Markets for Applied Research

A comparative analysis of R&D-systems in five countries

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NIFU

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Foreword

The main objective of this report is to identify strengths and weaknesses of the Norwegian system for applied research by comparing it to the systems in Sweden, Finland, Denmark and the Netherlands. The report was commissioned by the Norwegian Ministry of Education and Research, as part of the background analysis for the government white paper on research planned for 2013.

The Nordic institute for studies of innovation, research and education (NIFU) carried out the major part of the study. The project team was headed by Katarina Larsen, affiliated researcher at NIFU and based at the Royal Institute of Technology (KTH) in Stockholm. Major contributors from NIFU were Espen Solberg, Ole Wiig and Gunnar Sivertsen. NIFU has also collaborated with the Centre for studies in Research and Research policy (CFA) at the University of Aarhus (Denmark), represented by Kaare Aagaard. In addition, Inge Ramberg and Hebe Gunnes, both from NIFU, have provided input to the study.

The work was guided by an internal reference group consisting of prof. Sverker Sørlin (KTH/NIFU), prof. Magnus Gulbrandsen (University of Oslo), Susanne Sundnes and Karl Erik Brofoss from NIFU. Olav Spilling provided valuable input in the final phase of the project.

An informant group was set up in order to provide information for the case study of six technical research institutes. Their input was crucial for the analysis presented in chapter 8. For this we owe a special thanks to Dr. Jens Neugebauer (Fraunhofer-Gesellschaft), Dr. Leena Sarvaranta (VTT), Dr. Freek Heidekamp (TNO), Mr. Olof Sandberg (RISE), Mr. Ragnar Heldt Nielsen (GTS) and Mr. Ernst Kristiansen (SINTEF). We are particularly thankful to Mr. Kristiansen who coordinated input from the group throughout the project.

We would also like to thank Mr. Jan van Steen for sharing data and knowledge about public R&D budgets and about the Dutch R&D and innovation system.

Last but not least, the Ministry of Education and Research and the appointed reference group has provided valuable input, in particular by organising a workshop chaired by the Minister of Education and research. We thank the Ministry for financing this challenging and interesting project, and hope that this report will provide a useful background for the further development of policies for applied research and research institutes.

Oslo, 19.12.2012

Sveinung Skule	Olav R. Spilling
Director	Head of Research

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Executive summary

This study aims to assess strengths and weaknesses of the Norwegian system for applied research by comparing it to the systems in Sweden, Finland, Denmark and the Netherlands. These countries represent both similarities and differences which make them relevant for a comparison with the Norwegian system.

The benchmark is, however, rather ambitious, since all countries considered are strong, well developed and knowledge-intensive economies. The three Nordic peers are among the most R&D-intensive economies in the OECD area, and are characterised as “innovation leaders” in the Innovation Union Scoreboard. Norway, together with the Netherlands, appears significantly less R&D- and innovation intensive, mainly due to high exposure in traditionally low-tech and low R&D-intensive sectors.

Main policy trends

The countries also vary a great deal in terms of policy strategies and institutional set-up. Norway, Finland and the Netherlands all have a significant share of R&D performed by research institutes. Sweden has traditionally had a more dual system, with universities and technical state colleges serving the needs of industry and public sector. However, since the middle of the 1990s, Sweden has systematically strengthened the role of research institutes, partly in order to bridge the “valley of death” between industry and academia and overcome the Swedish paradox of high scientific quality and low value creation. Denmark seems to have moved in the opposite direction, by merging most public research institutes into the higher education institutions. This has resulted in a more dual system in Denmark, although a network of approved technological service providers (GTS institutes) remains an important bridge between academic research and industry.

The need for structural change and strategic orientation are hot topics in R&D policies in all the five countries considered. A concrete question is whether research institutions should be merged into larger entities in order to increase critical mass and allow for more cross-sectoral and cross-disciplinary research. Denmark is undoubtedly the country which has moved furthest in this direction – so far with rather mixed experiences, at least seen from an applied research perspective. Structural change is also high on the agenda in Finland, but in contrast to the Danish approach, Finland is focusing more on mergers between research institutes rather than incorporating institutes into universities. Norway and Sweden seem more preoccupied with strengthening the links and smoothing the division of labour between research institutes and higher education institutions. A major issue in Dutch R&D policies is the so-called Top sector initiatives, which include strategic steering, reallocation of funds and public-private partnership around nine selected areas.

A common concern for all countries seems to be the need to ensure that the R&D and innovation system is able to produce research which is oriented towards meeting societal challenges and securing future sources of growth.

Comparing supply and demand for applied research

Comparative data on research institutes and applied research is hard to obtain. However, by combining traditional and more experimental indicators, it is possible to draw a fairly comparable picture of the supply and demand for applied research in the five countries in question.

On the demand side, Finland and Norway appear with the most applied oriented systems with regard to public funding. Roughly half of all public funding in these two countries is considered to have an applied focus. The corresponding shares in the other three countries range between 20 and 30 per cent. Private funding for applied research is, however, less abundant in Norway and the Netherlands since these two countries are relatively less R&D-intensive. On the other hand, firms' propensity to purchase R&D from actors outside the concern is highest in Norway, where this form of purchased R&D amounts to nearly 25 per cent of business in-house R&D. Quite the opposite is the case for Sweden where the quasi totality of business R&D is performed within the concern. In summary, we find that Norway is characterised by a relatively large domestic market for applied research.

Our investigation of the supply side of applied research takes into consideration a broad range of actors. Unsurprisingly, we find that research institutes are most important in the Norwegian system, although both Finland and the Netherlands also have a considerable share of applied research performed by institutes. R&D-oriented consultancies seem to play an important role in both Sweden and Denmark, while such organizations appear less important in Norway. The latter observation should be seen in relation to the extensive role of business oriented technological institutes in Norway. Higher education institutions are particularly important suppliers of applied research in Denmark and relatively less important in the Norwegian system.

A closer look at six large technical research institutes reveals i.a. that Norway's SINTEF and the Danish GTS-institutes have a low basic funding compared to their peers in other countries. At the same time this basic funding for SINTEF comes with few strings attached and is therefore not used as a tool for strategic steering from government. In terms of total funding from abroad, the Danish technical service institutes (GTS) stand out as the most internationally oriented institutes. SINTEF and the Finnish VTT are however most competitive among the six when it comes to EU-funding. Through bibliometric analysis we also find that technical research institutes collaborate extensively with national universities and local universities of technology. SINTEF has the lowest level of international co-publication. However, the share of international co-authorship has risen considerably in all six institutes over the last two years. One conclusion from this case study is therefore that technical research institutes are important players in both local and international knowledge flows.

Bibliometric analysis is also used in order to study actors and dynamics in the area of social and welfare research. We find that Norway's scientific production in this area is much more dominated by research institutes than is the case in the other countries we compare to. When comparing within the group of institutes, Norway also stands out with the highest number of institutes, even regardless of the size of countries. This may indicate a risk of fragmentation and overlap between the Norwegian institutes in these areas. However, output results both in terms of publications and citations do not indicate that the total Norwegian scientific activity in these areas suffers from the fact that a relatively large share of Norwegian research is carried out by research institutes.

Strengths, weaknesses and policy options

By comparing countries according to a set of established indicators, we assess the strengths and weaknesses of the Norwegian system for applied research. In terms of scientific quality, Norway performs very well, although slightly lagging behind the leading countries.

The Norwegian system performs well also when it comes to cooperation patterns and relevance for the users. Innovation data reveal that research institutes are relatively frequent innovation partners for Norwegian firms. In addition, data from the first Nordic pilot study of public sector innovation indicate that Norwegian research institutes and universities (together) are considered important and relevant innovation partners also for users in the public sector.

In terms of international competitiveness, Norway seems to perform rather well in the competition for EU-funding, although all the other countries we compare to in this study have higher success rates in the EU-framework programme. Norwegian performance in this area is however largely due to the research institutes, while higher education institutions seem less active on the European arena than what is the case in the other countries.

Industry renewal seems to be a particular concern for the Norwegian system. Firstly, it is well known that the Norwegian industry structure is relatively low R&D intensive. Secondly, Innovation activity in Norwegian firms seems to be low and decreasing. Thirdly, industry specialization seems to be increasing to such a degree that Norway today is one of the most specialized economies in the OECD area. Even though the economy is strong at present, these observations raise the question of whether stronger action is required to stimulate innovation and industry renewal. The role of institutes should definitely be seen in relation to this challenge.

Confronted with this challenge we recommend that policies both aim to increase R&D and absorptive capacity in firms and at the same time increase the basic funding of institutes so that they are equipped to provide firms with the more forward looking and high risk research which is required for assuring the more long term renewal of the Norwegian economy.

A second issue of concern is the Norwegian system's ability to address broad societal challenges through R&D. The Norwegian R&D-system is characterized by a high degree of actor pluralism, both on the political level and on the performing level. This pluralism may be difficult to combine with an increasing emphasis on broad cross-sectoral challenges and objectives. Furthermore, we see a general need for policies aiming at strengthening the presence of Norwegian institutes on the international arena for applied research services.

Based on experiences from other countries, we do not recommend top down mergers in the Norwegian system. Nor do we find space for increased competition, as this aspect is already highly pronounced in the Norwegian funding system. Instead, we recommend that strategic funding and dialogue should be further explored as a way to obtain more concentration, better division of labour and cooperation towards multi-disciplinary grand challenges driven research. Strategic funding could also provide the industrial institutes with sufficient resources to avoid market driven specialization and lock-in.

1 Introduction

There is no consensus about what could be the optimal level and profile of research and development in a society. Nor is it possible to define the characteristics of an optimal R&D and innovation system. The only viable way to assess the performance of a system is to compare it across space and time (Edquist 2011). Comparative studies are therefore essential for the understanding of strengths and weaknesses of R&D- and innovation systems.

This project is about exploring the characteristics and the performance of the Norwegian system for applied research. In order to do so, we compare Norway to four other countries, namely Sweden, Finland, Denmark and the Netherlands. Although similar in many ways, these countries represent a number of different systemic features which provide us with useful benchmarks for assessing the Norwegian system.

At the outset, it is necessary to underline that the countries to which we compare the Norwegian system are all well-developed societies, with strong economic performance and advanced science systems. Hence, one should bear in mind that the benchmark is ambitious, and that lagging behind some of these nations is not necessarily an indication of alarming weaknesses.

Furthermore, international comparisons always encounter difficulties related to the availability and comparability of data. Unfortunately, this is particularly the case for international comparisons of research institutes and systems for applied research. As a result, many of our comparisons have had to compromise between the accuracy of country-specific data and the more superficial perspectives provided by international comparable data.

An analysis of research institutes and their role in national R&D and innovation systems must also be made with reference to a wider backdrop of societal and economic conditions. In our project, we take account of these contextual issues by highlighting some main characteristics of the five societies at large.

The role of research institutes in science and innovation systems is poorly understood, and has even been referred to as “the forgotten step-child of innovation policy”. Our analysis proposes some new ways of measuring and understanding both the supply and demand side of applied research. We hope that that these new approaches, as well our general analysis, may trigger the discussion and contribute to a broader understanding of the role of research institutes in national R&D and innovation systems.

2 Data, methodology and definitions

Our approach consists of three main elements:

- Extensive use of R&D and related statistics
- Desk studies of relevant research, evaluations and policy documents
- Interviews and reality checks with centrally placed researchers and policy makers in the countries concerned

This three-step approach has been used primarily in the general mapping of the five systems and to some extent in the two case studies.

2.1 Data and methodology

R&D statistics and data sources: Due to severe gaps in the data on research institutes and applied research in traditional R&D statistics, we also use alternative sources. This includes e.g. use of data on Government Budget Appropriations and Outlays for R&D (GBAORD), experimental data on government R&D budgets, as well as self-reported data from institutes and government (case studies). In addition, our use of bibliometric data has been more extensive than foreseen, since this has proved to be an appropriate way of framing research areas and groups of institutes which are not specified in traditional R&D statistics.

Desk research: A number of previous studies and mappings have been useful and inspirational for this project. We have also made extensive use of recent policy reports and evaluations in the five countries. The general findings from policy documents are summarised and presented in chapter 5.3.

Qualitative information from key informants: The project team comprised researchers from Norway, Denmark and Sweden. This has in itself been helpful in order to get a good and updated understanding of central issues and the national context in three of the five countries. This has also provided a network of key informants in all five countries. Contributions and considerations from these informants have been particularly useful for the chapter on recent policy developments (chapter 5.3). Finally, the project has profited from the established informant group with centrally placed representatives the institutes subject to the case study of six technical research institutes.

2.2 Bibliometric analysis

The bibliometric analysis in chapter 8 was conducted by searching Web of Science for publications containing the addresses of RISE institutes published 2002-2011. The synonyms of affiliated organisation names were homogenised and the types of publications included Articles, Proceedings Papers, Reviews and Letters. In total 2542 publications were included in the analysis. The address field and the country field of the addresses were used for the analysis of organisations. In the analysis of co-authorship data, the duplicates were removed (counting the number of co-published publications).

2.3 Some conceptual issues

The term **applied research** is a central element in this study. In the OECD Frascati Manual, applied research is defined as

"[…] *original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective*." (OECD 2002)

Despite this well established definition, the term is problematic in several respects. The practical distinction between applied research, basic research and experimental development is largely based on qualitative judgements from individual researchers and research administrators. Hence, the use and interpretation of the notion applied research varies to a great deal between disciplines, sectors and countries. Partly for this reason, a number of countries have refrained from reporting data for types of R&D. This includes Sweden, Finland and the Netherlands. Secondly, we have noted that the Ministry, in its call, uses the term "research for applied purposes in industry, public sector and society at large". For these two reasons, we base our project on a wider understanding of the term, but for practical reasons we generally use the term applied research throughout the report.

As a consequence, we have to approach the mapping of applied research in new ways, i.e. through institutional classifications used in official R&D statistics. Central to any study of markets for applied research in Norway is **the institute sector**. The Norwegian institute sector comprises various R&D performing units. Inevitably, research institutes, i.e. institutions primarily devoted to R&D, constitute the larger share, but the sector also comprises other institutions, private or public, performing R&D to a greater or smaller extent. The institute sector as a statistical concept has been used in national Norwegian R&D statistics for decades, and does not directly correspond to the R&D performing sectors defined in the Frascati Manual, i.e.:

- Business Enterprise sector
- Private-Non-Profit sector
- Government sector
- Higher Education sector
- Abroad

Despite an increasing interest in the role and performance of such organisations over the past few years, research institutes are not immediately distinguishable. The most commonly used basis for comparison is the Government sector. This conception, however, would give a too narrow picture by notoriously ignoring R&D institutes mainly serving firms, e.g. SINTEF, because they are accordingly classified in the business enterprise sector.

In addition, since the focus of this study is the supply of and demand for applied research regardless of institutional classification, all five sectors are in principle relevant. But the established classification makes it difficult to identify institutes across countries in a comparable way. This is a particular challenge since the research institutes are classified as a distinct sector in Norwegian R&D statistics. Our statistical approach will therefore have to handle some challenges related to asymmetries in the institutional classifications in the five countries. Thus the scope has to be broadened, and alternative, experimental use of data is necessary. We will return to this in chapter 7.

