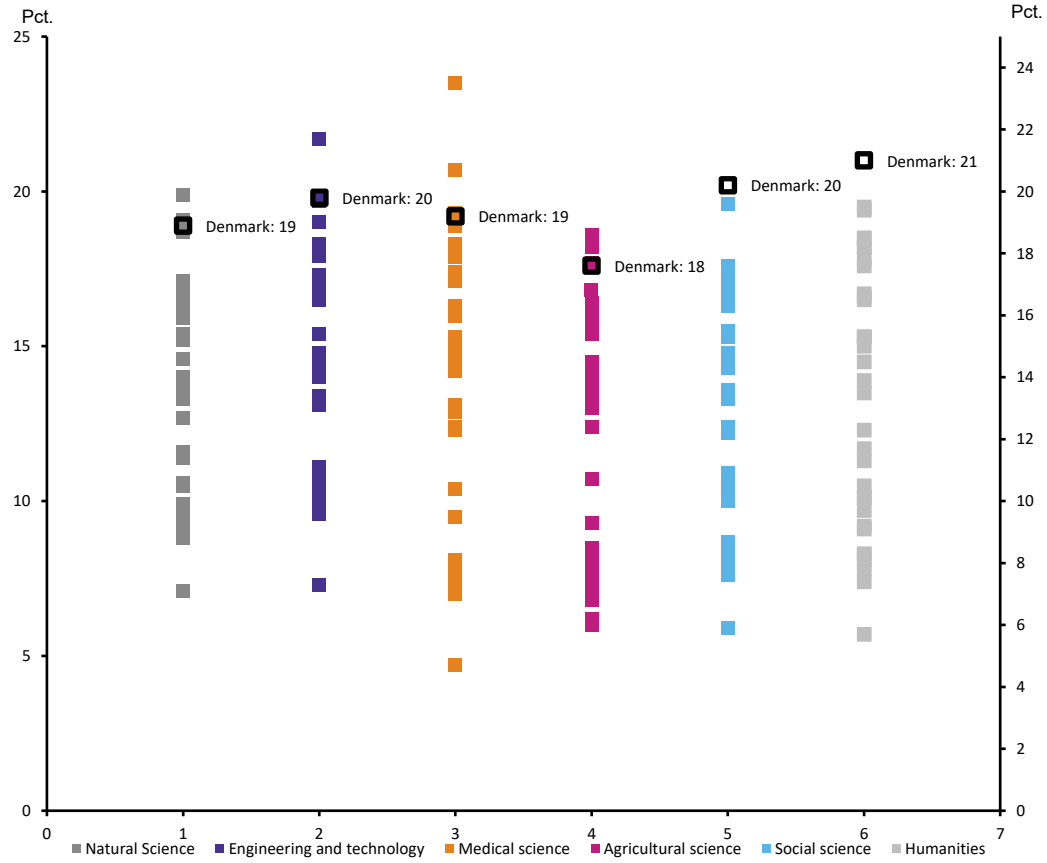


Source:Statistics Denmark and own calculations

Health and medical sciences received more than 50 percent of the private non-profit funds in 2016.

Danish research in general has a high scientific impact, as measured by the percentage of publications among the 10 percent of the most cited scientific publications worldwide, cf. **Error! Reference source not found.**30.

Figure 30: Share of 10 percent of the most cited publications distributed by scientific field, OECD, 2013-2017



Note: The indicator measures the proportion of publications with one or more authors from Danish institutions, which are among the top 10 percent most cited publications in the world. The indicator is field-weighted and self-quotations are included. Types of publications: articles, reviews and conference contributions.

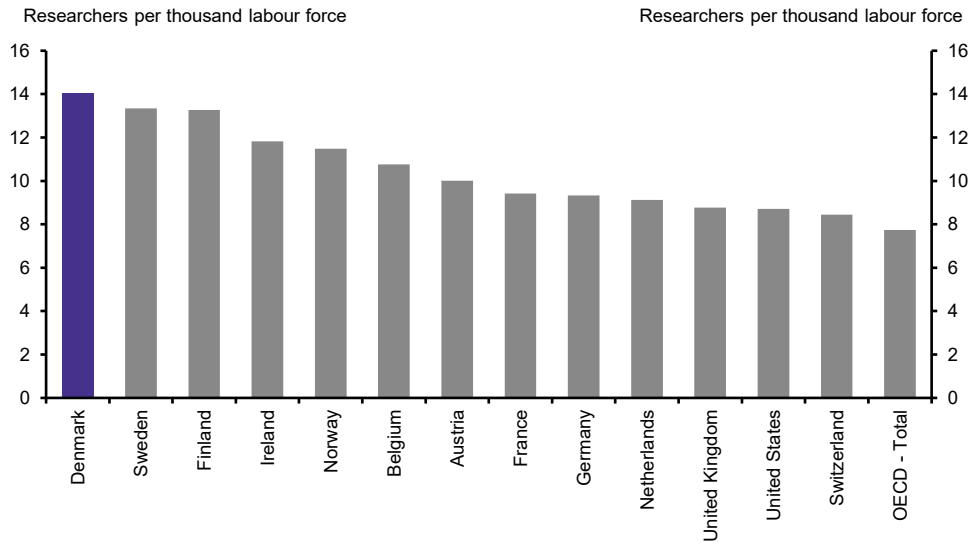
Source: Scival, Elsevier B. V. (2018). Scival is based on Scopus data

Approximately 19 percent of Danish publications within the medical sciences are among the top ten percent of the most cited publications worldwide, which is due in part to the strong Danish research profile within clinical medicine.

In addition, Denmark has the highest proportion of publications within the humanities among the top ten percent most cited publications in comparison with the OECD countries.

Denmark has the highest level of researchers per thousand members of the labour force among the OECD countries, cf. **Error! Reference source not found.**31. The other Nordic countries, such as Sweden and Finland, also have a high level of researchers in the labour force.

Figure 31: Researchers per thousand members of the labour force, 2016.



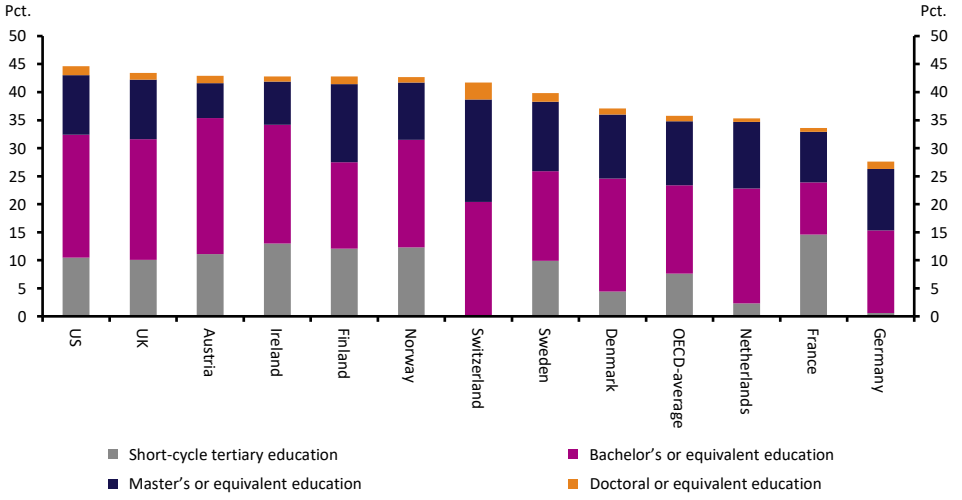
Note: Data for the USA, Switzerland and France are from 2015.

Source: OECD Science, Technology and R&D Statistics (database) "Main Science and Technology Indicators"

3.1.3 Human capital

The share of 25-64 year olds with a tertiary education was 39 percent in 2017 in Denmark. This percentage is very close to the OECD average but below that of a number of countries, including Nordic countries. In general, the education system has a large cultural component, and cross-country comparisons, such as the one in **Error! Reference source not found.**32, can be difficult. For example, some countries have a well-developed apprentice system, as in Germany.

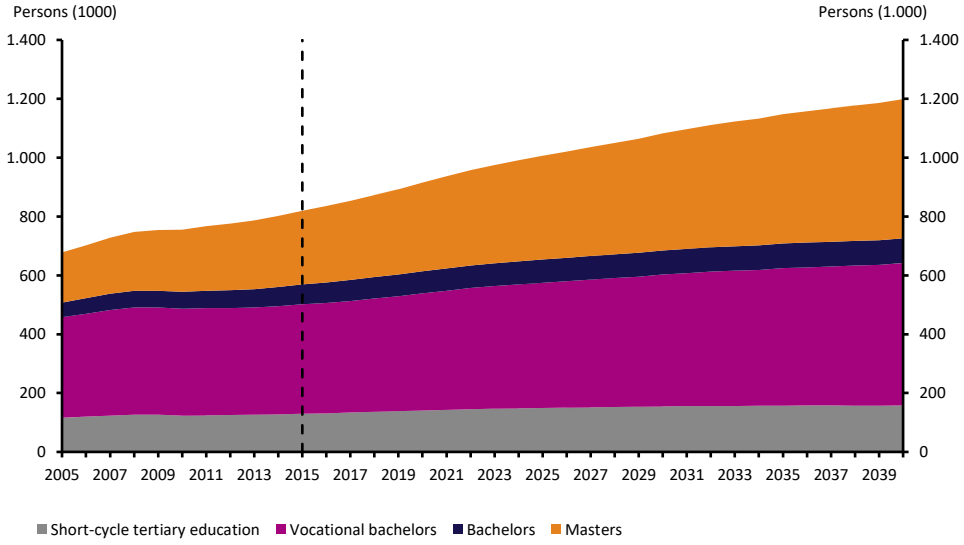
Figure 32: Education level, population, 25-64 year olds, pct., selected countries, 2017



Source: OECD's database, stats.oecd.org based on data from Labour Force Survey.

The number of persons with a tertiary education in the Danish labour market is expected to rise dramatically in the coming years from 800.000 persons in 2015 to 1.2 million in 2040. This is an increase of 50 percent.

Figure 33: Number of persons with a tertiary education in the Danish labour market, 2005 to 2040

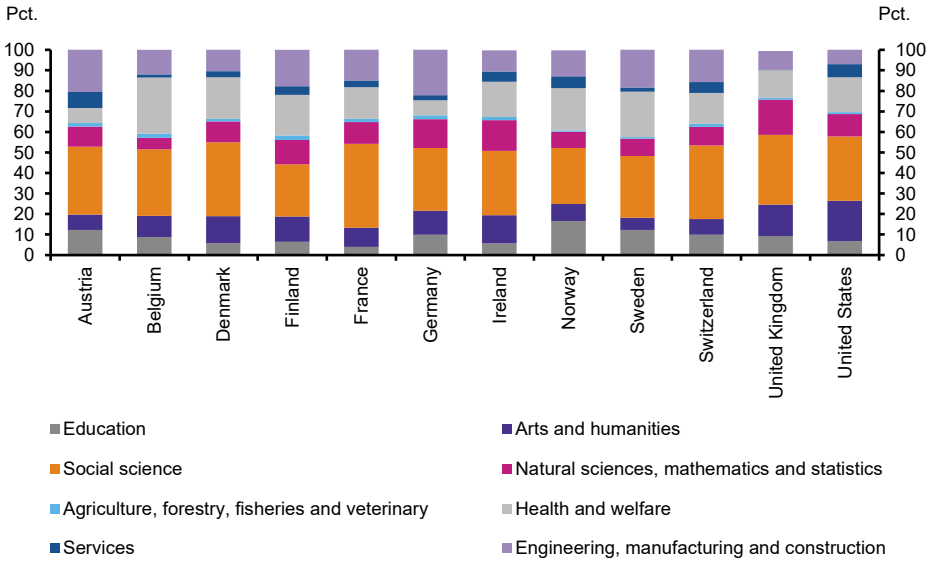


Note: 2005-2015 historical data. 2016-2040 is a projection.

Source: UFM (2017)

The distribution of graduates across the field of education in Denmark is close to the distribution in the comparison countries, cf. Figure 34. A cross-country comparison shows a diverse pattern. Denmark has a relatively high share of graduates within the social sciences and health and welfare and a low share of graduates within education and engineering, manufacturing and construction. However, a clear comparison is hindered by cross-country cultural and historical differences in education systems.

Figure 34: Fields of education, graduates, selected countries, percent, 2016



Note: Field of education is based on ISCED fields. Social sciences include business, administration and law, and natural sciences, mathematics and statistics includes Information and communication technologies.