Finally, the **notion of market** can be understood in a number of ways. Most definitions include the existence of a direct or indirect economic transaction. But the exchange of knowledge may very well be subject to softer and more indirect forms of transactions. For instance, in a recent project the OECD uses the term "Knowledge Networks and Markets", thereby suggesting that the supply and demand for knowledge may be subject to other dynamics than economic transactions (OECD 2011). This standpoint emphasises networks as a way of organising fields of activity and markets (Powell 1990) and learning processes associated with networks of small firms, institutes and universities (Powell et al. 1996). Our mapping of markets for applied research will therefore open for a broad understanding of the notion of market. This implies for instance that we also analyse and take into consideration the softer aspects of co-operation through co-publication and informal knowledge flows.

3 Changes in the R&D and innovation landscape

Markets for applied research, and the role played by the universities, research institutes and other actors in these markets, are changing.

The roles of universities in these changes have been conceptualised in a range of theoretical models, including triple-helix, development blocks, innovation systems and clusters, to mention a few.

The university sector, its evolution over time and funding mechanisms have been thoroughly analysed, also in cross-country studies of the economics of knowledge production and university roles in industrial transformation (Jacobsson 2002, Geuna 1999). A general picture is that universities move “downstream” to engage more with industry and society. Institutes have a longstanding tradition of interacting with both university and industry sectors, as shown in an analysis of technical-industrial research institutes in the Norwegian innovation system (Nerdrum and Gulbrandsen 2009).

Another general tendency is a shift towards actor complexity and funding diversity in innovation systems. Historically, a large responsibility for innovative capacity has been placed on universities, partly as research performers but even more so as providers of research-based training of undergraduates and advanced level students, what is commonly called the ‘human capital model’. Using Sweden as an example, this model with provision of great numbers of university trained students to a limited number of large R&D performing companies has been largely successful, but has run into serious problems in recent years.

This has been associated with globalisation and emerging markets, as well as an increasing complexity entering the innovation process where large numbers of small players with innovative technologies have increasing possibilities of performing vital innovative functions by means of cheap and small scale operations. Customer oriented, complex innovation in order to serve emerging and often unforeseeable niches in the market is not well taken care of by the traditional human capital model. That is one basic explanation behind a return to a more multi-faceted innovation agenda characterised by actor pluralism and strategic diversity. This diversity also translates to diverse niches occupied by different institutes (Bienowska et. al. 2010) affecting their modes of knowledge transfer, commercialisation strategies and interaction in the innovation system.

This also explains the renewed interest in institutes, and in particular research and technology organisations (RTOs). Universities will undoubtedly continue to have a fundamental role in the innovation systems of most countries by providing highly trained specialists to industry and public sector and by performing path-breaking research, sometimes in collaboration with industry.

However, it is difficult even for a diverse and large university system to cater to all kinds of needs that dynamic and ever changing innovation systems will have. That explains the need for flexible, and customer oriented R&D performers with a pronounced market and needs-based orientation.

In addition, international developments suggest alternatives to a university oriented model. In China universities receive only a fraction of public R&D spending, while a considerable share is directed to the large number of more or less sectoral and strictly mission-oriented public research institutes (Liu and White 2001). China in this respect has adopted a structure that has been common in Eastern European countries and the Soviet Union, with more research being performed in academies and institutes and less in universities (Chang and Shih 2004). In other countries the share of public funding directed to universities is much larger. In the extreme Swedish case a relatively small share of public funding is devoted to industrial institutes, for example compared to countries like Norway. In the US roughly one third of federal funding is directed towards university research and about the same share goes to federal laboratories and special institutes. Direct funding to firms that perform R&D is also a major feature of the US system.

These tendencies also create a need to *rearticulate the roles and missions* of various actors. Historically, the overarching idea for research systems, almost always nationally defined, was to think in terms of a division of labour. For example, the industry oriented institutes were expected to serve as a mediator or bridge academia and industry, thus giving them a role distinct from both industry and the universities. Similarly the role of institutes in other sectors involved a mission distinctive from those of the universities and government departments.

The tendency to move away from this clear cut division of labour means that institutions of different kinds increasingly overlap, in that they approach the same, competitive, funding sources and cater to similar customers. Institutes must both compete and collaborate among themselves and with universities and other providers. This calls for policies that make sure that different actors can assume these new roles. The state’s role as a primary funding agency for public universities is undisputed in Europe for the foreseeable future, and although growing shares of private funding and student fees are likely to be introduced, they will not substantially alter the basic proportions of private and public support.

At the same time the marketisation of research institutes, while a sound idea in many instances, has driven the basic/core funding of that sector down to levels that may in a longer term perspective undermine their functionality as research and advanced analysis organisations. This is acknowledged by governments in several countries, and the structure, funding and policies for institutes is therefore under discussion or undergoing reform in a range of European countries, including most EU member states. There is now a growing support for the institutes. In countries with solid and longstanding industrial research institute sectors, like Germany, the Netherlands, Finland, and Spain, institutes show few signs of weakening. On the contrary, they reaffirm their positions in the diversified landscape of R&D performers taking on more comprehensive roles and increasing their budgets and activities, leaving the three-hump model behind.

In countries with smaller institute sectors (and larger university sectors) there is a visible change of policy going on in adjustment to the new demands; RTOs are being entrusted with growing roles in the innovation systems, according to the logic just described. Sweden and Denmark are two examples of this. After a period of decline in the Swedish institute sector a phase of reinvestment and strengthening has now begun, in part in order to make advances in European service and R&D markets. In Denmark the GTS institutes have been restructured and are now the object of changes that aim to give them a more offensive, strategic role.

Some recent propositions in the Swedish science policy context argue for a shift to research funding and innovation systems geared towards entrepreneurial activity and societal use of research (Källén 2012, Braunerhjelm et al. 2012). There is also an anthology by the umbrella organisation for Swedish research institutes stressing the importance of a diverse set of actors performing research and also voices from industry about the importance of strong relations between academia, industry and society (RISE 2012).

From an innovation systems perspective, the entrepreneurial activity is only one of several dimensions of the innovation system. Hence, one challenge from a policy perspective is, firstly, to understand the different functions performed by the innovation system, and secondly, to target areas where there is scope for impact from policy intervention. Phrased in a system analytical way: the challenge for policy makers to identify the processes and components in a system where intervention is likely to matter most. This question is the starting point for previous work in the area of environmental innovations by defining different types of functions carried out by innovation systems in order to identify system weaknesses that calls for policy intervention (Jacobsson and Bergek 2011). Some examples of functions included are: knowledge development and diffusion, entrepreneurial experimentation, influence on the direction of search, resource mobilisation and market formation.

Another type of studies are evaluations of research investments and interaction between research performers including institutes (Arnold et al. 2007) in addition to analysis of more broader themes of "strong research and innovation systems" (Åström et al. 2011). For the Norwegian institute sector, some key points are addressed responding to various critical views of having too much funding devoted to institutes (Nerdrum and Gulbrandsen 2009, p. 328). The main points of concern associated with a large commitment to institute sector include::

- Absorptive capacity weakness of Norwegian industry (if skilled workers go to institutes instead of industry)
- Preventing university from modernising their research practices and relationship with industry
- The relatively large size of the Norwegian institute sector and public funding prevents university from enabling "a critical mass"

Much of this critique has been refuted both through various system evaluations and policy statements. The role and importance of institutes is however a topical issue in Norwegian R&D policy, and hence the main motivation behind this study.

4 The Systemic context in five countries

Applied research is by definition[1] directed towards specific aims and objectives. It is therefore important to consider supply and demand of applied research in the context of societal needs and structures. In this chapter we first give a broad overview of some main similarities and differences regarding economic and societal issues in the five countries concerned. We then look further into the main characteristics of the science and innovation system in each country.

4.1 The broader context

The five countries in question are all relatively wealthy, open and advanced knowledge economies. Measured in population, the four Nordic countries are in the category of small countries, while the Netherlands would be labelled a medium sized country. However, measured in GDP, all five countries are economies of a considerable size. Together, the five countries would have constituted the 9th largest economy of the world. Table 5.1 gives an updated overview of some key figures for the five countries.

Table 4.1 Key figures for the five countries + EU27 average

	Mill. population 2012	GDP/capita rel. to EU27 2012	Unempl. rate 2012	Share of pop. 30-34 years with tertiary education	Share of total employment in services 2008 (private/public.)
Norway	5,0	**181**	**3,0**	**48,8**	77 (39/38)
Finland	5,4	116	7,9	46,0	71 (37/34)
Sweden	9,5	126	7,8	47,5	76 (38/38)
Denmark	5,6	125	8,1	41,2	77 (42/35)
Netherlands	**16,7**	131	5,4	41,1	**80** (47/33)
EU 27		100	10,6	34,6	

Source: Eurostat/OECD

With the exception of Finland, all the countries studied are among the most service-intensive economies in the OECD area. The Netherlands is second only to the UK in this respect. While service

[1] See chapter 2 for a further discussion of the definition of the term “applied research”

employment in Norway and Sweden is evenly balanced between public and private sector, private sector services appear more important in the Danish and the Dutch economy.

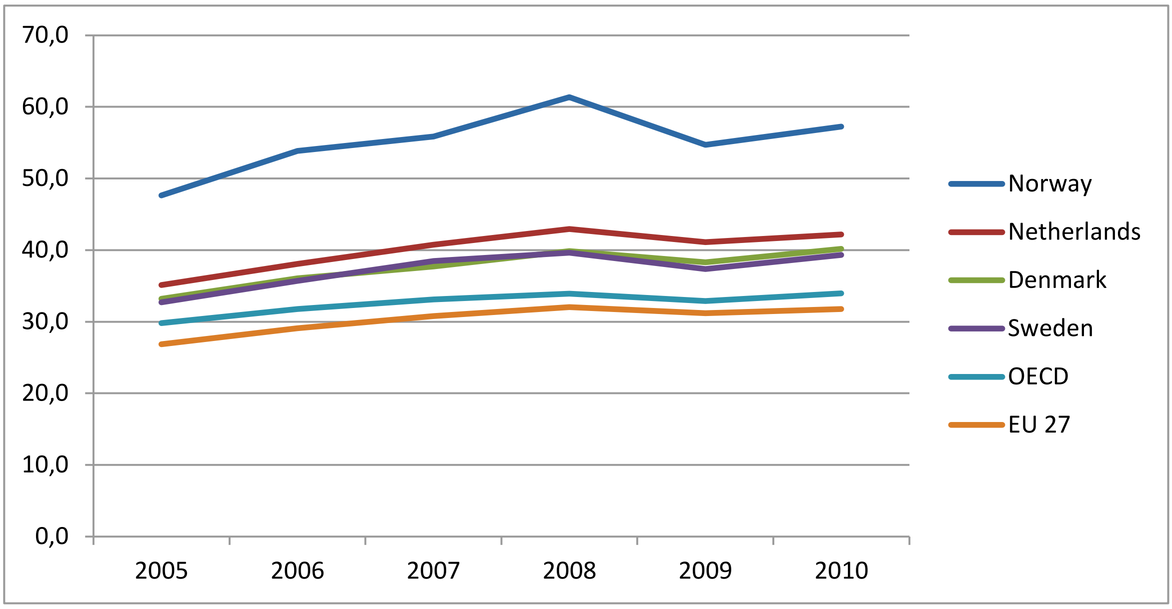


Figure 4.1 GDP growth patterns 2005-2010

Source: OECD MSTI 2012:1

In terms of economic cycles, Norway stands out with a persistently high level of GDP per capita, both compared to the other four countries and compared to OECD and EU average. All countries experienced high economic growth in the years before the crisis, followed by a downturn in 2008 and 2009. The countries seem to have recovered from the worst effects of the crisis. This is particularly the case for Norway and Sweden, while recovery seems to be more sluggish in the three other countries.

The public sector plays a strong role in the economy in all countries, but apparently less so in Norway, where government expenditure is below 50 per cent of GDP and more in line with the OECD average. However, one should take into account that Norway's GDP is considerably inflated by oil and gas revenues. Hence, if we look at Norway's Mainland GDP, the share of government expenditure in Norway is considerably higher.

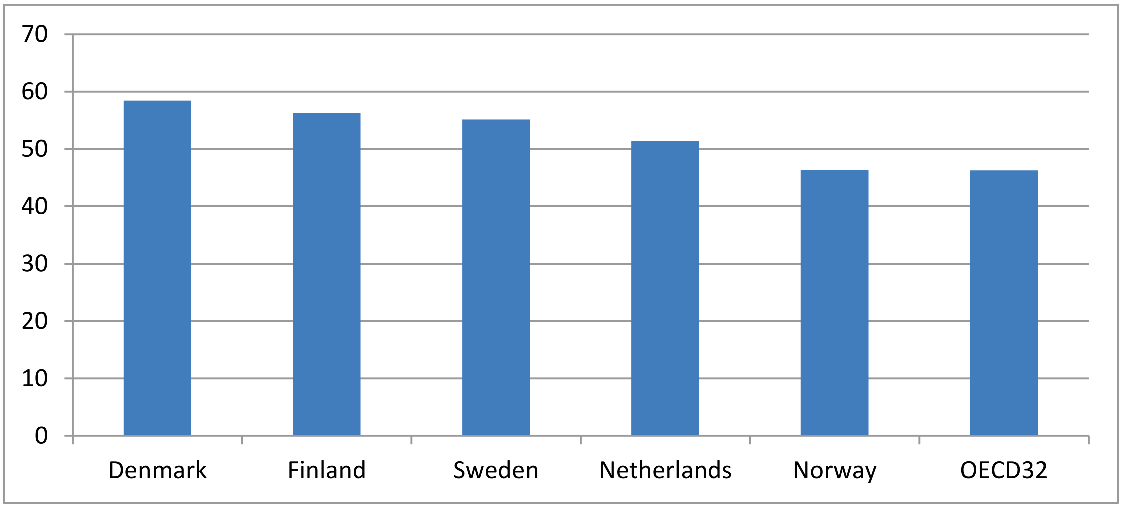


Figure 4.2 General government expenditures as a percentage of GDP (2009)

Source: OECD National Accounts

If we look at the profile of public spending, the countries have a quite similar profile. All Nordic Countries have a relatively large share of public expenses devoted to *general public services*. Norway has the highest share of expenses related to *health*, while Denmark stands out with the lowest share of public funding directed towards *economic affairs*. This latter category reflects the level of public spending towards business development in general as well as support to specific industry sectors.

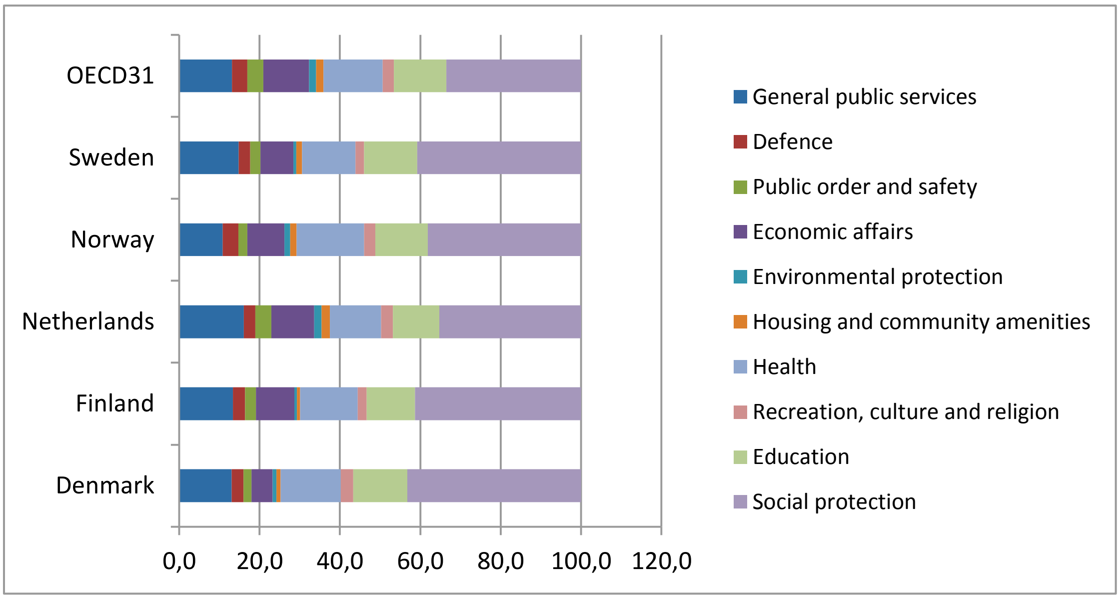


Figure 4.3 Structure of general government expenditures by main function (2008)

Source: OECD National Accounts Statistics

The country differences are more significant when we look at the industry structure. As figure 3.4 clearly indicates, Norway stands out with a significant share of industry value added from mining and quarrying, which in the Norwegian case more or less consists of the oil and gas sector. Finland is the country where manufacturing still accounts for a considerable share of industry value added, but the importance of manufacturing has declined significantly also in Finland, from a share above 25 per cent in 2000 to a level well below 20 per cent in 2009. The other side of the coin is of course a growing share of value added from the service sectors. This seems to be the pattern in all of the five countries in question, but more so in Denmark than the other countries.