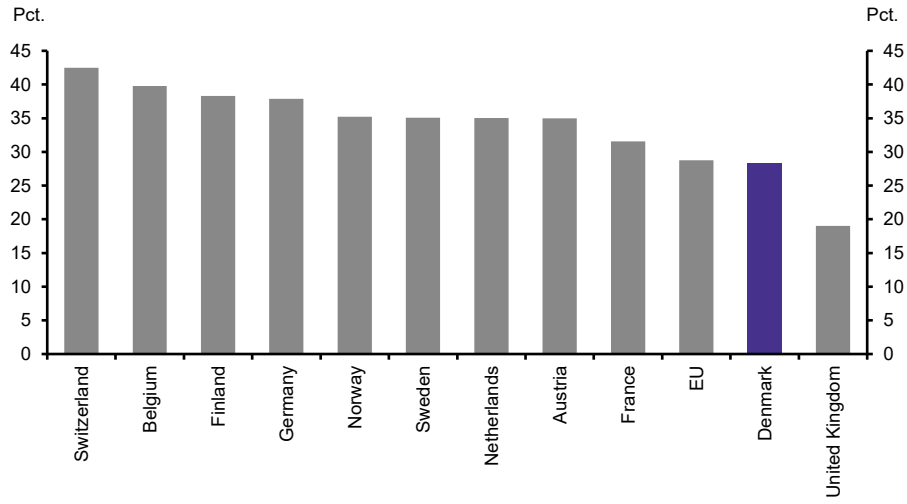
Source: OECD database. OECD.stats

3.2 Activities

Denmark has one of the lowest proportion of SMEs with in-house innovation among the comparable countries, cf. Figure 35. In-house innovating enterprises are defined as enterprises which have introduced product or process innovations either themselves or in co-operation with other enterprises or organisations.

In Denmark, 28 percent of the surveyed SMEs responded that they have in-house innovation, which is somewhat lower than, for example, in Finland, where 38 percent of the SMEs have in-house innovation.

Figure 35: SMEs innovating in-house, percentage of SMEs, 2014.



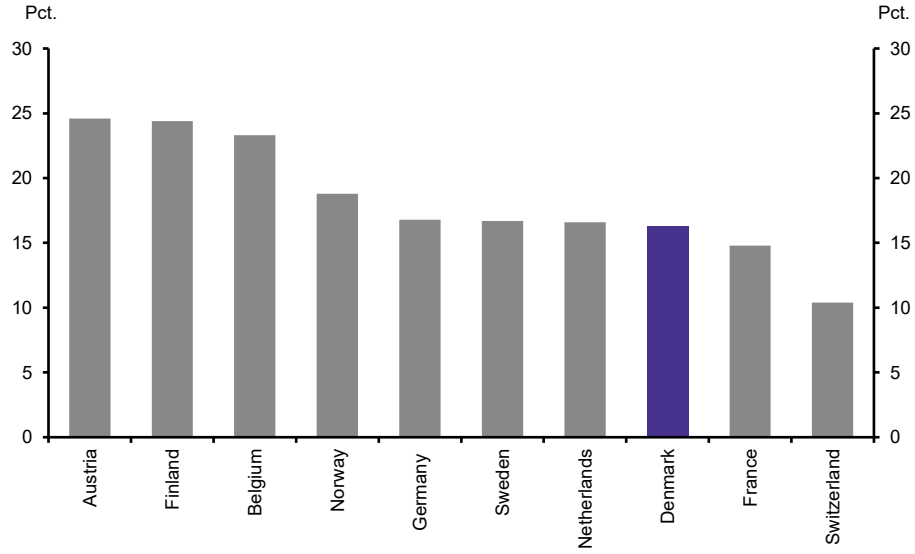
Note: SMEs are defined here as including all enterprises with 10 to 249 employees.

Source: Eurostat, Community Innovation Survey 2014

Denmark has a lower share of innovative companies cooperating with universities and other public research institutions than the majority of the comparison countries, cf. **Error! Reference source not found.**36. Approximately 16 percent of the innovative companies in Denmark cooperate with another research institution compared to 24 percent in Finland.

The level of cooperation between innovative companies and research institutions in Denmark is similar to other small research-intensive countries, such as the Netherlands and Sweden.

Figure 36: Innovative companies cooperating with universities, other higher education institutions, government, and public or private research institutes, 2014



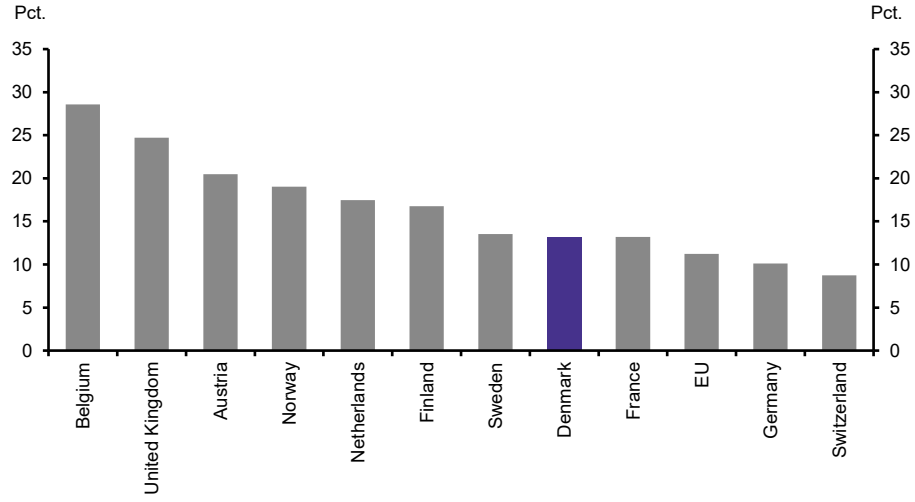
Note: Data are not available for the EU and the UK.

Source: Eurostat, Community Innovation Survey 2014

Denmark also has a lower share of innovative SMEs collaborating with others than the majority of the comparison countries, cf. Figure 37. Around 13 percent of the innovative SMEs in Denmark has collaborated with others compared to Belgium where 28 percent of the SMEs has collaborated with others.

The level of innovative SMEs collaborating in Denmark is similar to France and Sweden and are above the average for the EU 28 countries.

Figure 37: Innovative SMEs collaborating with others, percentage of SME, 2014



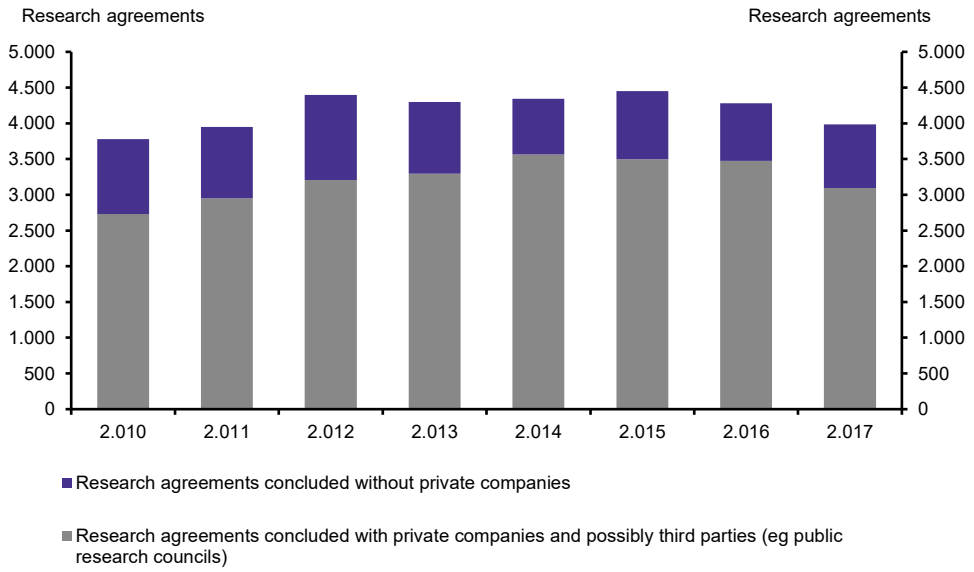
Note: SMEs are defined here as including all enterprises with 10 to 249 employees. Collaborating activities is defined as any co-operation agreements on innovation activities with other enterprises or institutions within the last three years.

Source: Eurostat, Community Innovation Survey 2014

From 2010 to 2017, the number of research agreements between public research institutions and private companies have increased in Denmark from 2,730 to 3,093 research agreements.

From 2015 to 2017, there has been a minor decrease in the number of research agreements between public research institutions and private companies. It should be noted that the minor decrease in research agreements in itself does not necessarily demonstrate a negative trend since the Figure shows only the number of agreements and does not show the economic scope of these agreements.

Figure 38: Research agreements between public research institutions and private companies, 2010-2017.

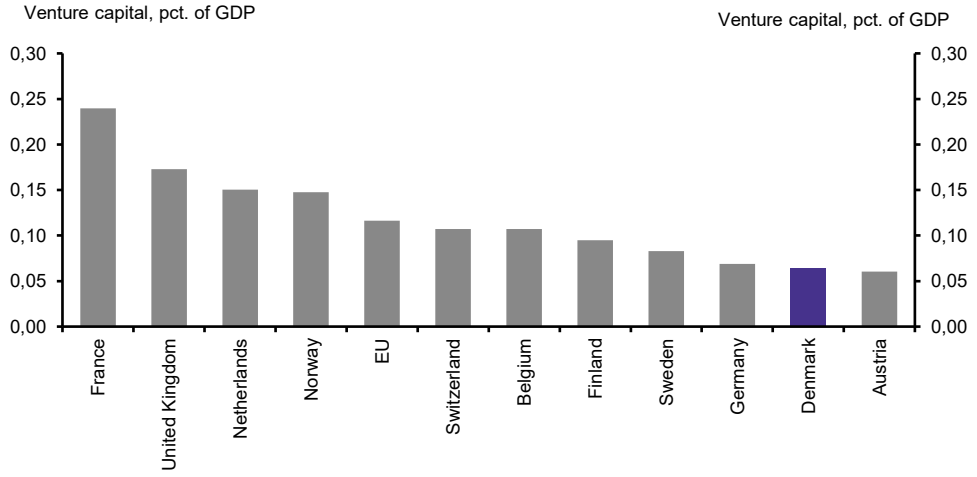


Note: Research agreements cover a variety of different type of activities, such as research projects funded by companies, projects co-financed by both parties or collaborations co-financed with a third party (for example, through public financing programmes, such as the Innovation Fund Denmark or the EU Horizon 2020 programme).

Source: Danish Agency for Science and Higher Education

Denmark has a low level of venture capital by percent of GPD, cf. **Error! Reference source not found.**39, in comparison with the other countries. In Denmark, venture capital, as a percentage of GDP, was 0.06 pct. in 2017, which is among the lowest across the comparison countries.

Figure 39: Venture capital, pct., 2017



Note: Venture capital expenditures is defined as private equity raised for investment in companies. Management buyouts, management buy-ins, and venture purchases of quoted shares are excluded. Venture capital includes early-stage (seed + start-up) and expansion and replacement capital. Pct. of GDP.

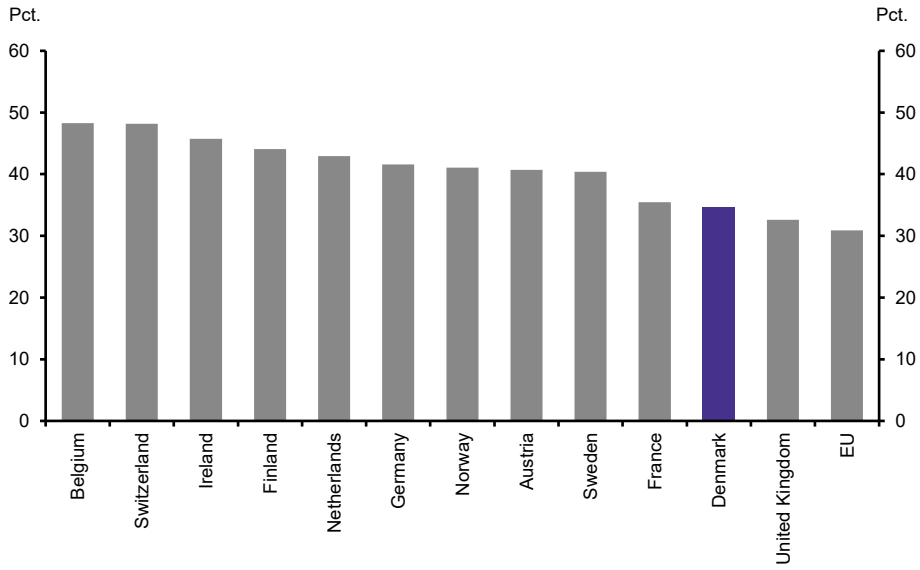
Source: European Innovation Scoreboard

Venture capital expenditures are volatile over time. Changing the Figure to include an average of 2016 and 2017 does not change the order of the countries, regardless of the order of magnitude.

3.3 Innovation output

Compared to other countries, Denmark has a rather low share of SMEs introducing product or process innovations to the market. Approximately 35 percent of the SMEs in Denmark introduced innovations to the market in 2014 compared to 48 percent of all SMEs in Belgium.

Figure 40: SMEs introducing product or process innovations as a percentage of total SMEs, 2014.

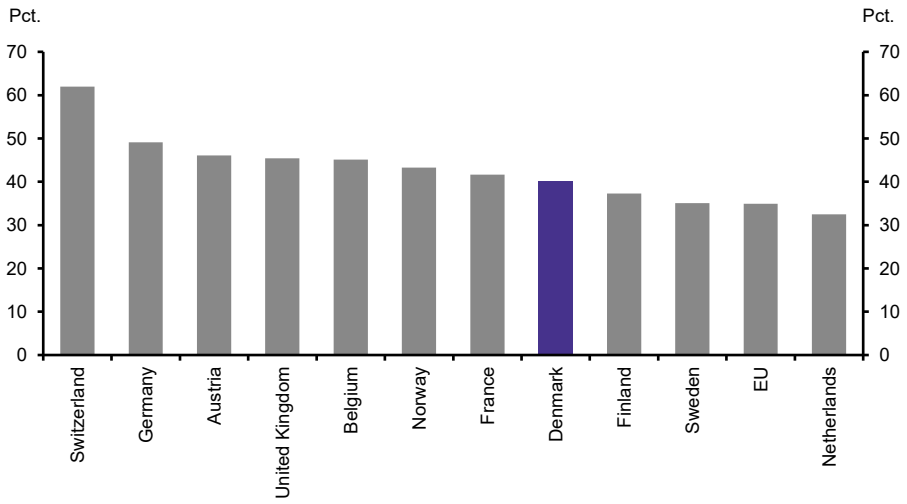


Note: SMEs are defined here as including all enterprises with 10 to 249 employee.

Source: European Innovation Scoreboard, Community Innovation Survey (CIS), 2014

Forty percent of the Danish SMEs has introduced marketing or organisational innovations in 2014, cf. Figure 41. This is the same level as similar small research intensive countries such as Finland and Sweden. The Danish level is above the EU average, but is significantly lower then in Switzerland where 62 percent of the SME have introduced marketing or organisational innovations.

Figure 41: SMEs introducing marketing or organisational innovations as a percentage of total SMEs, 2014.

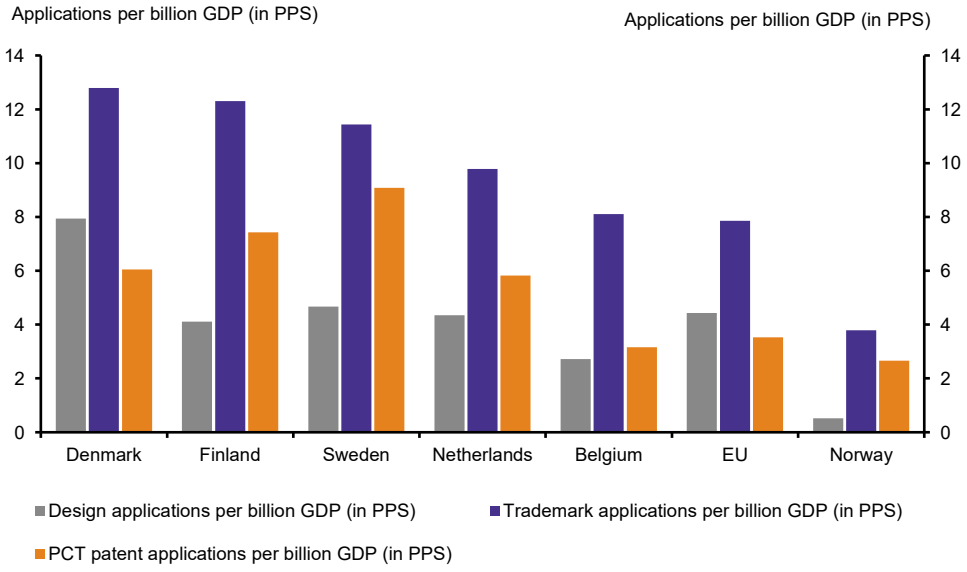


Note: SMEs are defined here as including all enterprises with 10 to 249 employee.

Source: European Innovation Scoreboard, Community Innovation Survey (CIS), 2014.

Denmark has a relatively high level of different forms of intellectual property rights (IPR) generated in the innovation process, including Patent Cooperation Treaty (PCT) patent applications, trademark applications and design applications, cf. **Error! Reference source not found.**42.

Figure 42: PCT patent, trademark and design applications per billion GDP



Note: Data for trademark and design applications are from 2017, while data for PCT applications are from 2015.

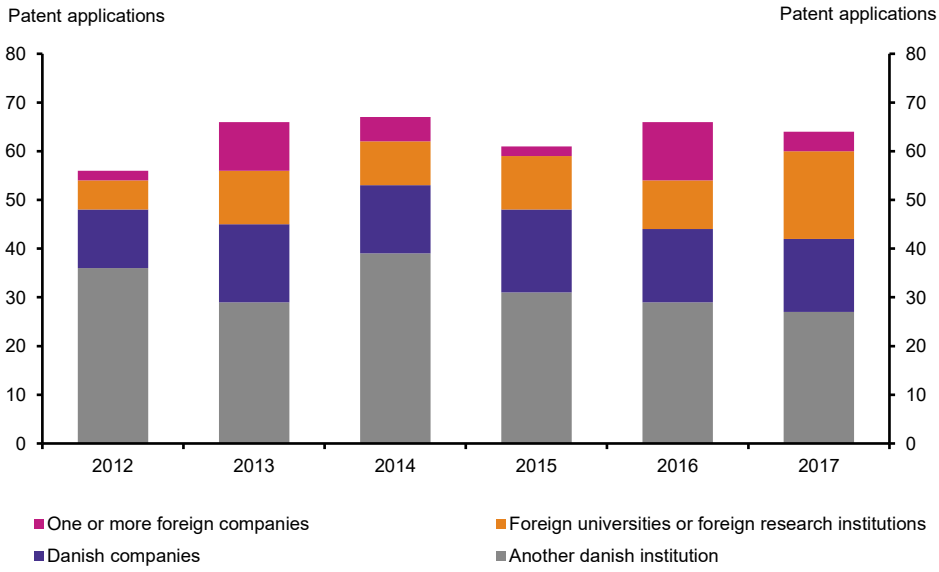
Source: European Innovation Scoreboard, 2018

In particular, Denmark has a high level of design applications, almost eight per billion GDP, which is the second highest among the comparison countries. Denmark also has a high level of trademark applications, approximately 13 per billion GDP, which is approximately the same level as in Finland.

Finally, Denmark has about six PCT applications per billion GDP, which is the same level as in the Netherlands but is somewhat lower than in Sweden and Finland. In connection with the interpretation of the indicators, it should be noted that they measure only the number of patent applications, which cannot be directly linked to whether or not these applications actually lead to a new product.

Each year, Danish universities report the number of joint patent applications that they have filed in the current year with the Danish Agency for Science and Higher Education. The majority of Danish joint patent applications originating from Danish universities are primarily between two Danish research institutions, for instance, two universities applying for a patent together, cf. **Error! Reference source not found.**43.

Figure 43: Number of university joint patent applications, by type, 2012-2017

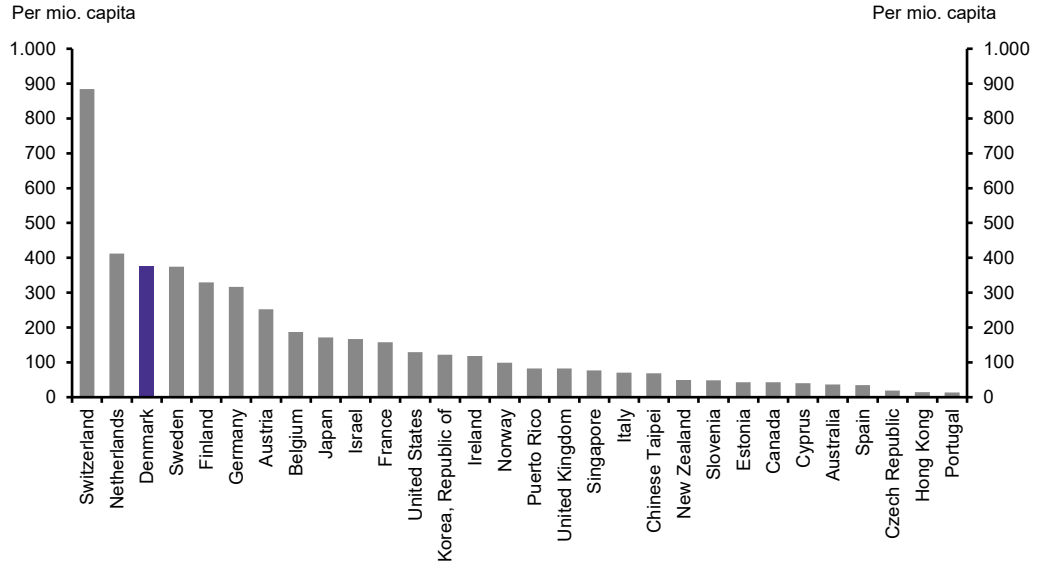


Source: Danish Agency for Science and Higher Education

On a yearly basis, Danish universities have approximately 15 joint patent applications with Danish companies. Danish universities also have some cooperation with foreign companies, but these patent applications represent a minor part of the total patent applications.

In 2017 Denmark applied for 377 EPO patents per million capita, which is one of the highest level among the comparing countries. Only the Netherlands and Switzerland had more EPO applications per million capita then Denmark in 2017. The Danish level is the same level as some of the other Nordic countries such as Sweden and Finland.

Figure 44: EPO patent applications by geographic origin, per mio. capita, 2017

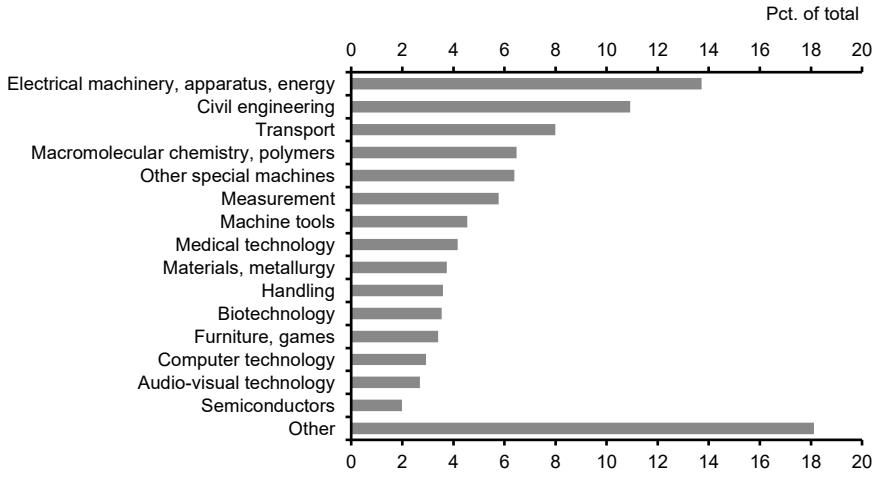


Note: European patent applications include direct European applications and international (PCT) applications that entered the European phase during the reporting period. The geographic origin is based on the country of residence of the first applicant listed on the application form (first-named applicant principle

Source: European Patent Office, 2018

Approximately 14 percent of the Danish EPO applications was filed within electrical machinery, apparatus, and energy, cf. figure below. Following the electrical machinery, a large share of the Danish EPO patents applications was filed within Civil engineering and transport that accounts for 11 percent and 8 percent of the applications, respectively.