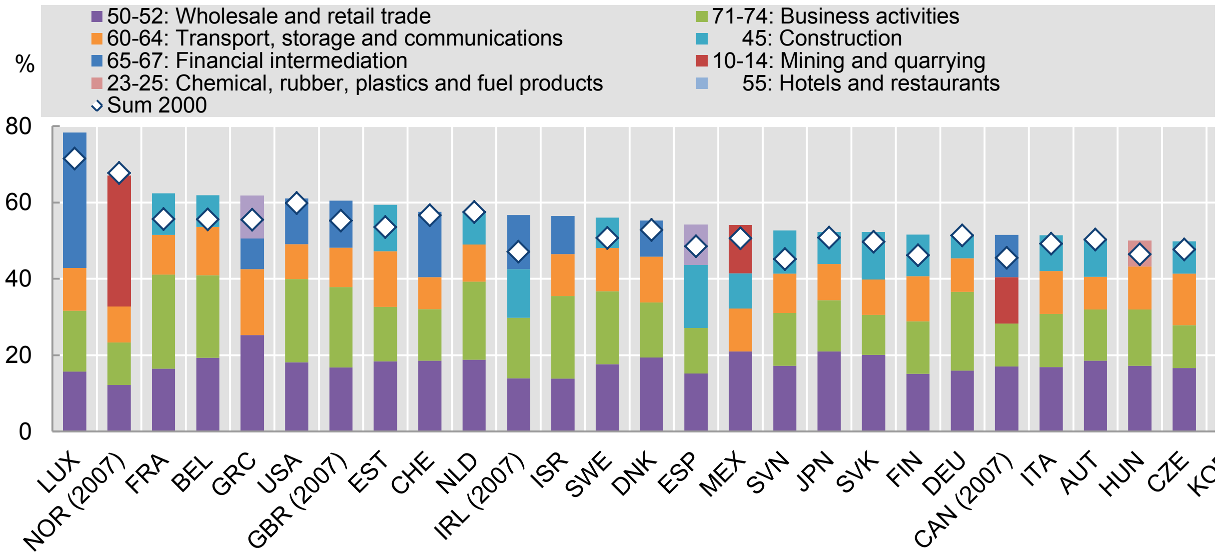


Figure 4.4 Structure of general government expenditures by function (2008)

Source: OECD, Structural Analysis Database (STAN), 2011

The societal and economic indicators in this section, provide a general background for the closer comparison of R&D and innovation systems in the following chapters.

4.2 Comparing five R&D and innovation systems

All five countries considered in this comparison have R&D and innovation systems with considerable strengths. The classical benchmark used in R&D comparisons reveals that Finland, Sweden and Denmark are among the world's most R&D intensive countries. Only three other countries (Israel, Korea and Japan) have R&D intensities above the "magic level" of 3 per cent of GDP. Norway and the Netherlands have considerably more modest R&D intensities when measuring total R&D expenditure as a share of GDP.

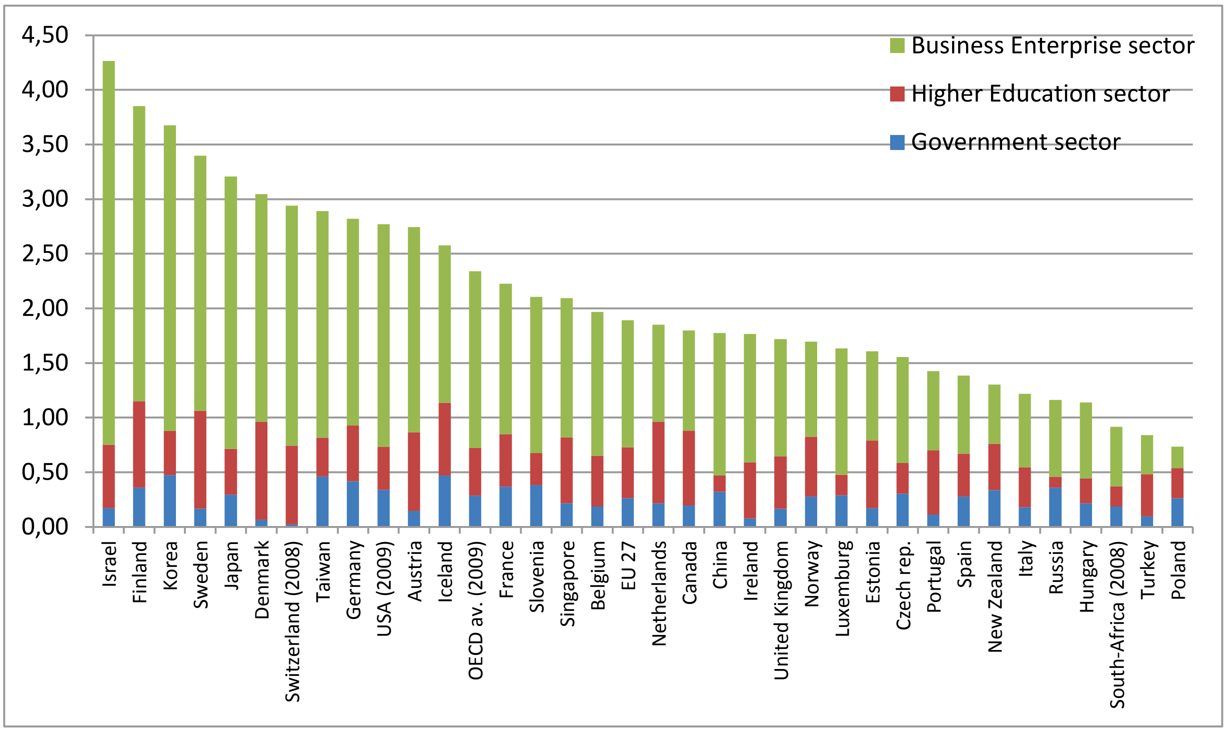


Figure 4.5 R&D-expenditure as a share of GDP by performing sector (2009)

Source: OECD, Main Science and Technology Indicators (MSTI) 2012:1

At the same time, the gap between Norway/Netherlands and the three other Nordic countries is almost entirely due to the level of R&D in the business enterprise sector. Hence, R&D intensity in the five countries is fairly similar if we only look at R&D in the government and the higher education sector. This is also reflected in the funding structure, where all five countries are characterised by a relatively high level of public funding to R&D.

As a consequence, R&D expenditure in the higher education sector is high in all five countries. In fact, as illustrated by figure 5.6 below, Sweden, Denmark, Finland and the Netherlands are the four leading OECD countries in terms of R&D expenditure in the higher education sector as a share of GDP. Particularly noteworthy in this respect is the steep growth in Danish public funding to R&D in the higher education sector. This reflects the recent mergers of public research institutes into the higher education institutions.

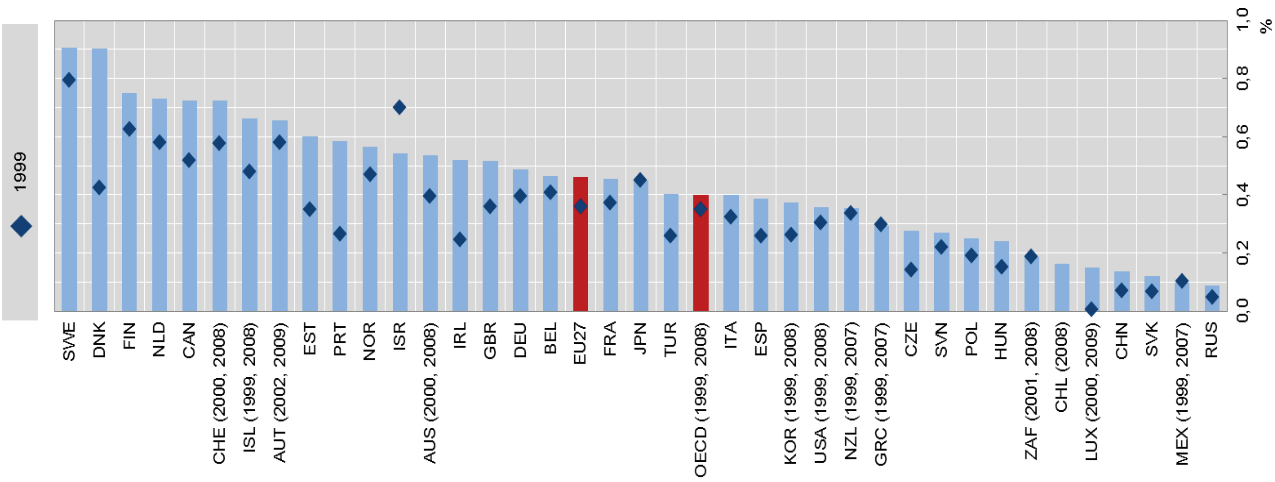
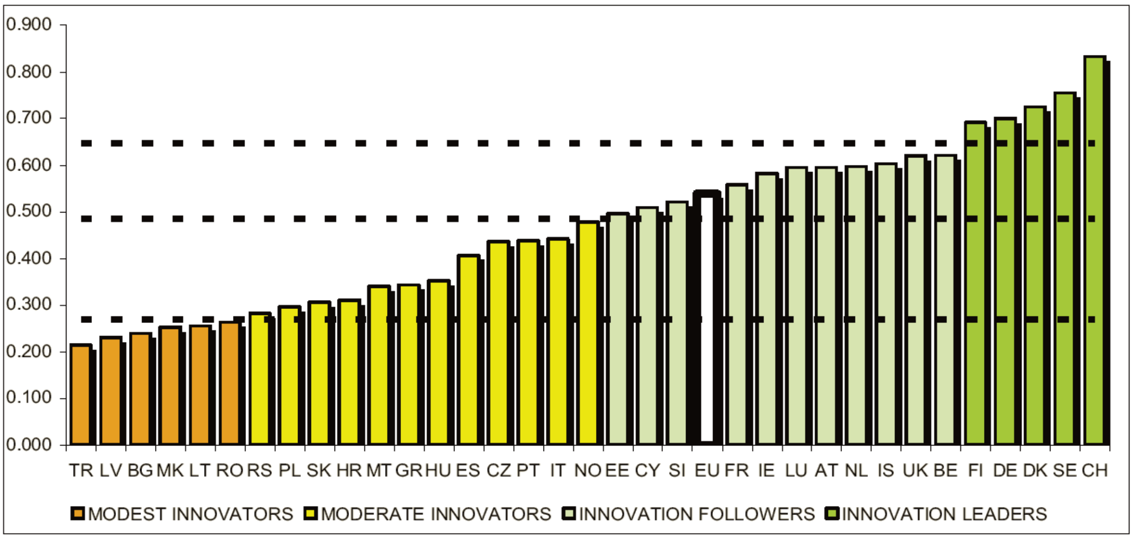


Figure 4.6 R&D-expenditure in the higher education sector as a share of GDP, 1999 and 2009

Source: OECD, Main Science and Technology Indicators Database, 2011

Again, we need to take into account the relatively high level of GDP in Norway. Hence, Norway's government expenditure on higher education R&D is among the highest when measured per capita.

The European commission's Innovation Union Scoreboard (IUS) is another frequently used benchmark for comparing national innovation systems. According to this set of indicators, Sweden, Denmark and Finland are all in the group of "innovation leaders". The Netherlands belongs to the group of "innovation followers", while Norway is considered to be among the so-called "moderate innovators".



Note: Average performance is measured using a composite indicator building on data for 24 indicators ranging from a lowest possible performance of 0 to a maximum possible performance of 1. Average performance in 2011 reflects performance in 2009/2010 due to a lag in data availability.

Figure 4.7: Average score in Innovation Union Scoreboard (IUS) 2011

Source: European Commission/UNU-MERIT, 2012

There is a considerable controversy over the relevance and accuracy of the IUS-indicators, in particular regarding the composite index which is the basis for the average score shown above.

Nevertheless, the scoreboard provides a well-established typology of innovation systems, where country-specific strengths and weaknesses are expressed by 24 different indicators. The IUS should therefore not be used as a benchmark for innovation performance, but rather as a tool for mapping characteristics of national innovation systems.

It is interesting to note that the five countries considered in this study share many of the same strengths, namely a particularly strong performance regarding scientific co-publication. All countries are considerably above the EU average in terms of scientific co-publications with international partners as well as co-publications domestically between public and private actors. In other words, there seems to be a strong tradition for scientific co-operation in the countries we consider. The moderate IUS ranking for Norway, and to a certain degree for the Netherlands, is therefore largely explained by low scores on indicators related to business R&D and high technology.

In its most recent Science, technology and Industry Outlook, the OECD proposes a set of indicators to characterise the policy mix in national R&D and innovation systems. In this comparison, The Norwegian system appears rather average regarding the balance between universities and public laboratories, while the system in total seems more oriented towards applied research, thematic research and project-based funding. These rough characteristics will be further explored in chapter 6, 7 and 10.

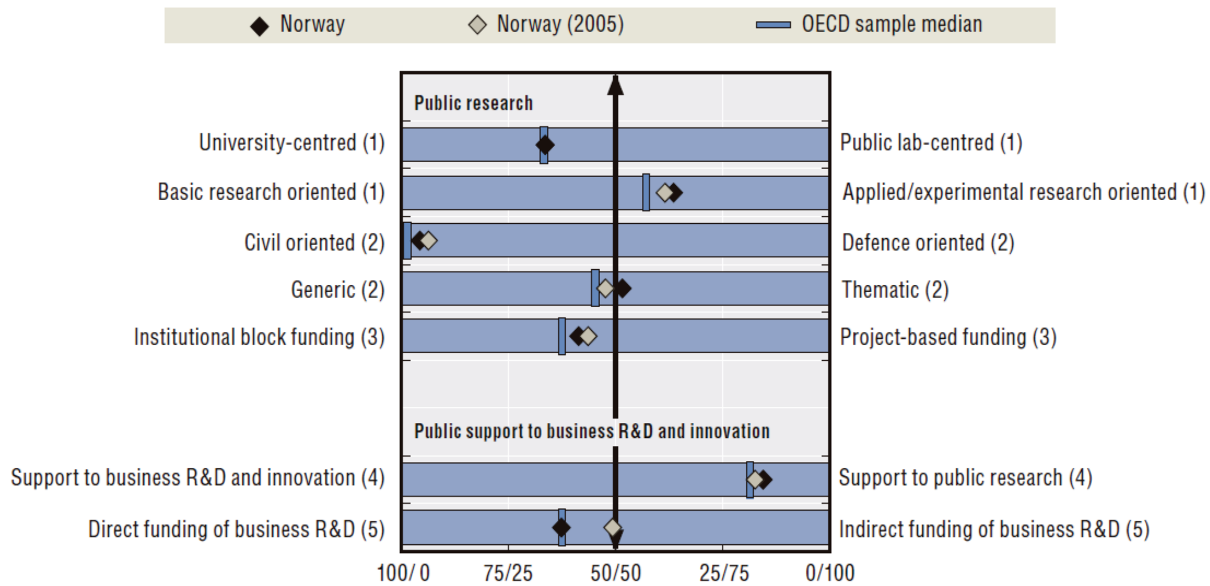


Figure 4.8 Policy mix according to OECD STI-Outlook

Source: OECD/STI Outlook 2012

5 Relevant policy trends and initiatives in the five countries

The following chapter gives a brief overview of the organisation and recent trends in the national R&D-systems in the five countries considered. A full comparison of all five systems is not possible within the framework of this project. We will therefore highlight some recent trends and processes in each country and see them in their particular national and systemic context.