Figure 45: Danish EPO patent applications by technology field, pct. of total, 2017

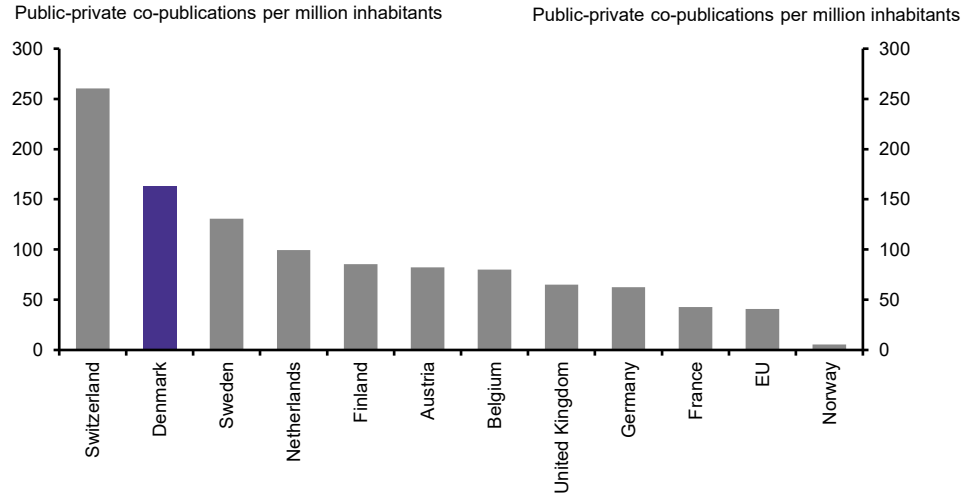


Note: European patent applications include direct European applications and international (PCT) applications that entered the European phase during the reporting period. The geographic origin is based on the country of residence of the first applicant listed on the application form (first-named applicant principle

Source: European Patent Office, 2018

Denmark has one of the highest number of public-private co-publications per million inhabitants among the comparing countries with 163 co-publications in 2017, cf. Figure 46. The Danish level is significantly higher than the EU average and other small research-intensive countries such as Finland and Belgium. Switzerland has the highest level of public-private co-publications per inhabitants in 2017.

Figure 46: Public-private co-publications per million inhabitants, 2017.

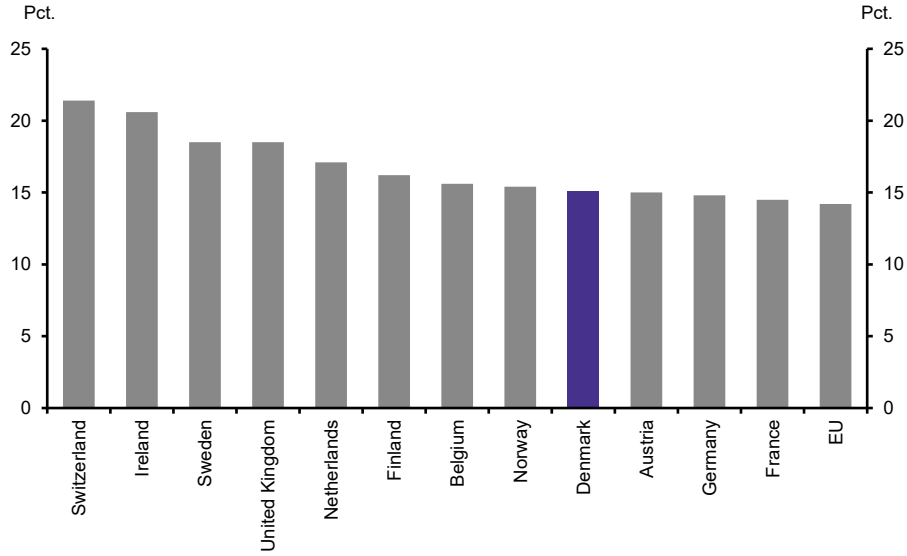


Note: Publications are assigned to the country/countries in which the business companies or other private sector organizations are located.

Source: European Innovation Scoreboard, 2018.

The proportion of employees involved in knowledge-intensive activities in Denmark was 15 percent of total employment in 2017, cf. **Error! Reference source not found.**47. This is approximately the same level of employment as in Norway and Austria. Switzerland has the highest level of employees engaged in knowledge-intensive activities at 21 pct. of total employment.

Figure 47: Employment in knowledge-intensive activities in percentage of total employment, 2017.

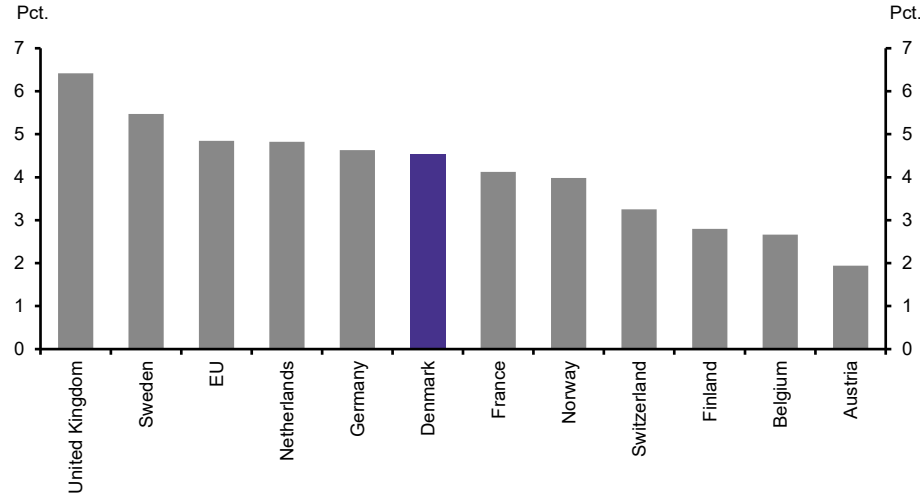


Note: Knowledge-intensive activities are defined, based on EU Labour Force Survey data, as all NACE Rev.2 industries at the 2-digit level, where at least 33% of those employed have a tertiary education degree (ISCED 5-8).

Source: European Innovation Scoreboard, 2018.

The proportion of employees involved in knowledge-intensive activities in Denmark was 15 percent of total employment in 2017, cf. Figure 48. The Danish level is approximately the same as other large countries such as France and Germany and higher than in Finland and Belgium. The Danish level is a bit lower than the average EU level and Sweden.

Figure 48: Employment in fast-growing enterprises in innovative sectors as percentage of total employment.



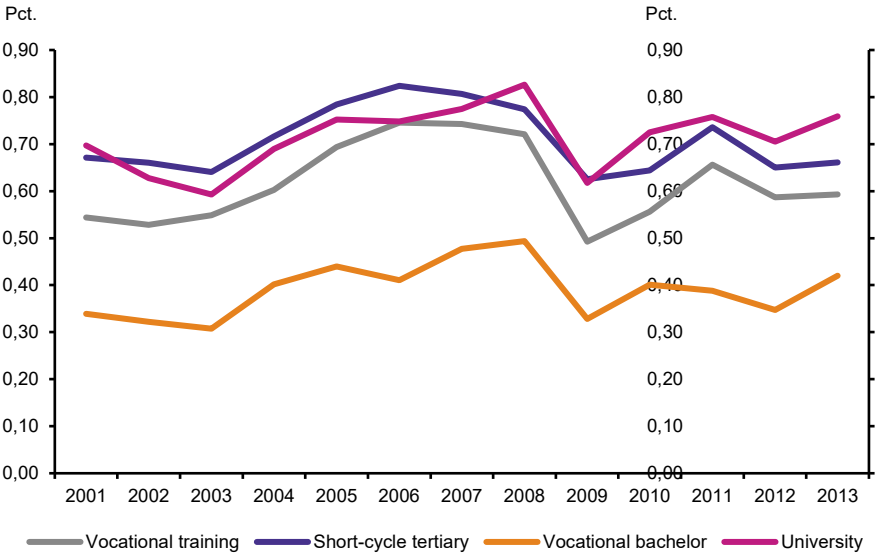
Note: Only enterprises with 10 or more employees are included. The following NACE industries is defined as the most innovative industries: B06, B09, C11, C12, C19, C20, C21, C26, C27, C28, C29, C30, C32, D35, E39, G46, H51, J58, J59, J60, J61, J62, J63, K64, K65, K66, L68, M69, M70, M71, M72, M73, M74, M75, and N79.

Source: European Innovation Scoreboard, 2018

3.4 Building more innovation

The share of university graduates starting a new business is the highest among the different types of education, cf. **Error! Reference source not found.**49. The share of entrepreneurs in the work force with a university education in 2013 was approximately 0.7 percent. This result is significantly higher than the result for entrepreneurs with a vocational bachelor's degree, which is approximately 0.4 percent.

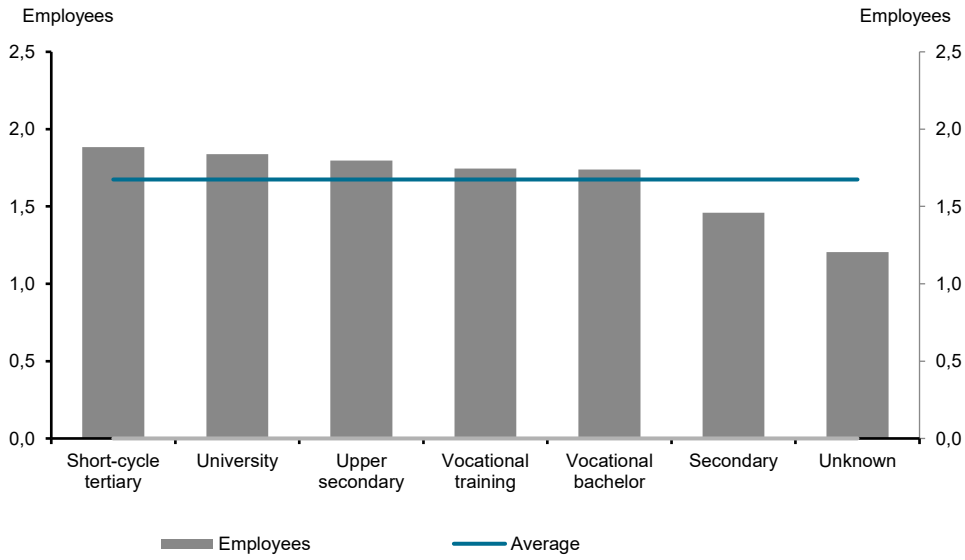
Figure 49: Share of entrepreneurs in the work force by type of education, 2001-2013



Source: Statistics Denmark and own calculations

The average firm size of entrepreneurs is 1.7 employees. Based on the type of education, entrepreneurs with a short-cycle tertiary education employ the most workers, followed by entrepreneurs with a university degree.

Figure 50: Average number of employees by type of education of the entrepreneur, 2006-2015

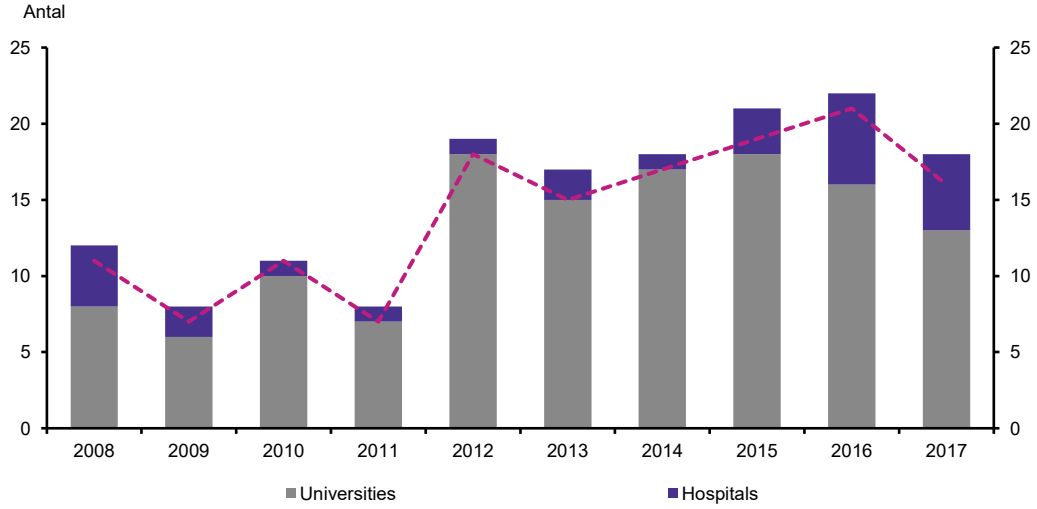


Source: Statistics Denmark and own calculations

The number of spin-out companies from Danish universities and hospitals has been relatively stable over the past six years, with approximately 17-22 spin-out companies per year, cf. **Error! Reference source not found.**51.

Spin-out companies from Danish hospitals have increased over the last three years, and five of the 18 spin-out companies originated from hospitals in 2016. However, Danish universities are still by far the type of public research institution that has created the largest proportion of spin-out companies.

Figure 51: Spin-out companies from Danish universities and hospitals, 2008-2017.



Note: Due to changes in the definition, the numbers of spin-out companies before and after 2012 are not comparable. Since some spin-out companies started through collaborations among several institutions, there are individual cases of double counting. The dotted line indicates the number of unique companies.

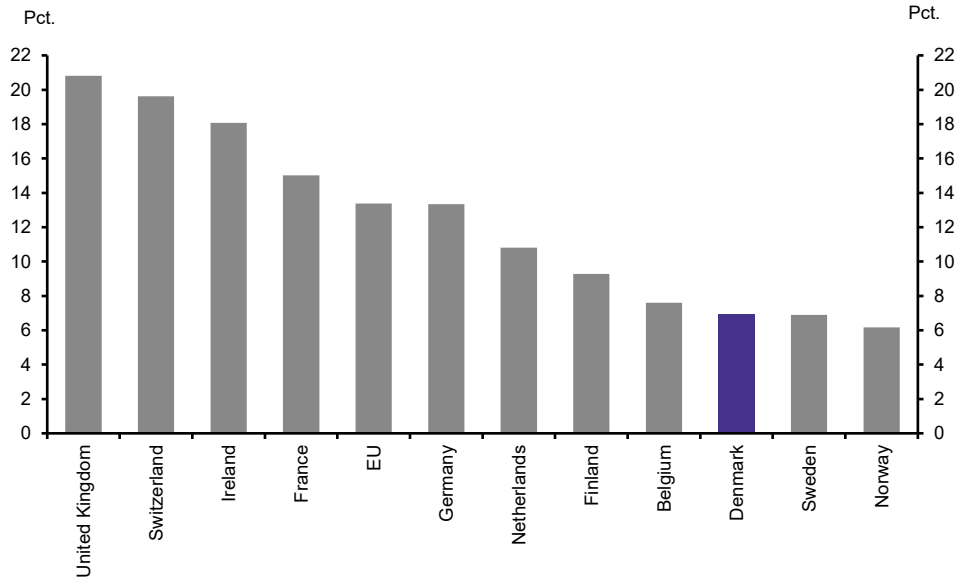
Source: Danish Agency for Science and Higher Education

3.5 Innovation outcomes

The sales of new-to-market and new-to-firm innovations as a percentage of total turnover constituted seven percent for Danish companies in 2014.

This is the same level as in Sweden and Norway but is substantially lower than in the United Kingdom, where sales of innovations constitute 20 percent of total turnover. The Danish level is approximately half of the EU average.

Figure 52: Sales of new-to-market and new-to-firm innovations as a percentage of total turnover, selected countries, 2014



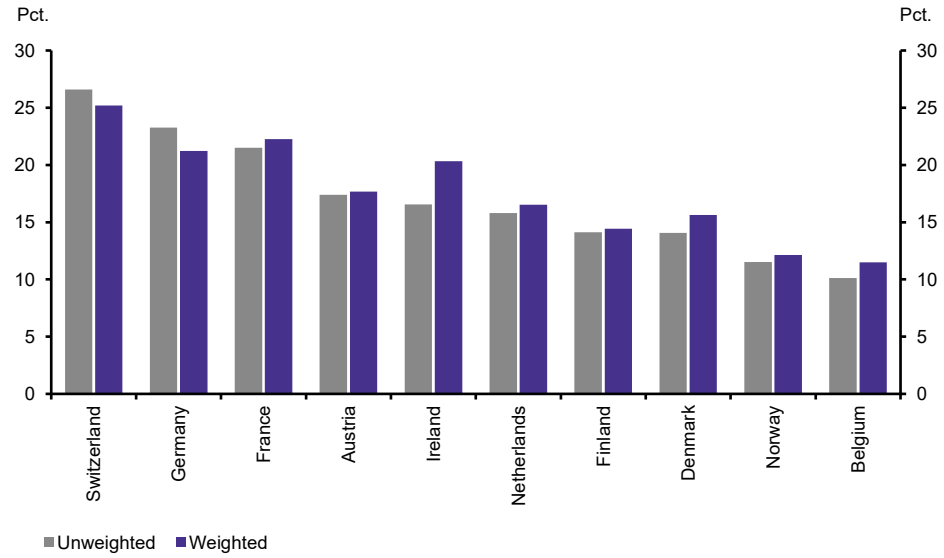
Note: This indicator measures the turnover of new or significantly improved products and includes all enterprises.

Source: European Innovation Scoreboard, Community Innovation Survey 2014

A general criticism against comparing countries unweighted sales of new and improved products is that they differ in composition of industries. I.e. Germany and France do have very large car industries, which is not the case in Denmark. But accounting for industry structure requires also better data, because estimates of sales of new and improved products must be available at the subindustry level.

A comparison across countries of unweighted sales shares of new and improved products in manufacturing reveal that Denmark is placed low. Sweden and the UK drops out, because the data is not available at such a detailed level for the countries in EUROSTAT. By weighting sub-manufacturing sales shares of new and improved products with a reference manufacturing structure, the weighted sales of new and improved products is calculated. The reference manufacture structure applied is the structure of the 10 countries total sales. The results only change marginally, though it improves the position of Denmark.

Figure 53: Sales of new-to-market and new-to-firm innovations as a percentage of total turnover in manufacturing, selected countries, weighted for industry structure, 2014

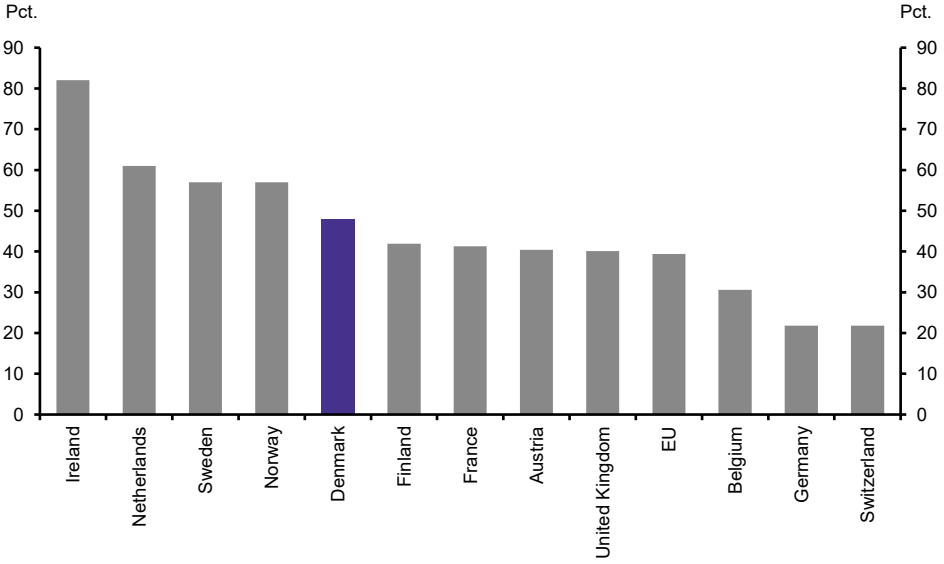


Note: Weights constructed by industry structure of all ten countries.

Source: European Innovation Scoreboard, Community Innovation Survey 2014

Another important dimension is the share of new and improved products that are new on the market often labelled radical innovations. Denmark, Sweden and Norway has a much larger share of radical innovations compared to sales of new and improved products.

Figure 54: Share of turnover from radical innovations, percentage, 2014.



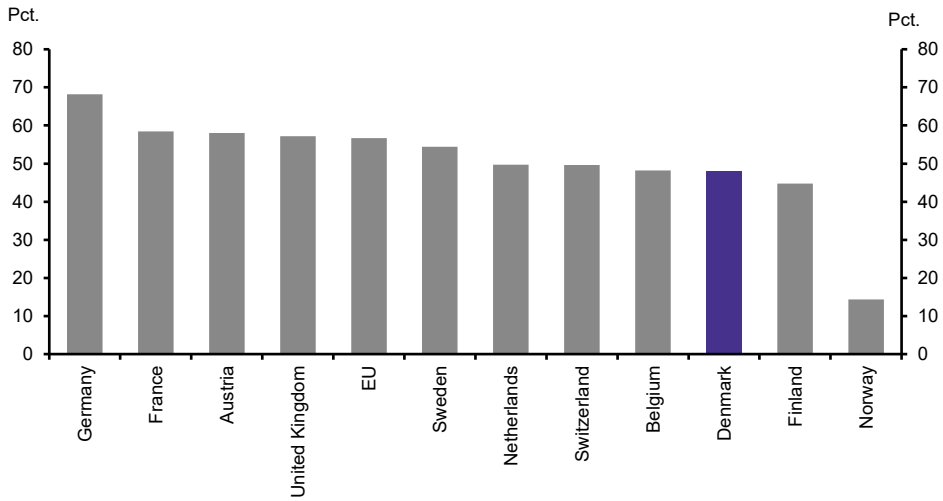
Note: This indicator measures the turnover from new or significantly improved products that were new to the market with turnover from new or significantly improved products only new to the firm to calculate the share stemming from radical innovations.

Source: European Innovation Scoreboard, Community Innovation Survey 2014

Nearly half of all Danish product exports are exports of medium and high technology products, cf. Figure below. This is approximately the same level as in Belgium and Switzerland.

The Danish level of medium and high technology products is still below the EU average, and large countries, such as Germany and France, export more high technology products than Denmark.

Figure 55: Exports of medium and high technology products as a share of total product exports, 2017.



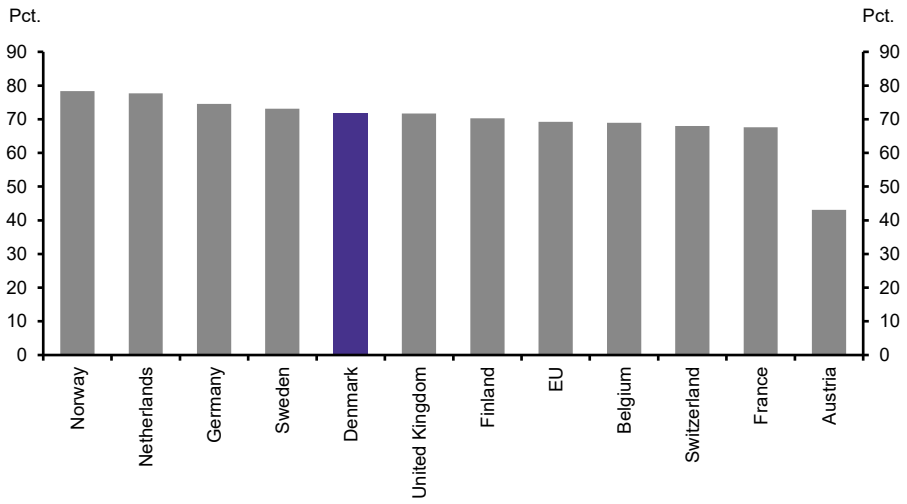
Note: See the European Innovation Scoreboard Methodology Report 2018 for a definition of medium and high *technology products.*

Source: European Innovation Scoreboard, 2018

Approximately 72 percent of all Danish services exports are exports of knowledge-intensive services. This is the same level as other small research-intensive countries such as Sweden and Finland and above the EU average of 69 percent.

Other small research-intensive countries such as Norway and the Netherlands have a higher level of service exports from knowledge-intensive services.