Of course, reforms and policy processes are not concurrent across countries. Therefore our brief overviews from each country will have to be somewhat asymmetric in scope and coverage. For instance, the Netherlands is currently in a state of transition between two governments, and it is therefore difficult to identify clear directions in Dutch R&D and innovation policies.

The need for structural change and strategic orientation are hot topics in R&D policies in all the five countries considered. A concrete question is whether research institutions should be merged into larger entities in order to increase critical mass and allow for more cross-sectoral and cross-disciplinary research. Denmark is undoubtedly the country which has moved furthest in this direction – so far with rather mixed experiences. Structural change is also high on the agenda in Finland, but in contrast to the Danish approach, Finland is focusing more on mergers between research institutes rather than incorporating institutes into universities. Norway and Sweden seem more preoccupied with strengthening the links and smoothing the division of labour between research institutes and higher education institutions. A major issue in Dutch R&D policies is the so-called Top sector initiatives, which include strategic steering, reallocation of funds and public-private partnership around nine selected areas.

5.1 Sweden - “Reinventing the institute sector”

The Swedish R&D system has long been characterised by a two-divided structure between, on the one hand, governmental funding of research at universities, and on the other hand, private sector research as an important research performer in the Swedish innovation system (Sörlin 2004, Ds 2007).

With this clear dominance of publicly funded research at universities and private R&D as the two major research performers in the innovation system, the rationale for strengthening the institute sector in Sweden has for a long time been based on the role of institutes as a “bridge” between academic research and industrial research guided by needs of users.

Recent policy for strengthening the institute sector in Sweden is responding to challenges of long-term policy and clear “rules of the game” for the institute sector. Thus, the restructuring towards increased co-ordination aims to improve strategic orientation, pool resources and exploit complementarities, as described in the OECD reviews of innovation policy 2012.

Most Swedish institutes have previously been run as foundations, with certain limitations on actions and financial freedom. Today, many institutes have been transformed into limited companies with partially private and partially public ownership. At the same time, the public ownership of the Swedish institutes was organised into a holding company, IRECO, which more recently changed its name to RISE - Research Institutes of Sweden Holding AB. RISE consists of four corporate groups with a total of 17 RTOs and their subsidiaries.

In light of the so-called Swedish paradox, suggesting that Sweden invests heavily in research without reaping the rewards in terms of innovation, organisations such as RISE represent an increased focus on user-driven and applied research as a remedy to the paradox. The recent Governmental research and innovation bill for the period 2013-2016 stress the importance of application-oriented research, and calls for a strengthened institute sector and increased interaction between institutes, private sector and higher education sector (Gov Bill 2012).

The 2012 Governmental Bill also states that the institutes will be further strengthened. The 2012 research and innovation bill is emphasising the role of institutes as an innovation infrastructure providing resources (demonstration facilities and equipment) for users including small companies in addition to the traditional role of institutes in supporting Swedish industry and performing R&D in collaboration with larger companies.

The focus on application-oriented research based knowledge in recent policy documents is accompanied by a description of institutes as a resource for research and development in both public sector and for private sector including small and medium sized companies (Gov Bill 2012, p. 21).

In the OECD 2012 review of innovation policy in Sweden, the recommendations regarding the public research institutes include: to keep the RISE-structure and let it grow moderately if it directly serves the SMEs/SME-dominated sectors; consider mergers between institutes and (smaller) universities if this would lead to strong regional actors with a clear thematic focus, and ensure policy that encourage and/or facilitate business investments schemes that ensures access to research or technology-related information but also non-technological services and advice (OECD 2012b).

In Sweden, there are 14 state universities, 21 state university colleges and about 15 private institutions, of which three are entitled to award third-cycle qualifications – the Chalmers University of Technology, the Stockholm School of Economics and the Jönköping University Foundation (ERAWATCH 2012). Several in the technical-industrial research institutes are located near or on campus areas of The Royal Institute of Technology (KTH) and there is a history of collaboration and interaction though affiliation of professors, shared facilities (Vinnova 2005).

The Swedish research governance system is characterised by a diverse set of actors in terms of funding agencies and foundations. The diversity of the Swedish funding system is apparent when describing the research governance structure, as shown in the figure below from the Swedish 2011 ERAWATCH report. The public funding is predominantly funding research carried out at universities while private sector research accounts for a large share of the total R&D performed. Institutes are located in the interface between public and private performers of research.

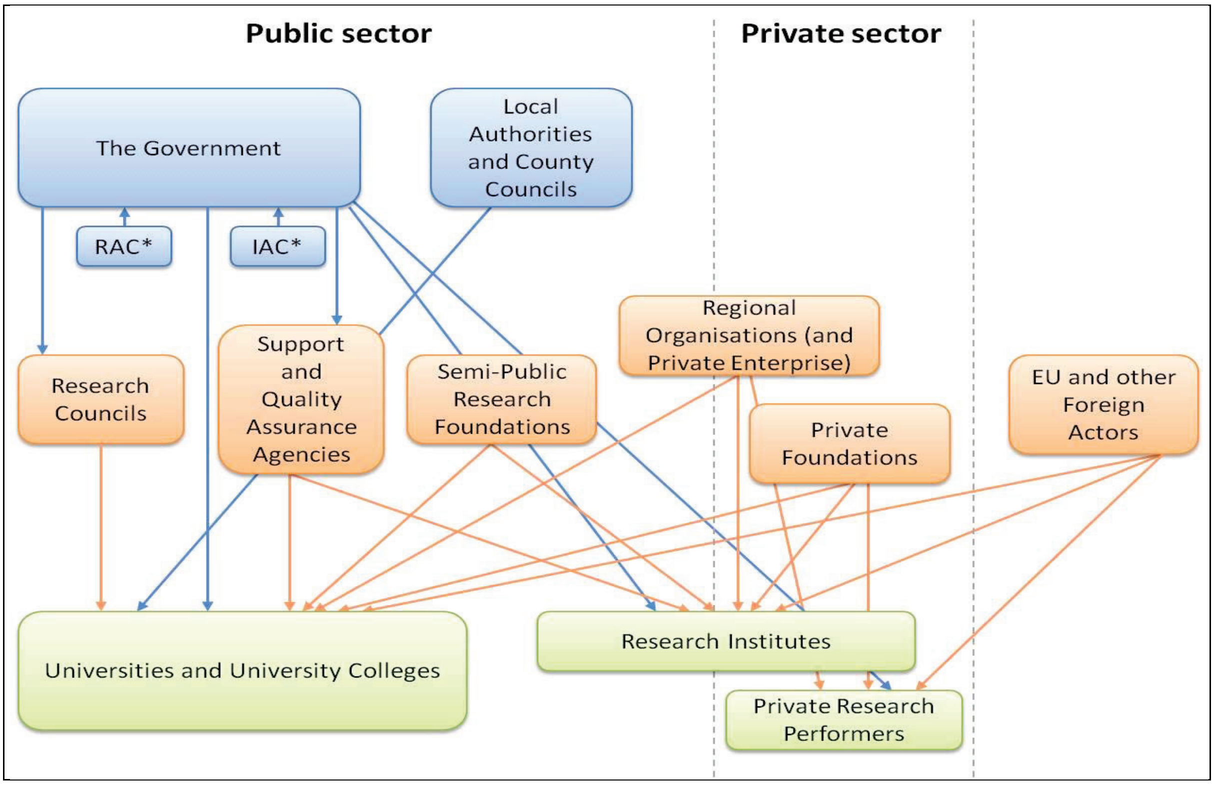


Figure 5.1 Overview of the Swedish R&D and innovation system

Source: ERAWATCH country report 2011

Institutes have been undergoing merger processes and there are also examples of active decisions to close down institutes. One example of the latter is the National Institute for Working Life (Arbetslivsinstitutet), which was the result of a merger between several institutes in 1995. The institute was closed down in 2007. Following the closure, the Government made agreements with 11 institutions to employ some of the researchers left unemployed. However, in the evaluation two years after the closure, the conclusions were that universities lacked the ability to assume the overall responsibility for working life research and that the capacity of work life research had been reduced (Albin et. al. 2009).

There are also examples of merger processes taking place among the technical-industrial research institutes combining areas of packaging research with paper and pulp research for example in the merger between the institute Packforsk and STFI in 2003. This process was characterised by emphasising existing networks and ongoing collaboration between the two organisations (Bienkowska and Larsen 2009).

One example of a merger between universities is the process of creating Linnéeuniversitet by merging two university environments (Högskolan i Kalmar and Växjö universitet) and create the new brand Linnéuniversitetet (Geschwind and Melin 2011). In this process, the key factors influencing the process were described as external, internal and regional; external research and education policy included i.a. increased share of external funds, reforms of funding allocation system, prospects and possibility to qualify as a university. Regional policies include local public policy, private firms and local media. While internal factors include internal organisation, economy, scientific quality, students, new brand etc.

The Swedish policy on concentration taking place by merging universities (Riksrevisionen 2012) is accompanied by policy for creating strong research environments in Centres of Excellence and Strategic research areas. The co-ordination and focus on the pre-defined areas can be considered to respond to a perceived weakness in the Swedish system relating to a fragmented system with little co-ordination in science and innovation policy and operations. On the other hand, there has been criticism raised about other (undesired) effects from concentrating resources on established research leaders and consequences for gender equality and career paths for younger scholars (Sandström et al. 2010, Sveriges Unga Akademi 2012).

5.2 Finland - “From sectoral inertia to grand challenges”

According to available rankings and indicators, Finland stands out as one of the best innovation systems in the world. As already shown, Finland is among the innovation leaders in the Innovation Union Scoreboard (IUS 2011), and has been so for several years. Finland is also considered to have favorable conditions for entrepreneurship, and is by far the country with the highest share of researchers in the working population.

Despite these strengths, the Finnish system faces a number of challenges and weaker points. In 2008, an international expert panel was appointed in order to provide an “outsiders view” of the whole innovation system. The panel presented their assessment in 2009 (Ministry of Employment and the Economy & the Ministry of Education, 2009). Among the main weaknesses and challenges they identified were i) a low degree of internationalisation throughout the whole innovation system, ii) lacking ability to create new growth companies and iii) a complex and fragmented public research system.

The last point may come as a surprise, given the fact that Finland is often considered to be “the one to watch” in terms of innovation system performance. Nevertheless, Finland has initiated a number of structural changes in its innovation system, both prior to and as a response to the aforementioned external assessment. At present, the Finnish public R&D and innovation system comprises three main groups of actors outside the business enterprise sector:

- 15 Universities
- 25 polytechnics
- 18 public research institutes

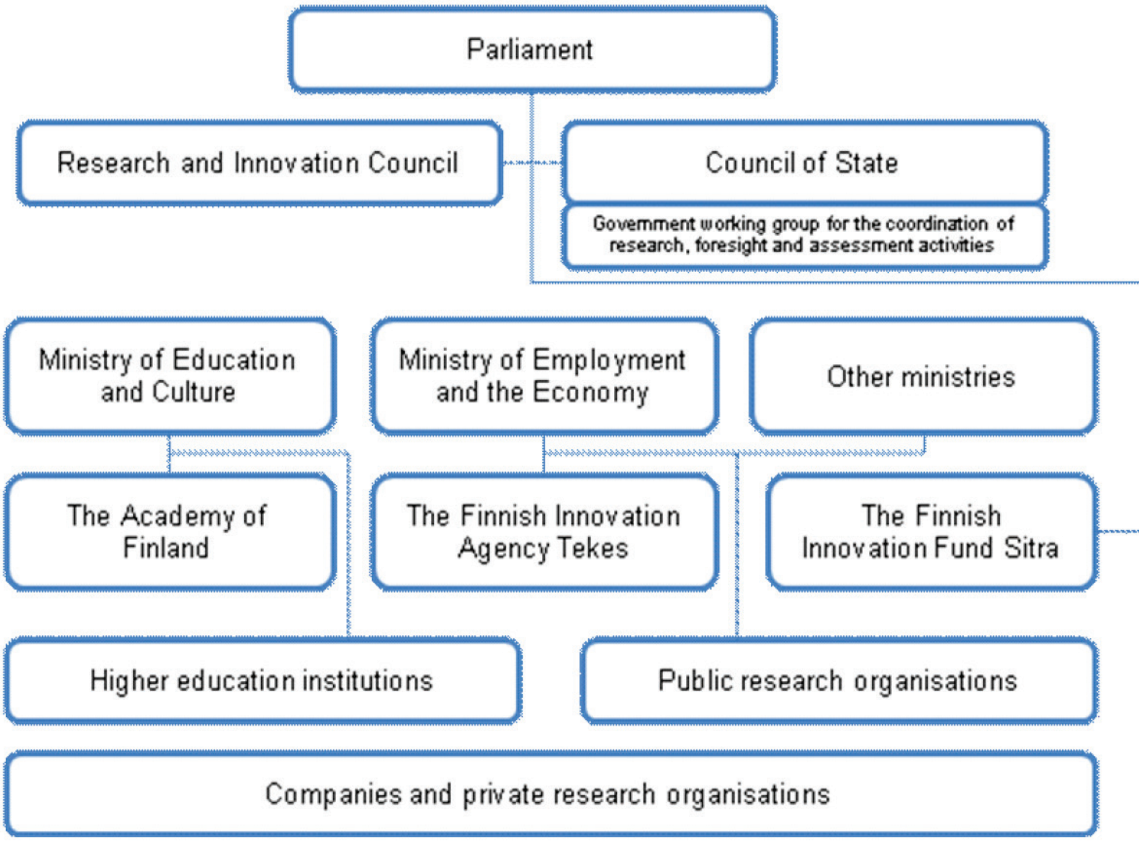


Figure 5.2 Overview of the Finnish innovation system

Source: research.fi

The higher education system has gone through a major reform in recent years. The new University Act was proposed in 2007 and implemented from 1 January 2010. The new act implies a number of structural and formal changes in the Finnish higher education system: the universities have changed their legal status from state owned entities to independent legal personalities. Each institution was given the choice of becoming either a corporation subject to public law or a foundation subject to private law. Universities have become more autonomous, both in terms funding allocations and in the management of human resources.

Universities are also increasingly encouraged to develop stronger profiles on the basis of their strengths. As a result, several universities have merged into larger entities. More precisely, eight universities have now merged into three large universities. This includes the establishment of the new Aalto University, which merged the Helsinki University of Technology, the Helsinki School of Economics and the University of Art and Design Helsinki.

The main purpose of the reforms is allegedly to increase the autonomy of higher education institutions, increase research quality and strengthen international competitiveness. There is not yet any evidence of the effects of these reforms.

The international evaluation of the Finnish system also identified a need to reform the public research institutes. In fact, changes in this sector were considered highly necessary and overdue. This was based on the observation that a number of attempts to reform the public research system had failed during the last decade. Noteworthy in this respect was a proposal in 2005 to reallocate large parts of the core funding to a system of competition based funding. Not surprisingly, this was not well received among various stakeholders and hence rejected as a too radical proposal.

Nevertheless, the evaluation panel saw the need to take up the reform proposal once again. In concrete terms, they identified a need to both merge existing sector research institutes into larger entities, and to incorporate others into the activities of universities. The panel found that the current structure of Finnish sectoral research was old fashioned and trapped into sectoral lock-in, where institutes were more oriented towards the needs and priorities of specific ministries than broader societal issues. According to the evaluation panel *"The current allocation of resources within the sectoral research reflects the past and does not correspond to future needs"* (Finnish Ministry of Employment and Economy 2009).

With this background, the Research and Innovation Council appointed an expert group, chaired by the State Under-Secretary Timo Lankinen, which was given the task of preparing a proposal of a reform of the public research institute sector. The expert group presented their proposal in October 2012. The proposal implies a radical process of mergers and a general shift from sector-oriented funding to a funding mechanism more targeted at research for broader societal issues. Some institutes are recommended to merge with universities, others into larger cross-disciplinary units, while a handful of institutes are advised to remain as separate institutes. More precisely, the expert panel proposed the following structural changes and mergers:

- Merger of the Finnish Meteorological Institute and the Finnish Environment Institute into a research and development centre for the environment
- Merger of the Finnish Geodetic Institute, the geographic information and aerial photograph functions of the National Land Survey of Finland, the geographic information research and geoinformatics functions of the Finnish Environment Institute, and possibly the Finnish Defence Forces' topographic services, into a research and development centre for geographic information
- Merger of the VTT Technical Research Centre of Finland, the Geological Survey of Finland and the Centre for Metrology and Accreditation into a multitechnological research and development centre
- Merger of the Agrifood Research of Finland, the Finnish Forest Research Institute and the Finnish Game and Fisheries Research Institute RKTL into a research and development centre for natural resource economy and bioeconomy
- Merger of the National Institute for Health and Welfare and the Finnish Institute of Occupational Health, and possibly the research unit of the Social Insurance Institution Of Finland, into a research and development centre for health and welfare
- Merger of the following two institutes with the University of Helsinki; National Consumer Research Centre; and National Research Institute of Legal Policy

Four institutes are recommended to remain independent, single institutes. These are: i) Finnish Food Safety Authority Evira; ii) Institute for the Languages of Finland iii) Radiation and Nuclear Safety Authority; and iv) Government Institute for Economic Research.

In addition, it is recommended that the Government accumulates non-earmarked funding to for the general disposal of the Government's horizontal projects. These funds will be reallocated from the institutes' core funding. (Finnish Research and Innovation Council 2012).

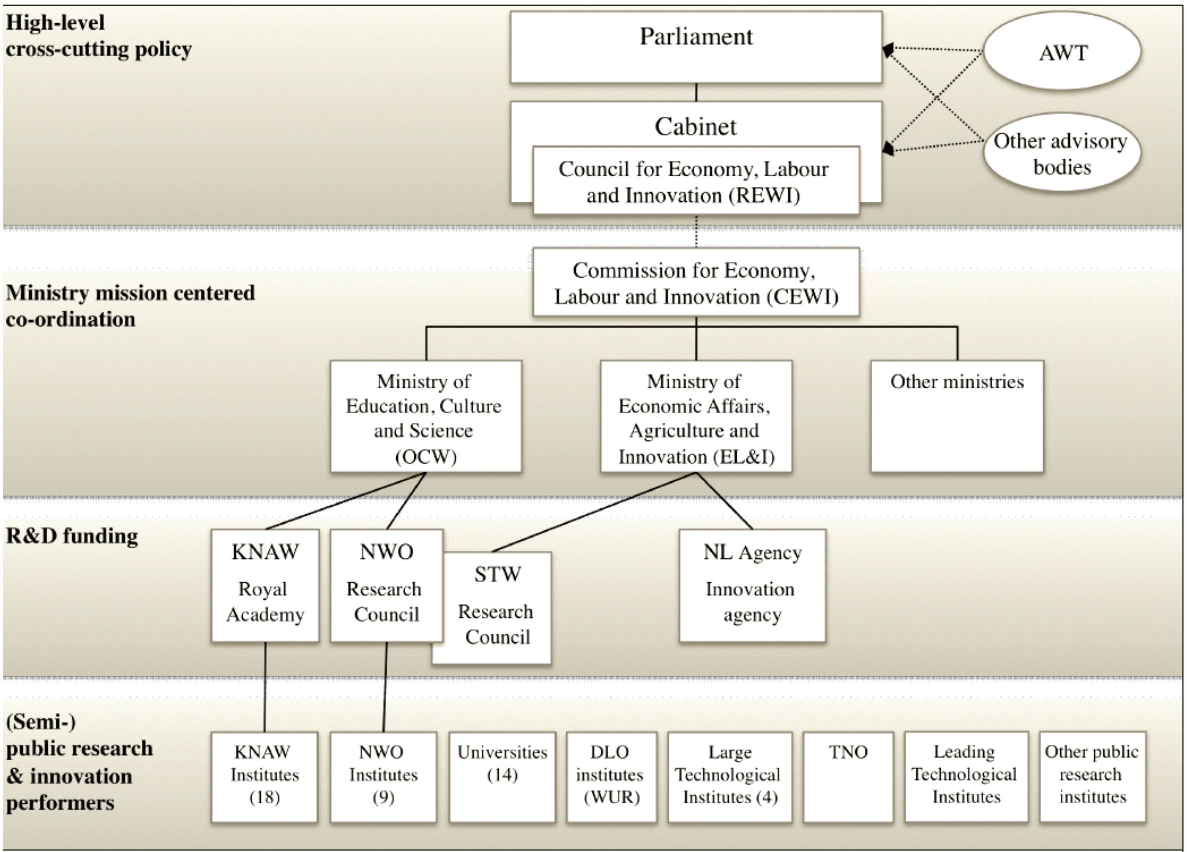
In summary, this extensive reform proposal reflects a general belief in top-down mergers and a significant reorientation from sector-oriented policies towards more challenge and mission-oriented policies, both at the funding level and at the performing level. This latter strategic shift seems also to bypass the role of TEKES and the Academy in Finland as instruments in the design of broad thematic policies. This appears as a clear contrast to for example the Norwegian system, where the Research Council is expected to play a major role in bundling various funding streams into larger thematic instruments.

5.3 Netherlands: "The enterprise in charge"

The Dutch science and innovation system has traditionally been regarded as a rather dual system, with industry on the one side and universities on the other side. This gap, without direct contact between industry and academia has been a concern for Dutch research policy throughout history. Hence a relatively wide ranging system of applied institutes has been developed alongside the development of the higher education sector (Boekholt and Den Hertog 2005).

At present, the Dutch research infrastructure comprises

- 13 research universities and one university for distance education
- More than 65 research institutes, of which the TNO is by far the largest and a main driver of innovative research and technology transfer in the public sector
- 42 universities of applied sciences (Hogescholen)



Note 1: the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) has been changed back to Ministry of Economic Affairs (EZ) recently (with the new installed Cabinet of November)

Note 2: in addition to the Leading Technological Institutes, Netherlands also has Leading Societal Institutes.

Figure 5.3 Overview of Dutch R&D- and innovation system

Source: ERAWATCH country report 2011

As mentioned above, Dutch industry is generally not very R&D-intensive. Innovation activity is also quite modest and not among the innovation leaders. As in the case for Sweden, industry R&D in the Netherlands is dominated by a handful of large multinational companies. It is estimated that the ten largest R&D companies together account for more than half of all business R&D in the Netherlands (ERAWATCH country report: Netherlands 2011). Increasing R&D-spending and innovation activity in companies has therefore been a major concern for Dutch innovation policy for quite some time. The fact that The Netherlands performs well in terms of scientific output (publications and citations) and only moderately in terms of innovation has also been referred to as “the Dutch paradox” (OECD 2008).

During much of the 1990s the need to boost private R&D was followed up by a rather hands-off and generic innovation policy, where governments reduced direct steering and funding and instead prioritised research via indirect measures. As this strategy proved insufficient in creating the renewal of Dutch industry, a more action-oriented strategy was introduced, including for instance measures promoting co-operation and partnerships around large scale programmes.

However, in 2010, a conservative/liberal government took office. They have returned to, and even reinforced the generic hands-off strategy from earlier periods. Apparently, this represents a clear ideological shift with major implications for the Dutch policy mix within the area of R&D and innovation. A number of direct, targeted measures have been discontinued (such as phasing out the innovation programmes) and replaced by general support mechanisms such as fiscal incentives and improvement of the general framework conditions for companies. Policies are generally enterprise-oriented. The dominant philosophy is that “the company knows best”, and that direct government interference should be avoided as much as possible.

An important exception to this hands-off approach is the so-called *top sector initiative*. This is a targeted approach, where 9 areas are prioritised as drivers for future innovation and growth. Among the prioritised areas are *agriculture, horticulture and propagating stock, high-tech systems and materials, energy, logistics, creative industries, life sciences and health, chemicals and water*. A major focus within each area is to stimulate business R&D. The Top sector initiative is also to a large extent a networking instrument, aiming primarily at bringing together actors from academia and industry. Again, the companies and their concerns and priorities are at the forefront.

The Top sector approach is much more than an agenda setting device. The initiative implies substantial reorientation of funding from research institutes to the Top sectors. For instance TNO is expected to contribute €200m to the Top sectors by 2015. This corresponds to more than 35 per cent of TNO’s total annual turnover. The funding will then be subject to innovation contracts between companies, research institutions and government and programming within so-called Top consortia Knowledge and Innovation (TKI). Hence, the Top sector policy seems to be a strategy for government to steer research institutions towards the needs of industry and towards R&D related to major societal challenges and to stimulate private R&D funding. It is interesting to note that even a government with strong ideological resistance against public intervention finds it necessary to conduct direct strategic steering of research institutions.

Structural change and reforms in the institutional set-up seem not to be high on the agenda in current Dutch policy. However, with respect to higher education institutions there is a general ambition to reduce fragmentation and duplication of academic research by promoting more specialisation and encouraging universities to develop distinct profiles. Government and higher education institutions have made performance agreements in order to realise this.

After the recent resignation of the conservative government, a new liberal-labour coalition is establishing a new government. According to our informants, there is reason to expect that the strong shift towards generic policies may be modified, but that the top sector initiatives will continue more or less in the same way.

5.4 Denmark: ”Forced voluntary mergers”

The Danish national system of innovation has traditionally been characterised by a rather sharp division of labour between three types of knowledge producers: universities, government research institutes (GRIs) and GTS institutes. The universities’ main focus has been on education and research; the GRIs have mainly produced research-based knowledge and information to policymakers; and the

GTS institutes have delivered technological knowledge to businesses, public authorities and institutes and constituted a bridge between the universities' research and businesses.

Although this division never was perfectly clear cut it has increasingly been eroded during the latest decade – and it has in particular been affected by a fast and large scale merger process initiated in 2006.

The university merger processes consisted of the integration of GRIs into the university sector, which were a target directly embedded in the Danish Globalisation Strategy; and mergers between universities, which were initiated by the government subsequent to the decision on the Globalisation Strategy (The Danish Government 2006; Ministry of Science, Technology and Innovation 2009).

The integration of GRIs had as its main aims: to stimulate research synergies between until now institutionally separated sectors, to fertilise the university sector with practice-oriented research leading to close contacts with societal, i.e. private and public sector agencies, and to make additional research resources available for educational processes, leading to a strengthening of the link between higher education and research. Furthermore, the mergers between universities and GRIs were meant to support the universities in their response to the needs of society, including creating better conditions for the universities contributing to economically relevant innovations in the private sector (Ministry of Science, Technology and Innovation 2009).

The mergers were voluntary as regards the universities; forced mergers would only have been possible through a change in the existing University Act - a change for which there was no majority in Parliament. As regards the GRIs the merging decision should preferably be supported by the boards of the GRIs. While the Ministry of Science, Technology and Innovation hinted at a preferred overall result of 6 universities, the actual result of the merger processes was a new university sector consisting of 8 universities, while also some of the government research institutions remained independent (Ministry of Science, Technology and Innovation 2009). Before the merger there were 12 universities and 13 GRIs. The present "map of public research" was accordingly implemented in the Danish university sector from 2007 (see below).

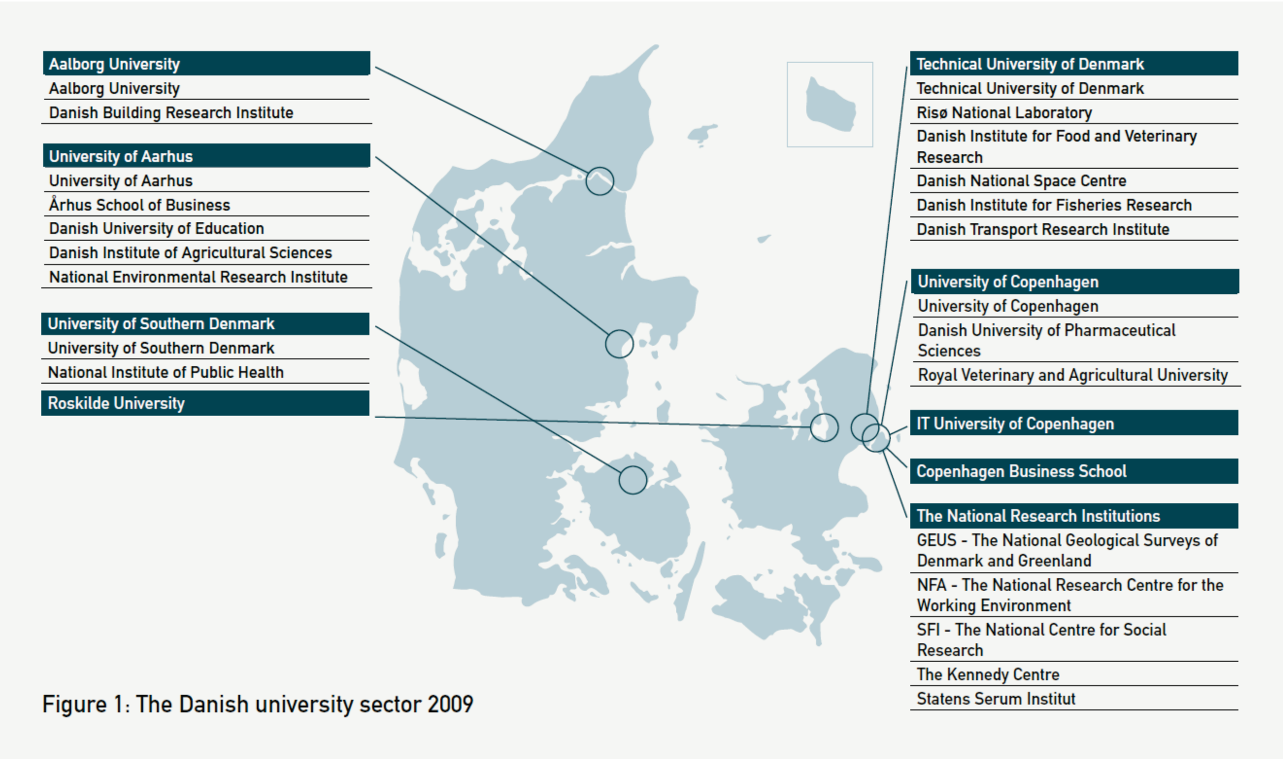


Figure 1: The Danish university sector 2009

Source: Ministry of Science, Technology and Innovation 2009

The GTS-system was not directly targeted by these mergers, but this system has also seen significant changes during the latest decades – not least as a consequence of earlier rounds of mergers and reorganisations within the system (Åström et al 2008). The three groups of organisations are briefly characterised in the following:

Eight Universities: As a result of the mergers, Denmark now has eight universities – University of Copenhagen; Aarhus University; Technical University of Denmark; University of Southern Denmark; Aalborg University; Roskilde University; Copenhagen Business School; and the IT University. The universities are all regulated by the University Act. The mergers have in particular concentrated resources on three very large universities (University of Copenhagen, Aarhus University and The Technical University) where some two thirds of all public Danish research now is conducted. The main functions of the eight universities are education and research as well as exchange and dissemination of knowledge. Following the mergers with GRIs the university sector moreover has competence in the area of research-based public-sector services as the sector now delivers research-based public-sector services to some of the ministries.