Figure 56: Knowledge-intensive services exports in percentage of total services exports, 2017

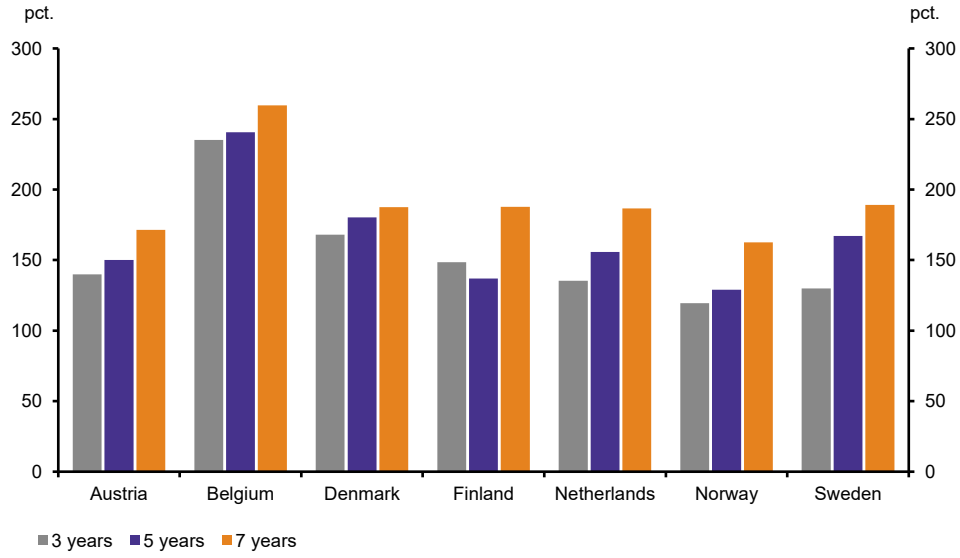


Note: For a review of the delimitation in relation to knowledge-intensive services, see European Innovation Scoreboard Methodology Report 2018

Source: European Innovation Scoreboard, 2018

The ability of young firms to scale up and grow is considered important for innovations to contribute to growth. The reason is that start-up firms are more productive (and innovative) than mature incumbent firms. Firms in Sweden and Netherlands continue to grow after five and seven years, whereas, for firms in Denmark, the profile flattens after the first three years of growth, cf. **Error! Reference source not found.**57.

Figure 57: Post-entry growth of firms, country average of final over initial years 2001 and 2004, surviving entrants of 3, 5 and 7 years, in percent



Source: Calvino m. fl. (2016)

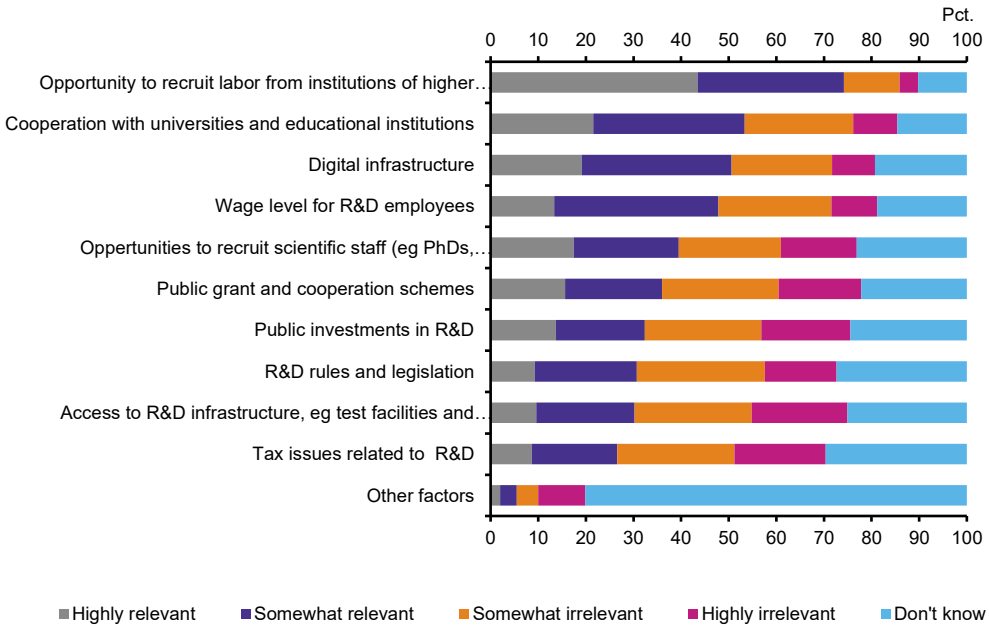
4 PRIVATE FIRMS PERSPECTIVE ON R&D

The following chapter summarizes key survey findings on Danish companies' perspective on their R&D activities. The survey was conducted among a representative group of R&D active firms in Denmark in the summer of 2018 for MHES. The companies have been asked questions regarding the Danish framework conditions for R&D, their own strategic choices concerning their R&D activities, as well as their views on advantages and disadvantages of participating in government programs.

4.1 Framework conditions for R&D activities

Access to higher education institutions and highly skilled labour is the most important framework condition for Danish companies R&D activities. A majority of companies rate '*recruitment of employees from higher education institutions'* and '*collaboration with universities and educational institutions*' as highly or somewhat relevant for their R&D activities.

Figure 58: Relevant factors for private companies' R&D activities. Share of R&D active companies indicating that the individual circumstances are relevant



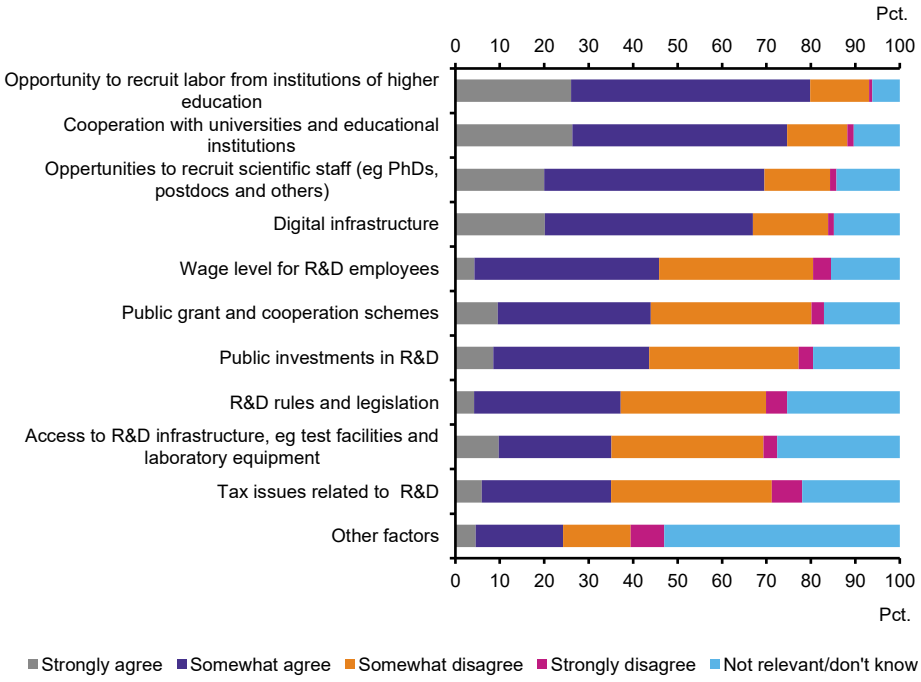
Note: Question: Which factors are relevant for private companies' R&D investments? Share of R&D-active companies. N=658

Source: Survey conducted by The Danish Ministry of higher Education and Science on the R&D-investments of the private sector

More than 80 percent of the R&D active companies strongly or somewhat agree that the framework conditions for recruiting labour from the higher education institutions in Denmark is good.

A majority of the companies also agree that framework condition for cooperation with universities as well as the digital infrastructure in Denmark is good. On the other end of the scale is access to R&D infrastructure as well as the tax issues related to R&D.

Figure 59: Companies' assessment of framework conditions in Denmark. Proportion of companies that assess the condition is good in Denmark, 2018



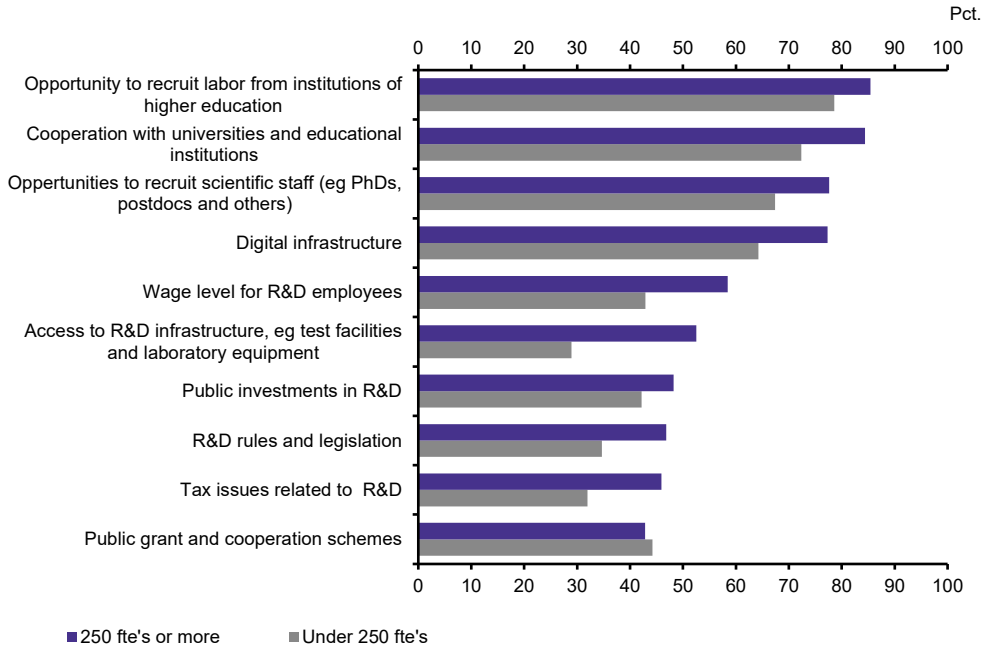
Note: Question: To what extent is the following external condition good in Denmark? The survey only includes companies which responded that the individual condition is relevant to their company's R&D activities. Therefore, the number of responses varies from N = 225 to N = 565 out of total N = 659. There are N = 66 that have answered "other conditions".

Source: Survey conducted by The Danish Ministry of higher Education and Science on the R&D-investments of the private sector

In general, both large and small companies largely assess the same framework conditions as good, cf. figure below. However, the large companies are generally a bit more positive in their assessment of the Danish framework conditions.

Companies with more than 250 FTEs are significantly more positive in their assessment of the conditions for collaboration with universities as well as access to R&D infrastructure than smaller companies.

Figure 60: Companies' assessment of framework conditions in Denmark distributed by the size of the company. Proportion of companies that assess that the condition is very or somewhat good, 2018



Note: Question: To what extent is the following external condition good in Denmark? The survey only includes companies which responded that the individual condition is relevant to their company's R&D activities. The survey only includes companies which responded that the individual condition is relevant to their company's R&D activities. Therefore, the number of responses varies from N = 225 to N = 565 out of total N = 659. There are too few respondents who have answered "Other factors" to report the result from this category

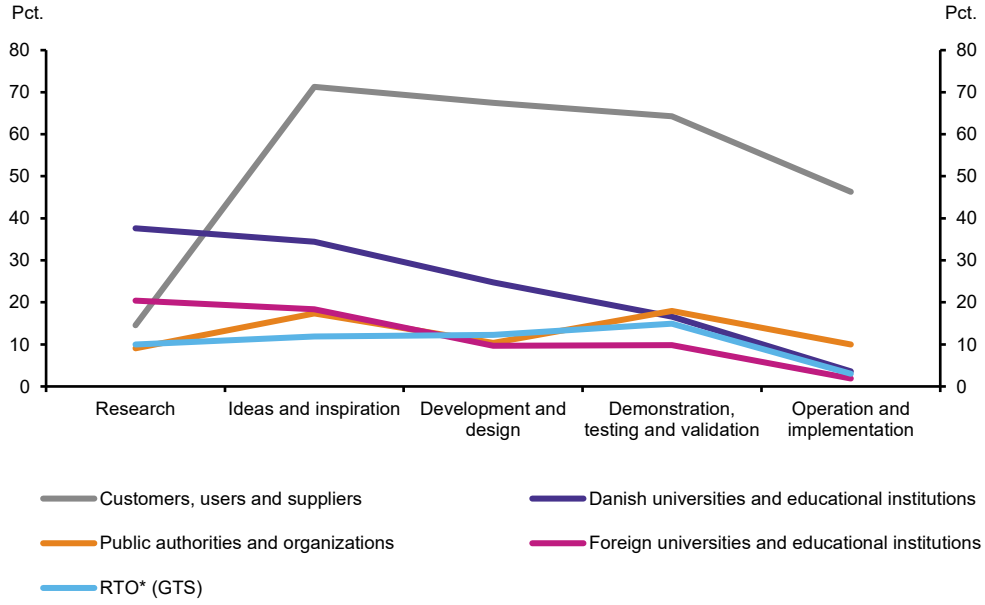
Source: Survey conducted by The Danish Ministry of higher Education and Science on the R&D-investments of the private sector.