Five government research institutes (GRIs): the five GRIs belonging to the post-merger institutional structure for research, under four different government ministries, are: the National Research Centre for the Working Environment (NFA); the Geological Survey of Denmark and Greenland (GEUS); the Kennedy Center; The Danish National Centre for Social Research (SFI); and Statens Serum Institut. The GRIs generally function within the framework of the Act on Government research institutions (Act 326 of 5 May 2004), which states that a GRI conducts research of the highest international standard with the following purposes:

- Offer counselling within its area
- Carry out research-based public-sector services
- Carry out development work with a clear societal focus
- Disseminate research results to relevant private and public stakeholders
- Maintain an operational capacity related to the activities mentioned

Nine GTS-institutions: Finally the public part of the NIS also comprises a network of nine independent Danish research and technology organisations – the GTS institutes. The GTS institutes each have their individual profile, which varies according to size, turnover, research intensity, sector vs. technological focus (broad or deep) and historical origin (Åström et al 2008). The main function of the network is to disseminate new knowledge and technology to companies and public institutions in order to support innovation and development.

A quite recent external evaluation of the Danish innovation system notices that the main responsibility for industry science linkages has been left to the GTS institutes. Although recognising that the GTS institutes are generally performing well in this respect, the review questions the ability of the recently merged universities to fill the gaps uncovered by the GTS institutes in terms of industry science linkages (ERAC peer review of 27. September).

Policy case: Experiences with mergers in Denmark

The extensive mergers between Danish universities and public research institutes described above have already been evaluated at several stages of the process:

First evaluation 2009: The first real attempt to assess the effects of the mergers was however done already in 2009 by an international Evaluation Panel (Ministry of Science, Technology and Innovation 2009). The evaluation was in general fairly positive, but it was acknowledged by the panel that it was too early to draw any clear conclusions.

CFA-report 2012: A more recent input to the assessment of the effects of the mergers with regard to the former GRIs was delivered by The Danish Centre for Studies in Research and Research Policy in a report published in March 2012 (Bloch; Pedersen & Aagaard 2012). The report presented the results of a large survey that examined how the staff involved had seen the merger process and how it subsequently had affected their working conditions and career choices. At the same time it also examined the working conditions and career choices of the employees of the government research institutes, which have not been merged.

General findings:

Across the majority of the merged institutions, the survey draws a remarkably negative image of the employees' experiences of the mergers and their implications for their current job situation. The dissatisfaction concerns both career paths and career choices, but this is not where the differences are most evident. The dissatisfaction and criticism appears most clearly in relation to the experience of the merger process, the assessment of the current job situation and in relation to job satisfaction.

Synergies

The survey uncovered a widespread scepticism towards the rationales of the mergers. Many respondents indicated that the issue of academic synergies had been given insufficient attention and that the arguments for the outcome of the processes were unconvincing. It was in particular emphasised that a couple of more thorough analyses that actually were carried out prior to the decisions were completely disregarded. Many also pointed out that the level of information and the degree of involvement had been scarce, and that this might be related to the speed of the process as well as the lack of additional funding for the merger processes (the merger processes were supposed to be cost-neutral).

Both freedom of research and services to authorities seem to have suffered

On the one hand many respondents expressed that the freedom to choose research projects has diminished. In comparison with the current government research institutions, it is particularly noteworthy that 58 per cent of the staff of the merged institutions partly or wholly disagreed with the statement that there is greater freedom of research now, while the corresponding figure for employees in the non merged institutes was about 30 per cent.

On the other hand a large majority also indicates that the conditions for carrying out consultancy and applied research have been impaired. There was among the respondents a widespread feeling that their service to the ministries was under pressure and that it has become increasingly difficult to obtain space, recognition and accreditation of authority work and different types of customer-based research. Several describe it in this context as a paradox that public-sector services and the social and business-relevant research is down-scaled and pressured in spite of explicit political desire to strengthen precisely these kinds of research. Also in relation to these issues the survey pointed towards difficulties associated with a shift in identity and culture as a result of the mergers. It was emphasised that the former government research work was characterised by a common professional identity and a sense of jointly working towards the same societal goals while researchers within universities tend to focus more on individual identity formation based on their own research. Again, this was highlighted as a trait, which ultimately threatens the former GRI research within a university framework.

Lower job satisfaction and more uncertain career opportunities

Similarly a majority of the respondents report lower job satisfaction and indicate that the issue of work environment not has been sufficiently prioritised. Likewise, it was also a widespread experience that questions about future career development was very uncertain. In general the results accordingly show that employees of the merged institutions were generally less satisfied with both wages and working conditions and social and collegial relationship than their counterparts on the current government research institutions. Particularly job security and satisfaction with management are two areas where the merged institutions stand out negatively.

A large number of the survey respondents in the CFA-study were in the middle of the second phase of the merger process when the assessment was made. This situation has probably affected the survey results in a negative direction due to the uncertainty associated to the processes. It is also as a more general note important to emphasise that the investigation as a whole may show an overrepresentation of negative/critical respondents, as they often will have greater incentive to make their views known than respondents who are neutral or positive. The results should in other words be treated with caution.

Conclusion

Together the available documentation draws a picture of a lengthy and still ongoing merger process between the universities and the former GRIs which so far has created frustration and uncertainty among the employees and where the potential positive benefits not yet appear to have been realised. It is, however, important to emphasise that the employee perspective on the implications of the mergers only is one valid perspective among several others. It is accordingly still unclear how the ministries and the central leadership of universities view the results of the mergers. It is also uncertain to what degree the experiences are the outcome of challenges related to mergers of this type per se, and to what degree it is the outcome of the way in which the process has been organised.

6 Mapping the demand for applied research

A common concern behind all the reforms and policy actions described above is to ensure sufficient and high quality applied research for industry, public sector and society at large. But what is the amount of applied research required in each of the five systems? Already at the outset, this question encounters a number of difficulties.

Firstly, as described in chapter 2, international data on this issue suffer from the fact that many countries have refrained from distinguishing between basic research, applied research and development in their reporting of R&D activity. Secondly, even if this indicator was available across countries, it is widely agreed that the notion of applied research is highly questionable and not directly representative of the total production of research based knowledge to be used in different parts of society (Brofoss and Wiig 2012). Hence, it is both necessary and recommendable to measure this phenomenon by an alternative set of indicators.

In the following we will examine the demand for applied research by public sources, industry and international sources.

6.1 Public demand for applied research

The international trend in public R&D-funding seems to be a general decline in applied research and a corresponding increase in basic research. Both Norway and Denmark are examples of this trend, although the increase is quite modest in both countries[2]. On the one hand, this should not come as a surprise, given the strong emphasis on basic research as a driver of long term growth and the general development of knowledge societies. On the other hand, most countries seem to pay increasing attention to the need for R&D policies to address societal challenges and to focus on the concrete impacts of R&D investments. These relatively recent “megatrends” should, in principle, call for a stronger emphasis on applied research.

A common simplification is to assume that public R&D funding towards the higher education sector (HERD) reflects the total demand for basic research and general advancement of knowledge, while financing of R&D in the government sector (GOVERD) reflects the need for more applied research. Of course, this is a very rough assumption, but at least a set of data which is comparable across nations and over time.

[2] Sweden, Finland and the Netherlands do not report data on basic/applied R&D

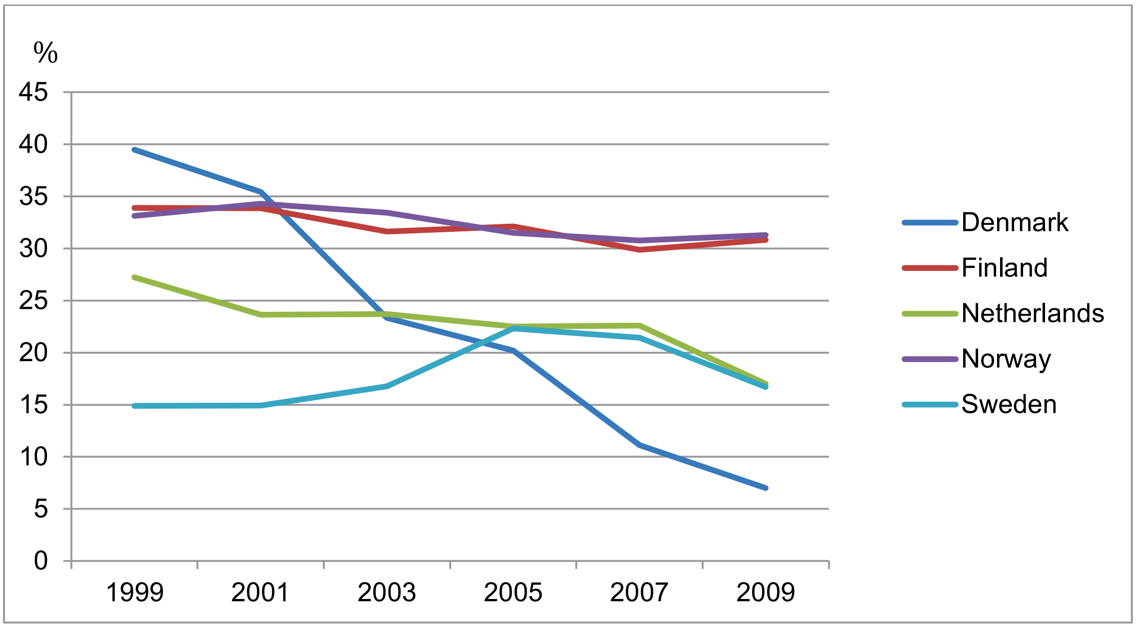


Figure 6.1 Share of public R&D-expenditure in Government sector (GOVERD), 1999-2009.

Source: OECD Database

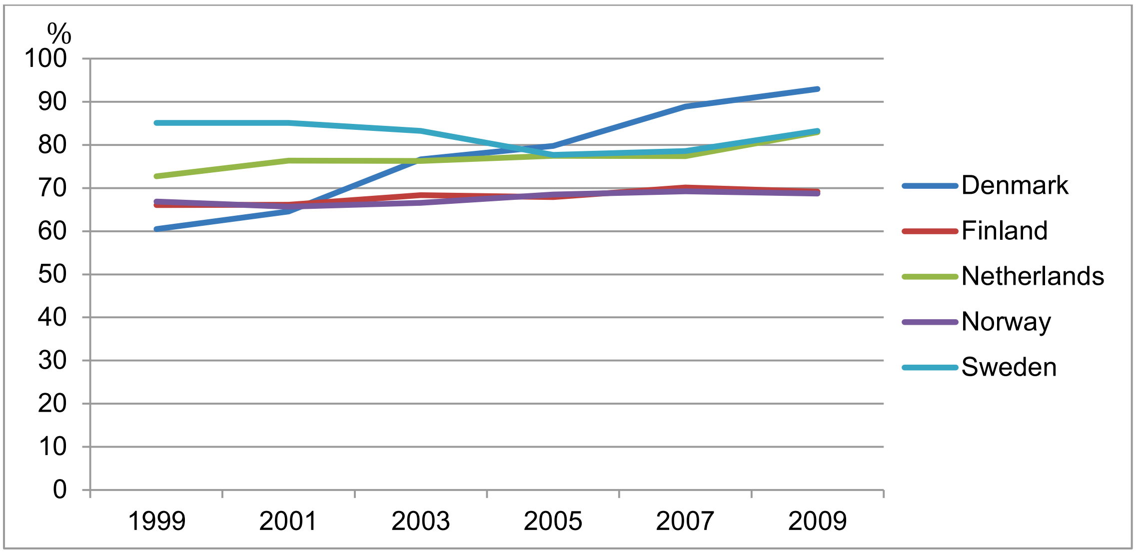


Figure 6.2 Share of public R&D-expenditure in higher education sector (HERD), 1999-2009.

Source: OECD Database

One obvious conclusion from this comparison is that Finland and Norway have the most applied profile in their public R&D spending, while Sweden and particularly Denmark have a more academic-oriented funding pattern. Furthermore, all countries seem to experience a general shift in public R&D expenditure from the Government sector towards the higher education sector. This pattern is particularly pronounced in Denmark and to a certain degree also for the Netherlands. The radical shift in the Danish pattern should of course be seen in light of the extensive merger processes, but this shift is visible also in the years prior to the reforms.

In Norway and Finland the shift is more moderate, while Sweden experienced a shift in the opposite direction (more funding towards the Government sector) around 2005-2007. However, in recent years, the Swedish funding pattern also seems to go in the direction of more funding to universities. These observations indicate that most countries combine an increased focus on R&D for societal challenges with an increased funding to universities. One possible explanation could be that the strong focus on thematic priorities in most countries is not yet transformed into action through concrete budget allocations.

Alternatively, it might be the case that public research institutes are losing some of their "applied hegemony" to the institutions in the higher education sector. In fact, this is one of the core questions of this study, and will be further discussed in the next chapter.

An alternative approach is to look at Government budget appropriations or allocations to R&D (GBAORD). These data look at public R&D from the funding perspective, more precisely through reports based on government budget figures. This approach has the clear advantage that government R&D-budgets are broken down on a standardised selection of socio-economic objectives.

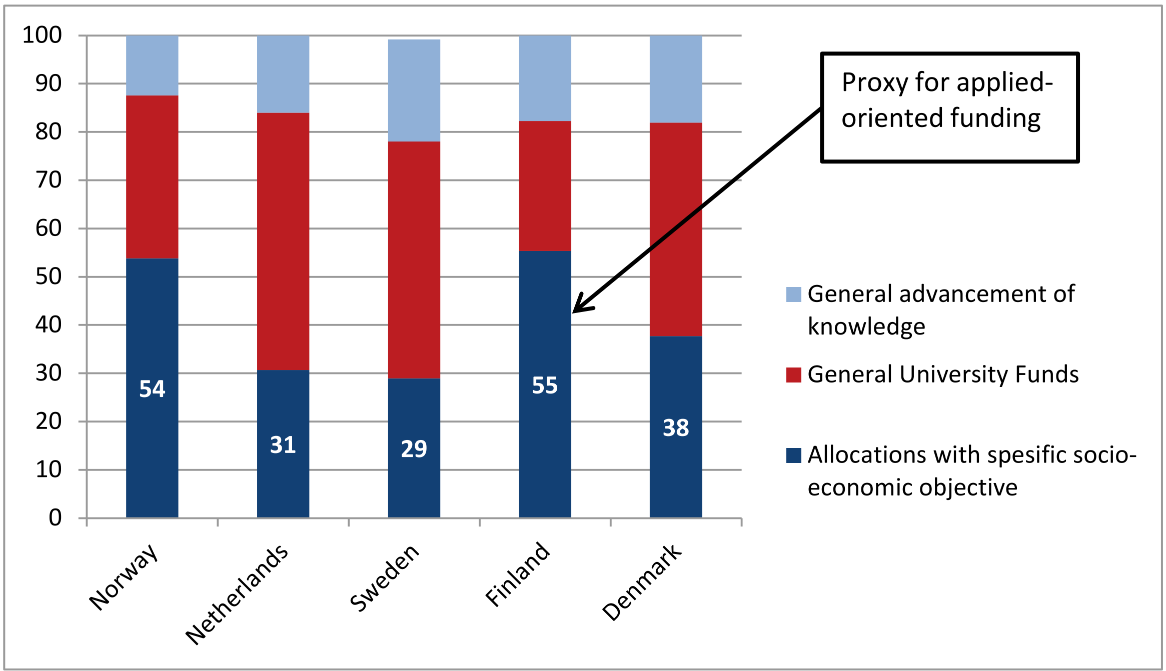


Figure 6.3 Share of GBAORD to specific and non-specific socio economic objectives, 2011

Source: OECD

In the figure above, the share of R&D budget allocations to general university funds and general advancement of knowledge are in the two upper parts of the bars, while budget allocations to specific socio-economic objectives are bundled in the blue/lower parts of the bars. The assumption is that this latter category reflects the relative importance of applied research in public R&D budgets. Of course, general funding to higher education institutions and general advancement of knowledge may perfectly well be used in applied research. However, our perspective in this context is to study public demand for applied research by comparing the declared *intentions* behind budget allocations in the five countries.

With this perspective we see that Finland and Norway stand out as the most applied-oriented countries, while Sweden appears to have the lowest share of R&D budgets to applied research. It is also interesting to note that Denmark now appears slightly more applied-oriented than the impression left from looking at performing sectors. This may indicate that publicly funded R&D in the Danish higher education sector includes a relatively high share of applied research.

A closer look at the different socio economic objectives reveals a number of interesting country differences.

Table 6.1 Public R&D-funding by socio-economic objectives, percentage share of total GBOARD, 2011

Socio-economic objective	Norway	Netherlands	Sweden	Finland	Denmark
Exploration and exploitation of the Earth	1.5	0.6	0.7	1.2	0.4
Environment	2.5	0.6	1.9	1.6	2.1
Exploration and exploitation of space	2.6	2.9	0.3	1.6	1.3
Transport, telecommunication and other infrastructures	1.8	3.1	4.6	1.7	0.9
Energy	3.2	2.2	5.3	10.9	4.8
Industrial Production and technology	8.7	8.0	2.3	19.6	10.0
Health	15.1	5.1	1.4	5.8	8.0
Agriculture	7.0	3.1	1.6	4.6	3.4
Education	0.9	0.2	0.2	0.1	2.5
Culture, recreation religion and mass media	0.8	0.4	0.2	0.7	1.3
Political and social systems, structures and processes	5.3	2.8	2.6	5.0	2.6
General advancement of knowledge : R&D financed from General University Funds (GUF)	33.7	53.3	49.1	26.9	44.2
General advancement of knowledge : R&D financed from other sources than GUF	12.5	16.0	20.4	17.8	18.1
Defence	4.4	1.6	7.8	2.6	0.32
Total	100.0	100.0	100.0	100.0	100.00

Source: OECD

The table shows that five areas or objectives appear as particularly prioritised in Norway compared to the other countries; i) *social systems and structures*, ii) *agriculture, iii) environment, iv) exploration and exploitation of the Earth*[3] as well as *v) health related research*. Country differences in the latter category should, however, be treated with caution, since countries differ in categorising hospital research together with general university funds or as a separate category and objective[4].

Equally important as the objectives of public funding is *the way* in which public R&D budgets are allocated. Based on some new and experimental indicators developed for the OECD, it is possible to shed some more light on country differences in this area (Steen J. v, 2012). Particularly relevant for this project are the indicators which distinguish national public project funding from direct institutional funding, as expressed in the figure below.

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[3] This includes i.a. geology, climate research, polar research, hydrology, meteorology etc. m

[4] For instance, we have reason to believe that R&D-funding to the Swedish Karolinska institutet is categorized as General university funds

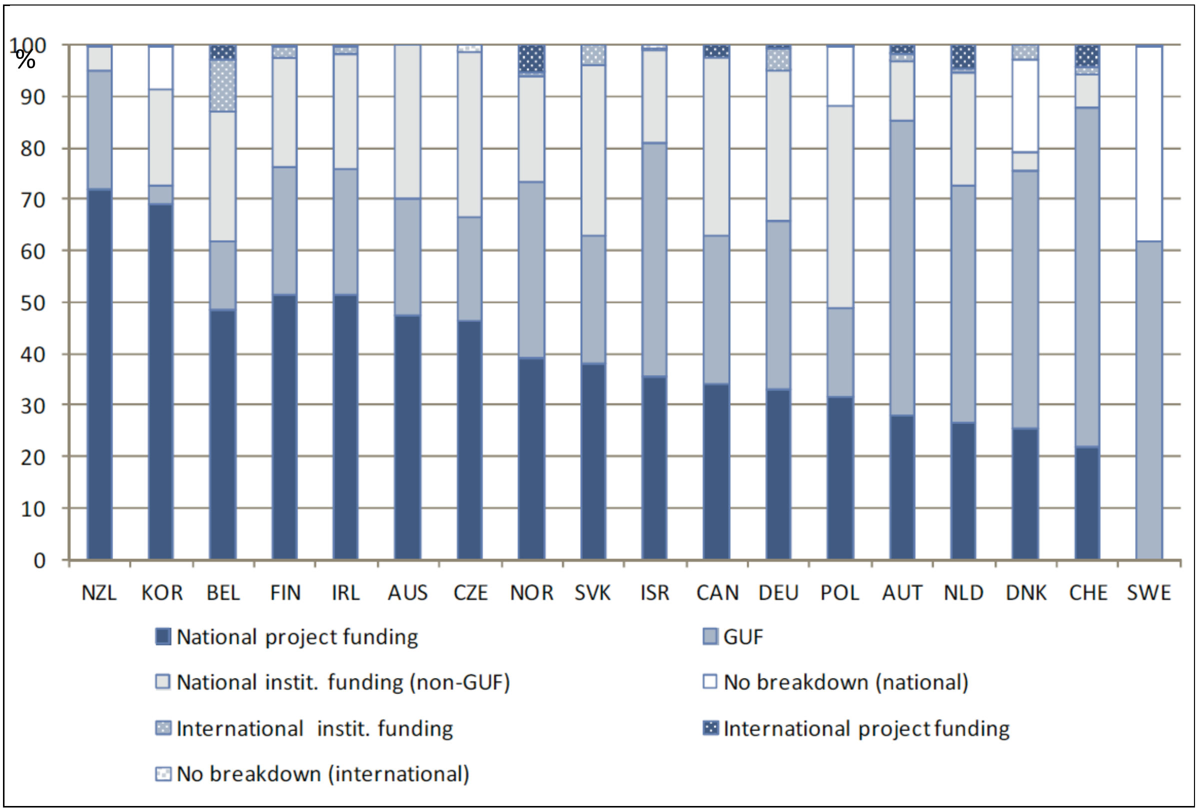

Figure 6.4 National public funding by funding type as percentage of total public funding, 2008

Source: OECD, based on experimental data from NESTI-project on public R&D funding (2010)

Noteworthy in this context is the share of project-based funding. This category comprises public funding through contract research as well as funding through research councils and similar intermediate funding agencies. Although preliminary and incomplete, this indicator shows that Finland and Norway appear to have a rather competition based funding pattern, while Denmark and the Netherlands are among the countries with a high degree of direct funding to institutions. Data for Sweden are incomplete, but seem to place Sweden in the latter category.

In summary, the statistical mapping exercise above reveals two general findings concerning the public demand for applied research in the five countries:

1. A larger share of public R&D-funding in Finland and Norway is oriented towards applied research

2. Public funding in Finland and Norway is more exposed to competition than public funding in the other three countries

6.2 Private demand for applied research

Country differences in private demand for applied research are primarily dependent on two factors. First, the general R&D intensity in domestic firms is decisive for their ability to perform R&D and absorb research based knowledge. Second, the balance between R&D performed within (intramural) and outside the company (extramural) is decisive for firms' propensity to purchase R&D from actors outside the company.

One important question in this respect is whether country differences in total R&D intensity are due to real differences in companies' willingness or abilities to invest in R&D, or whether this is a question of industrial structure. Calculations done by the OECD shed light on this question. The figure below shows real R&D intensity in selected countries as well as R&D intensity levels adjusted for country differences in industry structure.

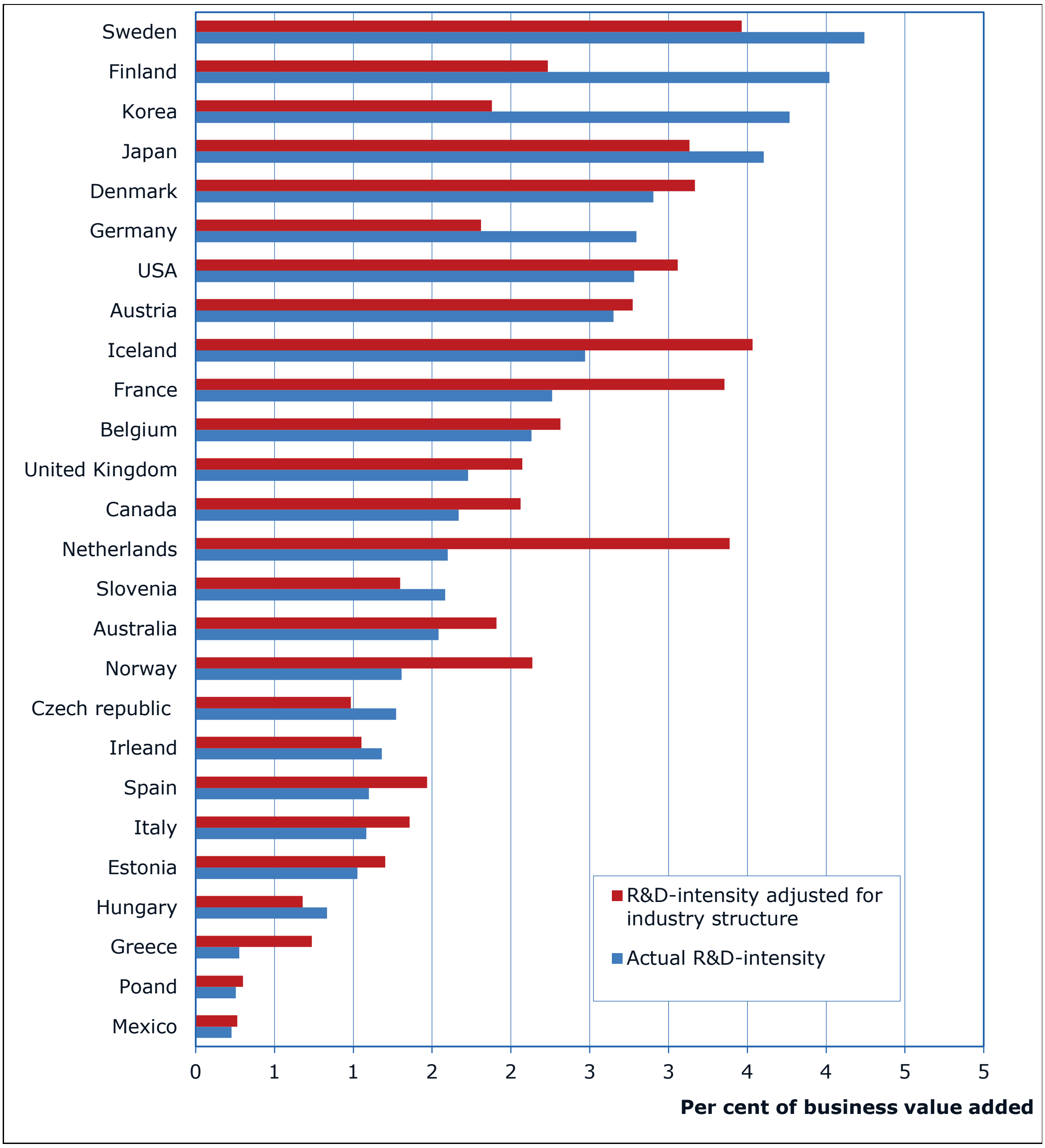

Figure 6.5 Real business R&D intensity and R&D intensity adjusted for industry structure, 2008

Source: OECD, calculations based on STAN/ANBERD databases and MSTI 2011

This exercise gives very different results for the five countries in question. While Sweden and Finland reduces business R&D intensity significantly with a hypothetical OECD-average industry structure, the opposite is the case for Norway and the Netherlands. The consequences for Denmark are not very significant. In other words, value creation in Finland and Sweden is dominated by high-technology and traditionally R&D intensive industries. In contrast, Norway and the Netherlands specialise in industries which are not R&D intensive.

This has, of course, significant implications for the markets for applied research. On the one hand, low economic activity in R&D intensive industries, implies a lower absorptive capacity for R&D services in domestic industry. On the other hand, one could argue that the absence of R&D intensive sectors and so-called high tech locomotives creates some sort of ”R&D vacuum” which needs to be compensated for by, for instance, technological research institutes.

The latter point is closely related to companies' purchase of R&D from external sources, the second decisive factor mentioned above. In principle, innovation systems where large shares of business R&D is purchased from entities outside the company (extramural) would have a correspondingly large market for applied research.

By collecting data from national statistical offices we are able to compare firms’ propensity to purchase R&D in four of the five countries subject to this study. Data for Finland are not available. The results of this exercise are illustrated in figure 6.7 below.