The companies participating in the survey were also asked how different partners such as the universities, RTO's, etc. play a varying role during different stages of the innovation process, cf. Figure 61.

The partners that most of the companies participating in survey highlight are customers, suppliers and users. They are highlighted by most companies in almost every part of the innovation process.

The companies highlight their cooperation with the universities as important during the research stage. In relation to the companies' research, the universities are the partner that most emphasizes. The companies primarily cooperate with the Danish universities in the early phases of the innovation process e.g. research process and as well as the idea and inspiration process.

Figure 61: The involvement of companies' business partners during the different stages of the research and innovation process. Share of companies with their own R&D, 2018



Note: In which stages of the company's development process are external partners included? Only companies which responded that that they cooperate with external partners in their development process has had the chance to answer the question. N = 529. The research and technology organisations (RTO) refer to the Danish GTS-institutes.

Source: Survey conducted by The Danish Ministry of higher Education and Science on the R&D-investments of the private sector

5 APPENDIX

5.1 Data sources

The analysis is based on data regarding different aspects of the innovation process from a variety of available international data sources. It is possible to access the databases by following the links below:

European Innovation Scoreboard:

https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

OECD (Innovation): http://www.oecd.org/innovation/inno/inno-stats.htm

OECD (Education): http://www.oecd.org/education/

Community Innovation Scoreboard: https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database

Statistics Denmark:

https://www.statistikbanken.dk/statbank5a/default.asp?w=1920

In relation to the interpretation of the results in the report, it is relevant to beware of the different timespan as well as the underlying methodology of each data source.

The newest data in this report originate from Statistics Denmark where preliminary data regarding the Danish companies R&D expenditures is available for 2017. The preliminary Danish 2017 data is however only available on a macro level and the more in-depth analysis such as R&D expenditures by subindustries in Denmark is from 2016.

Most of the international data from OECD and the European Innovation Scoreboard is from 2016. However the data originating from the Community Innovation Scoreboard that mostly relates to the output indicators dates back to 2014. The Community Innovation Scoreboard is expected to be updated with 2016 data in the near future and the results might change as a consequence of the update.

In relation to the methodology behind the data collection of the Community Innovation Scoreboard it should be noted that the countries apply different survey methodologies. The majority of the countries carried out a combination of sample survey and census of the enterprises with mandatory participation. For some ccountries such as the United Kingdom, Belgium and Germany it is however not mandatory for the enterprises to participate.

Because of this, the non-response rate varies between the countries where for instance Denmark has a non-response rate of 3 percent compared to the United Kingdom that has a non-response rate of 50 percent. This could potentially

introduce a bias to the dataset, however Eurostat attempts to correct for this by employing a variety of methods such as weighing regimes.

5.2 High technology and knowledge intensive sectors

The second chapter offers a short introduction to the Danish economy and its strengths. The definitions regarding high technology manufacturing industries and knowledge intensive services applied in the chapter are derived from Eurostat. The table below specifies which industries that are included in the analyses.

Table 1: Eurostat definition of high- and medium high technology manufacturing and knowledge intensive services

High and medium- high technology manufacturing industries NACE Rev 2. Codes – 2 digit level		
High-technology	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations;
	26	Manufacture of computer, electronic and optical products
Medium-high technology	20	Manufacture of chemicals and chemical products;
	27 to 30	Manufacture of electrical equipment; Manufacture of machinery and equipment n.e.c; Manufacture of motor vehicles, trailers and semi-trailers; Manufacture of other transport equipment
Knowledge intensive services		
Knowledge intensive Market services (excluding high-tech and financial services)	50 to 51	Water transport; Air transport;
	69 to 71	Legal and accounting activities; Activities of head offices, management consultancy activities; Architectural and engineering activities, technical testing and analysis;
	73 to 74	Advertising and market research; Other professional, scientific and technical activities;
	78	Employment activities;
	80	Security and investigation activities; services to buildings and landscape; other business services
High-tech Knowledge intensive services	59 to 63	Motion picture, video and television programme production, sound recording and music publish activities; Programming and broadcasting activities; Telecommunications; computer programming, consultancy and related activities; Information service activities;
	72	Scientific research and development;
Knowledge intensive financial services	64 to 66	Financial and insurance activities (section K).

Source: Eurostat

5.3 Additional indicators

In addition to the abovementioned databases, the analysis report draws on data from four publications published by the Agency for Science and Higher Education on a yearly basis. These publications primarily focus on the Danish research and development system with a special focus on the public sector.

Research Barometer 2018 – this publication has a primary focus on the Danish research system in regard to R&D funding, scientific publications and their impact as well as Danish participation in the European scientific programme Horizon 2020.

Knowledge of growth 2018 – this publication has a primary focus on technology transfers from Danish public research institutions.

Business enterprise research and development expenditures 2018 – this publication has a primary focus on Danish business enterprise R&D investments over the past 8 years.

Research awards 2018 – this publications focuses on research funding from Danish public research councils.

The full dataset for the four abovementioned publications has been made available in a separate appendix "Supplementary Figures and tables for Danish publications from Danish Agency for Science and Higher Education 2018".

DANISH INNOVATION POLICY IN A HISTORICAL CONTEXT

This document describes the development of Danish innovation policy during recent decades.[1] It elaborates on how Danish policy has moved from a linear innovation model in the research and industrial policies of the 1980s, to a policy with clearer focus on the interdependencies of research, innovation and business in the beginning of the new millennium.

1 1970-1990: INDIVIDUAL SECTOR-SPECIFIC INDUSTRIAL POLICIES

In the 1970s the energy crisis exposed the vulnerability of the Danish economy in an increasingly globalized world. Denmark had experienced a slowly accelerating societal change away from the sectored agrarian and industrial society towards a society under growing international influence. Loss of old industries and the establishment of new ones as well as increased awareness of the global influence on Denmark's ability to secure future welfare, created a need for new political priorities, primarily in industrial policy.

Denmark tried out – initially forced by necessity, but increasingly of its own free will – new policies to improve its industry's competitiveness and increase the country's welfare. Since the 70s, Denmark gradually abandoned its laissez-faire industrial and research policy in favour of a managed and active technology policy with a cohesive, and in some contexts proactive, innovation policy that encompassed significantly more areas and elements of the national economy.[2]

Up until, and through the 1970s, it had been a political objective to improve competitiveness via devaluation and cuts in production costs, primarily through lower wage growth. This period was characterized by growing unemployment, high inflation and interest rates as well as pronounced political uncertainty. In an attempt to stabilize the economy, the government introduced a fixed exchange rate policy in 1982 pegging the Danish krone to the Deutschmark to reduce economic uncertainty and strengthen Denmark's development potential. This objective also led to new policy approaches to secure and support Danish industry's competitiveness, firstly via improved conditions for knowledge sharing between Danish Research and Technology Organisations (RTO) and industry, secondly via support for new research based knowledge and thirdly technology policy to support industrial product development, and to a lesser extent process development.

[1] This document builds primarily on unpublished work by Ebbe Krogh Graversen, associate professor at The Danish Centre for Studies in Research and Research Policy

[2] Aagaard, 2000

2 1980S – CONTINUED TECHNOLOGY PUSH MINDSET

In the early 1980s, the idea took hold that a more active, focused and coordinated policy of research-based technological innovation would help solve Denmark's structural problems of high budget deficits, high unemployment and declining competitiveness. This originated from academic researchers, the OECD and the example of some other European countries.

The political mindset in the 1980s was informed by the linear innovation model i.e. scientific knowledge as input to technological development, which industries can then use to improve production.[3] The international trend thus continuously moved towards comprehensive, complex and not least cohesive and active innovation policy. This also occurred in Denmark, albeit slowly and driven by the wish to see technology policy contribute to solving societal needs, and with pronounced traits from the technology push mindset.[4]

Danish policy development in the 1980s and 1990s found inspiration and ideas in other countries. The OECD's analyses and recommendations, and especially its evaluations of Danish research and technology policy in 1988, and of research, technology and innovation policy in 1994 was also of importance for the development of Danish policy.

From 1983, political initiatives changed toward a nascent dynamic and active industrial policy with strategic support via R&D programs under a technology policy and with a gradual blurring of the separation of research policy and industrial policy.[5] In these years, Danish innovation policy was generally based on a combination of various industry services, e.g. technological service from RTO's and regional technological information centers as well as technological research programs in the fields of biotech, energy, environment, materials, food, information technology etc.

The program for Research and Technological Development from 1985 is a manifestation of the shift in objectives towards research with focus on industrial technology.[6] However, even though the coupling of technology policy and overall politically determined societal needs was present via the research programs, an acknowledgement of the interactive link between research, industry and market was neither stated nor framed at this point in time, except for elements of interactivity within the RTO's development of new technological services.

The technology programs that were launched focused on certain politically prioritized, sectors, and aimed to reallocate resources in favour of technological

[3] Karnøe, 1991; Rothwell, 1992; Freeman and Soete, 1997

[4] Christiansen and Sidenius, 1988

[5] Christiansen and Sidenius, 1988

[6] Christiansen and Sidenius, 1988

development in an otherwise unregulated market. So, despite a sound economic-theoretical foundation, the programs were still influenced by the simplicity of the technology push mindset. By supporting technological knowledge, the state was able to improve the framework conditions for Danish industry, which needed the new technologies developed in the research programs. A more direct coupling between technology policy and small enterprises was still lacking despite the presence of support for the Danish RTO's.[7] However, during this period, ideas of a more cohesive approach to drive societal growth and change emerged, e.g. in the joint discussion paper by the ministries of labor, industry, research and education.[8]

Political priorities did not always result in economic-rational initiatives, but economic-rational societal arguments became a guiding factor in the selection of initiatives in an increasingly interventionist technology and industrial policy in the second half of the 1980s.[9] From an industry-neutral, passive and relatively modest research and technology policy in the 1970s, focus now shifted to strategic initiatives, collaboration, knowledge facilitation and service and just overall a more active engagement by the state.

International influence and coining of Danish innovation policy

In 1988, Denmark asked the OECD to evaluate Danish research and technology policy, but did not find it relevant to ask for an evaluation of its innovation policy (OECD, 1988). However, six years later, in 1994 Denmark asked the OECD (1994) to evaluate all three policies. Innovation policy had thus reached the level of research, technology and industrial policy.[10] Innovation had become a positive word late in the decade, but innovation policy was still mainly conducted via industrial and technology policy. The intensity and scope of initiatives were still growing, however.

Even though innovation policy was still targeted at industry, it became increasingly clear in the second half of the 1980s that several ministries could join in increasing the effect of the current policies by coordinating them. The first inter-ministerial programs for businesses were launched in a partnership between the ministries of industry, energy and environment, and later on science parks were established and seen in a broader perspective of matching targeted and applied research with industrial needs.[11] In the same category, in 1985, the European cross-national EUREKA program for market-driven industrial research

[7] Mandag Morgen, 1995; Nyholm and Langkilde, 2003; Lindgaard Christensen, 2003

[8] Arbejdsministeriet et al., 1986

[9] Christiansen, 1988

[10] Olesen-Larsen, 2003; Mandag Morgen, 1995

[11] Forskningsministeriet, 2000

and development was established in Paris.[12] Likewise, the European Union's research-driven framework program for research, technology and development was increasingly seen as a proactive and useful national instrument that could also benefit the industry via research partnerships with universities.

3 1990S: NEW POLICY APPROACH EMPHASIZING SYSTEMIC RELATIONS AND SYNERGIES

In 1989-90, the Technology Board under the Ministry of Industry and Commerce took the initiative to reorganize and merge the 36 RTOs from 1973 into fewer and more robust institutes.[13] The institutions that remained after 1990 were still quite diverse. The RTO-institutions established the 'Institution Council' (now the "Advanced Technology Group") today, in order to better coordinate the development of the RTOs.

In general, the initiatives and programs from that period were still targeted at the enterprises with the absorptive capacity to apply the knowledge required to benefit from the participation. Despite the increased efforts to disseminate new knowledge to businesses, the dominant policy trend was to improve the framework conditions for the industry via technology push, i.e. it was up to the businesses to absorb and employ the knowledge that had already been produced.

The demand for a genuine innovation policy became increasingly pronounced up through the 1990s and was gradually operationalized and implemented. However, responsibility for an overall innovation policy was not centralized into one ministry at the time. In reality, the Danish Agency for Trade and Industry headed the development of a systematic clarification of Danish innovation policy and culture at the time. On the Agency's initiative, a group of researchers including Bengt-Åke Lundvall provided an overall description of the Danish national innovation system[14] almost two decades after the initial policy steps during the energy crisis.

Among the most significant coordination initiatives in the 1990s was the establishment of the Industry and Trade Development Council (ITDC) and the Council for Technological Service, CTS, in 1996. The ITDC would advise the government about conditions for and the development of production and about factors affecting the international competitiveness of Danish industry. CTS were responsible for planning and coordinating the technological service under ITDC and primarily for coordinating activities at the Danish RTO's and the remaining trade promotion system.

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[12] Danish Agency for Science, Technology and Innovation, 2011

[13] In 1990 they were 20, in 1995 14, and today there are 7 GTS institutions, which are gathered in a national GTS network to improve the coordination and impact of their industrial contact (GTS, 2008).

[14] Lundvall, 1999

The CTS included technological, societal and industrial expertise and was specifically responsible for overseeing the RTOs. Every three years, the council presented an overall strategy for development of technological service in Denmark and allocated subsidies to the RTOs based on their strategy and action plans. The CTS recommended focus on strengthening certain elements in the service structure. This was done via increased support to the RTOs as an element in public knowledge service.[15] (The innovation policy tasks of ITDC and the CTS were superseded in 2001-02 by the Danish Council for Technology and Innovation.)

New initiatives were ready for implementation in the late 1990s. One example is the innovation incubator scheme, which offered support to start-ups through office space, business advice and preseed capital investment. The initiative came the year after the entrepreneur scheme in 1997, which among other things introduced subsidies for very small companies' initial contacts with the RTOs. Inspired by the notion of an interlinked national innovation system, and OECD's (1994) recommendations, entrepreneurship climbed higher on the policy agenda. The establishment of the Danish Growth Fund in 2001 - a state investment fund that provides capital for dynamic companies - is another example of the increased focus on improving framework conditions and reducing barriers to SMEs. Other initiatives at this time were the technology-push TIC-centers directed at SMEs; the Industrial researcher scheme (An adaptation of an existing private researcher program to fit with universities ph.d. programs) and the Centre contracts which co-financed large cooperative research and development activities with multiple public and private partners.

In 1993 the Ministry of Research was established. In the ministry's early years its field of responsibility was limited to research and ICT policies, including the introduction of a number of research programs and centers. This illustrated a continued "linear" belief that it was possible to improve Danish competitiveness by making new technology available to Danish industry through research activities (Forsknings- og Teknologiministeriet, 1993). A decade later, this ministry would take over responsibility of knowledge based innovation.

Danish Council for Independent Research and Council for Technology and Innovation

As a complement to industry's more short term application-oriented approach to specific competitiveness problems, publicly funded knowledge production at the universities was increasingly viewed as an important strategic source of knowledge for industry.[16] This renewed role for research policy manifested itself in an increased focus on strategic research funding via the coordinating so called Research Forum (Forskningsforum) and the attached academic research

[15] Erhvervsfremmestyrelsen, 1995, 1999

[16] Økonomisk Råd, 1997

councils.[17] Starting in 1997, the Research Forum would coordinate joint initiatives, including strategic research initiatives that it deemed to be of societal importance for Denmark across the academic research councils' domains. Examples are continuation of existing strategic programs for biotechnology, materials, health, etc., and introduction of new programs like welfare research, elderly research, food technology, etc. The Research Forum and the six academic research councils were transformed in 2002 to the Danish Council for Independent Research, the Strategic Research Council, and five new academic research councils with more industry- and society-related names.

After two decades of Danish research, technology and industrial policy, a growing focus on synergy via coordination of policies took hold in the 1990s. Late in the period, individual sector-specific industrial policies were put aside in favour of a a new policy approach emphasizing systemic relations and synergies, and the new bottom line focus became competitiveness in a globalized world; A holistic outlook; consensus seeking; coordination and a pro-system approach. This is the background of the government's establishment of the Council for Technology and Innovation, CTI in 2002. CTI was established with the purpose of promoting growth and innovation in Danish industry and society. A similar mindset later led to the establishment of the Danish Globalization Council in 2005.

4 2001 – PRESENT: STRONGER NEXUS BETWEEN EDUCATION, RESEARCH AND INNOVATION

With the establishment of the new government of November 2001 a major change to the national organisation of innovation policy was implemented. Relocating a big part of the Ministry of Business to the Ministry of Research that changed its name to the Ministry for Science, Technology and Development (Ministeriet for Videnskab, Teknologi og Udvikling). The rationale for this major reorganisation was expressed in the government declaration with the words: "*The government wishes a stronger nexus between education, research and innovation*".[18] For the Ministry of Research it also meant integrating staff, instruments and schemes from the Ministry of Business. This included the approved RTO's, the Innovation Incubators, the Industrial PhD scheme, Centre Contracts, and the Regional Growth Centres (Regionale Vækstcentre).

The Law of Technology and Innovation (Lov om Teknologi og Innovation), entering into force in 2002 also gave the legal basis to establish the Council for Research and Innovation under the Ministry for Science, Technology and Innovation. The major tasks of the council included advising the minister, especially preparing the approval of the Danish RTO's and the Innovation Incubators, as well as to take decisions on the instruments delegated by the minister.

[17] Forskningsstyrelsen, 2003

[18] Regeringsgrundlag 2001

With the reorganisation of the state apparatus in 2001 innovation policy was established as a major political focus area, split into a general innovation policy at the Ministry of Business and a knowledge- or research based innovation policy that during the 2000s would be crystalized at the Ministry for Science, Technology and Innovation (Now the MHES). In the Ministry of Business, innovation policy had been and would remain wide in its focus articulated alongside general framework conditions (taxation, business regulation, legislation), while the Ministry for Science, Technology and Innovation (through the Council for Technology and Innovation, and the Council for Strategic Research) would focus on science and technology-based schemes and programs.

This system for knowledge based innovation was elaborated with the later addition of the Advanced Technology Foundation (2005) and the works of the Globalization Council - a cross sectoral council under the PM who should give advice on a strategy for Denmark in the globalized economy, with a focus on education, growth, innovation and research (2006),[19] as well as the merging and creation of the national innovation networks (2008). Hence, in the years after the turn of the millennium, the Danish knowledge-based innovation system saw a growth in the number of funding bodies and their areas of responsibility.

In the 2012 ERAC peer review of the Danish research and innovation system[20] the existing system was assessed as overly complex. The report also expressed a concern that activities were not coordinated effectively and pointed out that instruments overlapped.

A central recommendation was that the number of funding bodies should be reduced, pointing out that a possible solution could be "…one funding council for basic/strategic research and another for applied/innovation oriented research as in several other countries, such as Finland, the Netherlands, Norway, Sweden, etc."[21]

A direct response to this was provided in the strategy: Denmark – the land of solutions. Drawing on the recommendations in the ERAC peer review, the strategy pointed to the necessity of simplifying the research and innovation funding system. The government chose to combine all the three areas of strategic research, innovation and high technology in one new comprehensive fund. The strategy was realized by merging the three former independent councils and funds into one new organization: Innovation Fund Denmark (IFD). This meant

[19] Fremgang, Fornyelse og Tryghed, Regeringen 2006

[20] ERAC peer review of the Danish research and innovation system, Expert Group Report prepared for the European Research Area Committee, 2012: https://ufm.dk/publikationer/2012/peer-review-of-the-danish-research-and-innovation-system-strengthening-innovation-performance

[21] ERAC peer review of the Danish research and innovation system, Expert Group Report prepared for the European Research Area Committee, 2012, p. 3

that funding of innovation projects was centralised in the IFD, while funding of institutions stayed within the MHES.

Furthermore, as a direct reflection of the peer review it was decided to expand the advisory remit of the former Danish Council for Research Policy to encompass innovation, so that it now has become a Research and Innovation Policy Council.

The ERAC peer review also recommended concentrating policy priorities on fewer areas aligned with Danish economic strengths and investigating the integration of foresight activities involving key stakeholders to a greater extend. Subsequently this is mirrored by the outlining of the Research2025 catalogue, which offers a broadly consolidated guideline for policymakers, funding bodies and research institutions on national research priorities. Furthermore, a new grand challenge-initiative is currently under development with the aim to promote public-private partnerships in applied research and innovation in specific fields.

Another concern of the ERAC peer review was the complexity of the innovation policy mix directed at SMEs, which was considered overly fragmented with too many instruments. Thus, the review recommended to investigate merger and simplification of policy instruments and funding programmes informed via use of more systemic evaluations. Concurrenly it has also been a priority in the Government declaration of 2015 to overlook the entire business support system. The following review of the Danish business promotion system (November 2016) and a report from the simplification committee (Forenklingsudvalget, April 2018) found, that the Danish system was too complex and demand driven. Based on the recommendations from the simplification committee, the current government and the Danish People's Party entered into an agreement in May 2018 with the aim of simplifying the existing business promotion system.

Following the agreement a new act on business promotion came into effect 1st of January 2019., Support measures are now to be concentrated at municipal and national level with no regional operators. meaning that the Danish Regions no longer offers regional business promotion. The agreement and new act on (simplification of) busness promotion also put a stop to support for the RTOs outreach work providing unexperienced SME's with reviews of technological innovation potential. By reducing the number of actors it is expected that private companies will experience a simpler support system. The law is under the jurisdiction of the Ministry of Industry, Business and Financial Affairs.

At national level, it has been a political prioritisation that risk capital instruments will be concentrated at The Danish Growth Fund, whereas soft funding will be concentrated under the IFD. This also means that the innovation incubator scheme is due to be replaced by proof of concept-funding for researchers from IFD as well as new credit facilities from The Danish Growth Fund.

The ERAC peer review also had a broad scope addressing how to increase innovation capacity throughout the educational system. For instance, recommendations were given to promote entrepreneurship training, introduce a more performance-based funding system for education, and redirect student uptake towards STEM-educations and private sector employment. Even if not

directly emanated from the ERAC peer review, initiatives in these fields have later been implemented by the Government.

5 CURRENT REVIEWS AND POLICY DECISIONS WITHIN KNOWLEDGE BASED INNOVATION

5.1 Review of university knowledge transfer

As part of the current Government's research and innovations strategy, it is stated as an objective that the transfer of knowledge and technology from universities to SMEs and entrepreneurs should be increased. The transfer processes to SMEs and entrepreneurs should become more agile, and the terms in negotiation of IP agreements should be simplified and - if possible - standardized. This reflects a view from some entrepreneurs and business organisations that university TTO's are not sufficiently professional and accommodating.

In reply, The Ministry of Higher Education and Science jointly with the universities in 2018 initiated an inspection of the universities' technology transfer activities. This will also encompass the overall legislation in the area. The aim of the inspection is to remove any possible barriers and counteract any over-implementation of EU regulations.

The final report is due for the first half of 2019.

5.2 Evaluation of the Innovation Fund Denmark

As an integral part of the political decision of establishing the Innovation Fund Denmark in 2013 it was decided that the IFD should be evaluated in 2018. This evaluation was commenced in the autumn of 2018. An international panel of experts does the evaluation. Results of the evaluation are expected by April 2019.

5.3 Investigation of the supply of technological services

The Danish not-for-profit RTO's are supported through a system of approval by the minister followed by the opportunity of seeking financial support through performance contracts that co-finance specific R&D activities at the RTO's. The Danish RTO's enjoy a general support by interested parties. However, occasional suggestions for redesign of the RTO-system has been voiced. To investigate this the MHES conduct a specific exercise consulting interested parties on the suitability of the current system. The work is done within the framework of the review of the Danish knowledge based innovation system. Conclusions from the consultations are expected in March 2019 and will be presented to the panel of international experts to reflect upon.

6 RECAPITULATION

The Danish knowledge based innovation system has developed from an original industrial policy over technological and research policies to present day innovation policy. The development have been driven by technology, by certain industrial sectors, and to some degree by a technology push mindset. This has

also meant that the policy originated with a focus on multiplier activities bringing technology and innovation knowledge from few activities to many recipients. Today this approach have been supplemented by projectfunding in the IFD, with a substantial part of the funding for one on one projects with industry and research.

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This background report for the Peer Review of the Danish R&I system focuses on providing the key indicators on knowledge-based innovation in Denmark and sets these indicators in the context of the developments in innovation policy in the country. Appendices to this report (separate reports) entail a self-assessment of the Danish knowledge-based innovation system by the Danish Ministry of Education and Science and a literature review and assessment of the Danish knowledge-based innovation support system, commissioned by the Ministry.

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