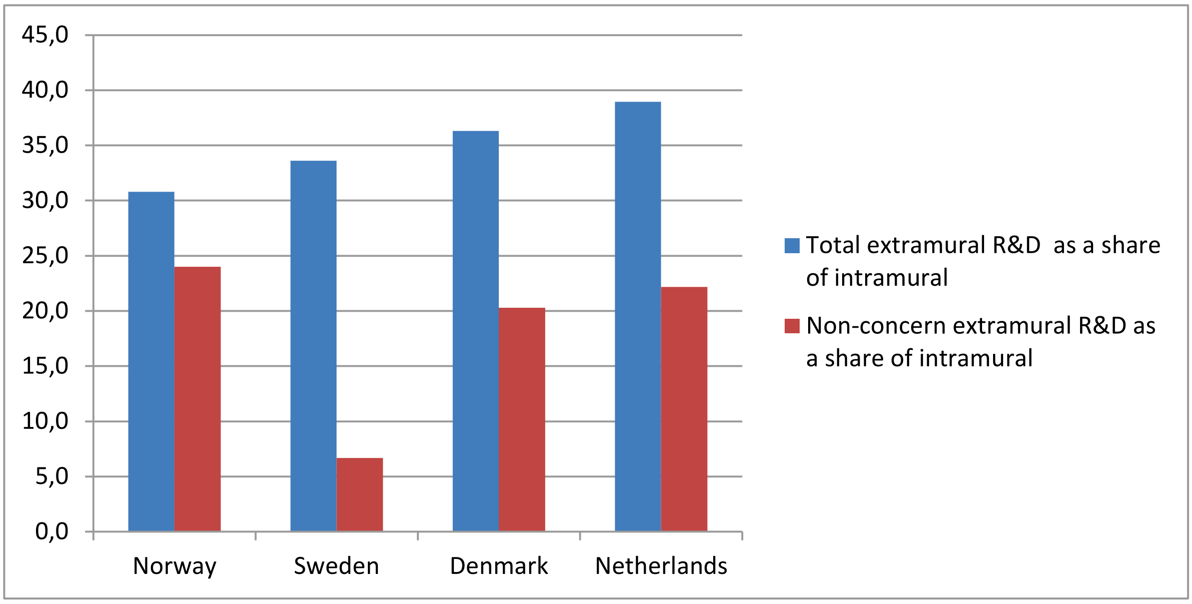

Figure 6.6 Figure: Extramural business R&D in percentage of intramural R&D, including and excluding purchase within the same concern/enterprise group, 2009

Source: National statistical offices (NOR, SWE, DEN, NL)

As illustrated in the left/blue bars, purchased/extramural R&D as a share of intramural R&D ranges from just above 30 per cent in Norway to almost 40 per cent in the Netherlands. A similar pattern also appears if comparing extramural R&D using data from the Community innovation survey (CIS 2010). However, data on total extramural business R&D have the clear weakness that extramural R&D also includes R&D purchased from companies within the same concern, both domestically and abroad. There is reason to doubt that business R&D purchased from entities within the same concern really represents a potential market for research institutes and other providers of applied research. Excluding the part of extramural R&D spent within the same concern would therefore give a more realistic picture of the actual private market for applied research.

The result of this extraction is illustrated by the red/right-hand bars in the figure. Interestingly, Norway is the country with the highest share of R&D purchased from outside the same concern. In contrast, the quasi totality of purchased R&D in Swedish companies is purchased from entities within the same concern. In fact, the total amount of R&D purchased from outside the concern is almost identical in Norway and Sweden (app. €500m). A natural conclusion is therefore that external actors are most important for business R&D in Norway, while Swedish companies are significantly more oriented towards entities within the same concern. In addition, it is interesting to observe that 70 per cent of the

Swedish R&D purchased from companies within the same concern goes to companies abroad. This dimension is significantly lower in the other countries, with 37 per cent in Denmark, 31 per cent in the Netherlands and only 17 per cent in Norway. This point confirms that Swedish business R&D is strongly reliant on multinational concerns.

6.3 A typology of public and private demand for applied research

Based on the statistical exercises above, we can now develop a typology of domestic markets for applied research. The figure below illustrates this by combining the above-mentioned proxies for public and private demand for applied research. Public demand for applied research is expressed through public R&D-budgets allocated to specific objectives (excluding General university funds and non-oriented R&D) as a share of total R&D budgets. Private demand is expressed as business R&D purchased outside the concern as a share of in house business R&D. The size of the bubbles illustrates these two figures in total numbers (€m).

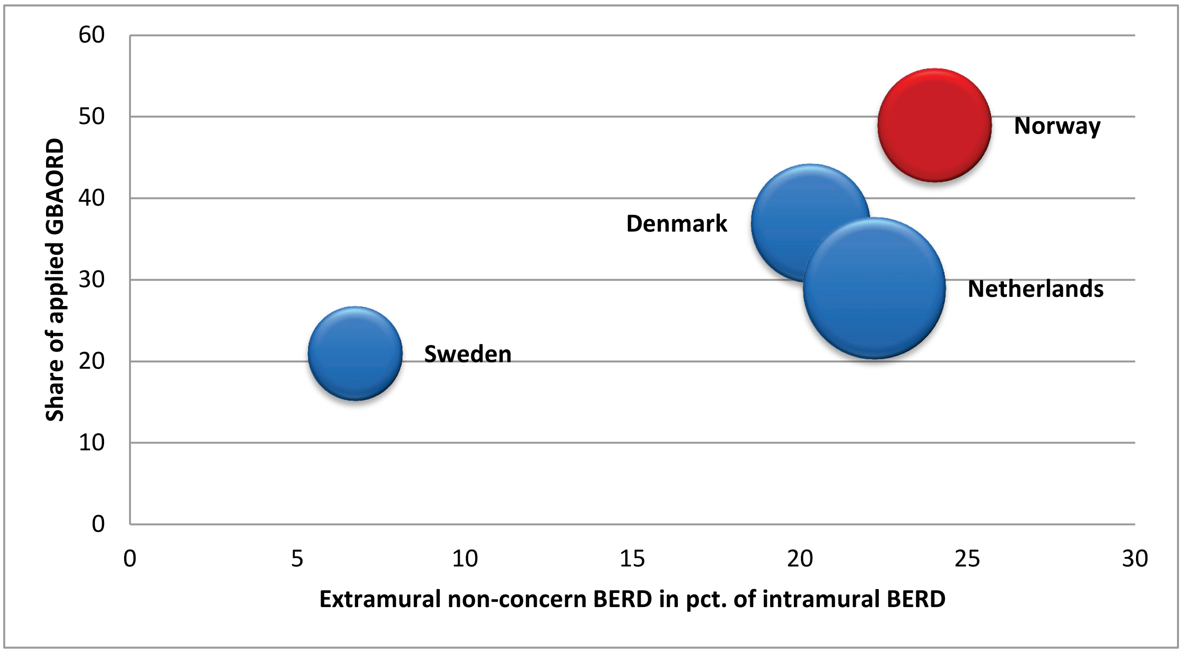

Figure 6.7 Public and private demand for applied research, Expenditure on extramural R&D as a share of turnover and of intramural R&D, all innovation active companies, 2010

Source: NIFU based on OECD/GBAORD and National statistical offices

Defined in this way, the market for applied research appears most important in the Norwegian system. Firstly, public R&D funding in Norway seems strongly oriented towards socio-economic objectives and hence more applied than in the other three countries[5]. Secondly, a relatively larger share of business R&D in Norway is purchased from entities outside the company and the concern. Norway is therefore placed in the upper right corner of this figure.

It is also interesting to note that the estimated market for applied research is larger in Norway than in Sweden, also when measured in total numbers. This indicates clearly that the Swedish system is still dominated by a research performed within universities and within companies and group of companies. If we also consider R&D purchased from other entities in the same concern, the size of the Swedish market for applied research increases considerably.

[5] The same is the case for Finland, but Finland is left out of this total comparison since we lack data for extramural R&D in Finnish companies.

6.4 International demand for applied research

A third dimension in national markets for applied research is the demand and financing from international sources. The two major sources of foreign R&D financing are international organisations and foreign companies. Although the picture is mixed, the share of R&D-financing from international sources is generally increasing in OECD-countries. Among the five countries in this study, the Netherlands has the highest share of total R&D financed from international sources, followed by Sweden. International R&D financing in Norway and Denmark are around EU average, while Finland has a relatively low share of foreign of foreign financing. The latter strengthens the impression of a general need to increase the internationalisation of the Finnish innovation system.

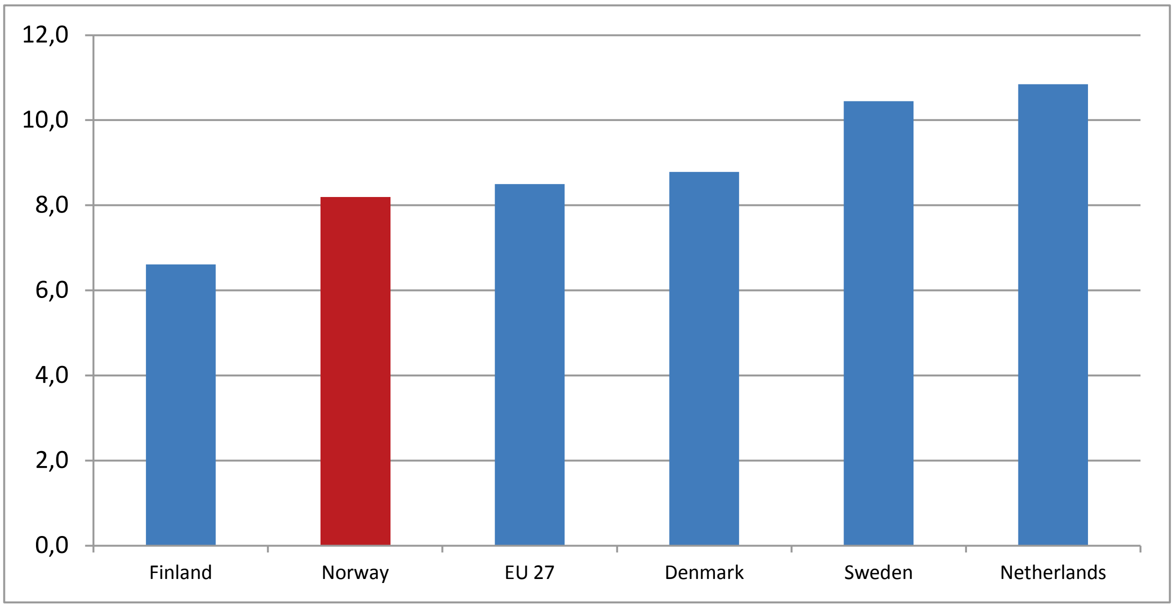

Figure 6.8 R&D expenditure financed by abroad as percentage of total R&D expenditure, 2009

Source: OECD, MSTI 2012/1

R&D financing from foreign companies is most significant as a source of income for technological research institutes (RTOs). This is also demonstrated in our case study of selected RTOs in chapter 8. However, on a general basis, there is reason to say that there is still a potential to increase the international financing of Norwegian R&D. For research institutes in small countries, the domestic market for applied research is limited and often highly specialised. An orientation towards customers abroad is therefore a viable strategy for expanding the market for contract research (Sörlin and Arnold 2009)

The European framework programmes for research and technological development constitute a particularly important source of finance for research institutes. Whether the framework programmes constitute real markets for applied research is surely a matter for discussion. Participation in EU funded projects is certainly not to be regarded as a pure source of income, given the fact that EU projects generally require a substantial amount of internal finance from participants. Many actors regard the EU framework programmes as primarily an arena for networking and strategic positioning. Even so, funding from the EU is and will be a crucial element in the national R&D system in all participating countries. As we shall see in chapter 10, research institutes play an important role in the EU participation in several countries.

The upcoming framework programme Horizon 2020 is expected to become an even more important arena for research collaboration. The programme will run from 2014 to 2020 and represents a total budget of close to €80bn. The indicative breakdown of the budget clearly shows that research and innovation to tackle societal challenges will constitute the major bulk of the programme budget.

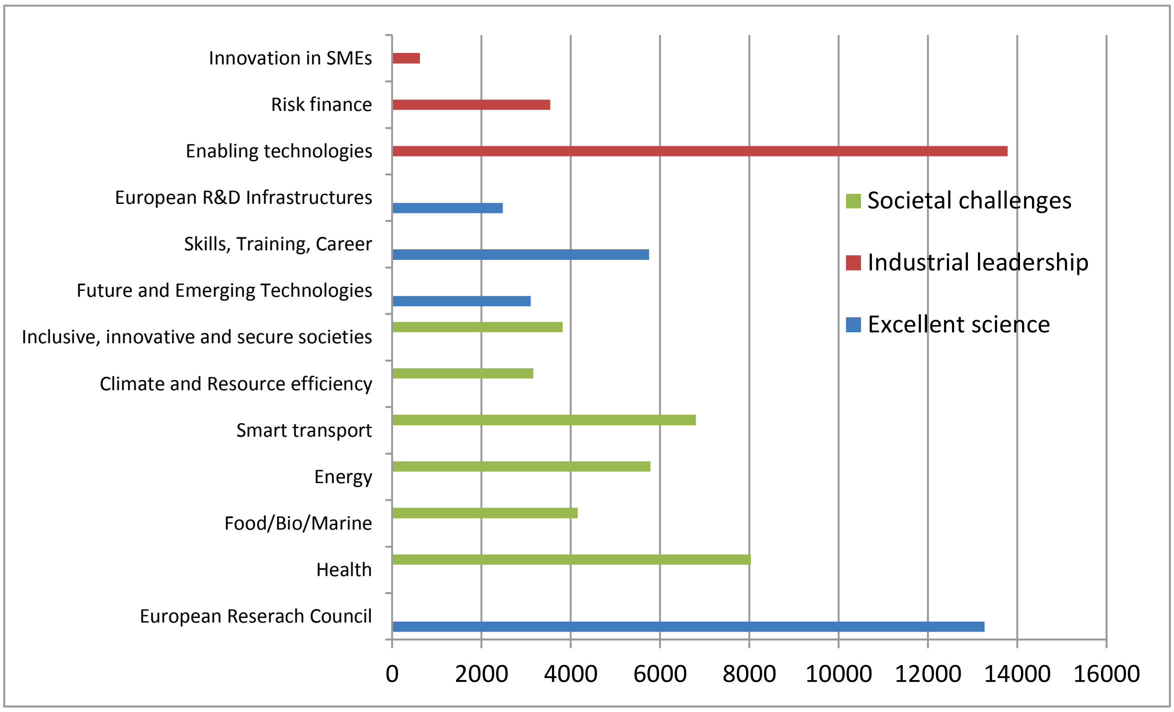

Figure 6.9 Indicative breakdown of Horizon 2020 budget. €m, constant 2011 prices

Source: European Commission

In addition, a substantial amount of the budget will be devoted to R&D related to enabling technologies and emerging, future technologies. These are all areas which will constitute important markets for applied research in all countries in the following decade.

7 Suppliers of applied research

Following the study of the demand for applied research, we now turn to look at the supply side of the issue. The core questions in this respect are: what kinds of actors are involved in the supply of applied research? What are their roles in the market? How important are research institutes in this market?

In Norway research institutes have traditionally been considered the most important actors in terms of performing applied research. In many ways, providing applied research to industry and public sector is the very raison d'être of research institutes. R&D performed in the Government sector is the most commonly used proxy for defining a comparable institute sector across countries. This proxy is, however, highly unsatisfactory. As already demonstrated in figure 4.5, only a small share of total R&D is performed in the Government sector. This is the case for all five countries, and particularly for Denmark, where this sector is almost negligible.

Furthermore, research today has to be responsive to a wide range of actors and societal goals that require a broad base for decision-making. In other words, the institutional context allowing access to knowledge matters (Murray 2002, OECD 2012, p. 36).

As a consequence, there is reason to consider a broader set of actors and actor groups when studying the suppliers of applied research. We propose to distinguish five groups of actors which all play a role in the supply of applied research. These five groups are:

1. Research and Technology Organisations (RTOs)
2. Public Research Organisations (PROs)
3. Private non-profit organisations (PNP). This category consists of private foundations and companies involved in knowledge intensive services
4. Contract Research Organisations (CROs) and consultancies specialising in R&D-services
5. Higher education institutions, (through their external, applied mission):

The first two groups are normally considered research institutes, and if we include the third category (Private non-profit organisations - PNP), we have a definition that corresponds fairly well to the term "institute sector" used in the Norwegian R&D statistics. The fourth group is often referred to as consultancies. They differ formally from research institutes by a lack of public basic funding and by having a "for profit" objective of their activities. Nevertheless, as long as they perform R&D-activities, they are potential providers of applied research. Higher education institutions in group 5 are primarily responsible for higher education and basic research, but are also, to varying degrees, involved in applied research.

This classification of actors in the market for applied research may be illustrated as follows:

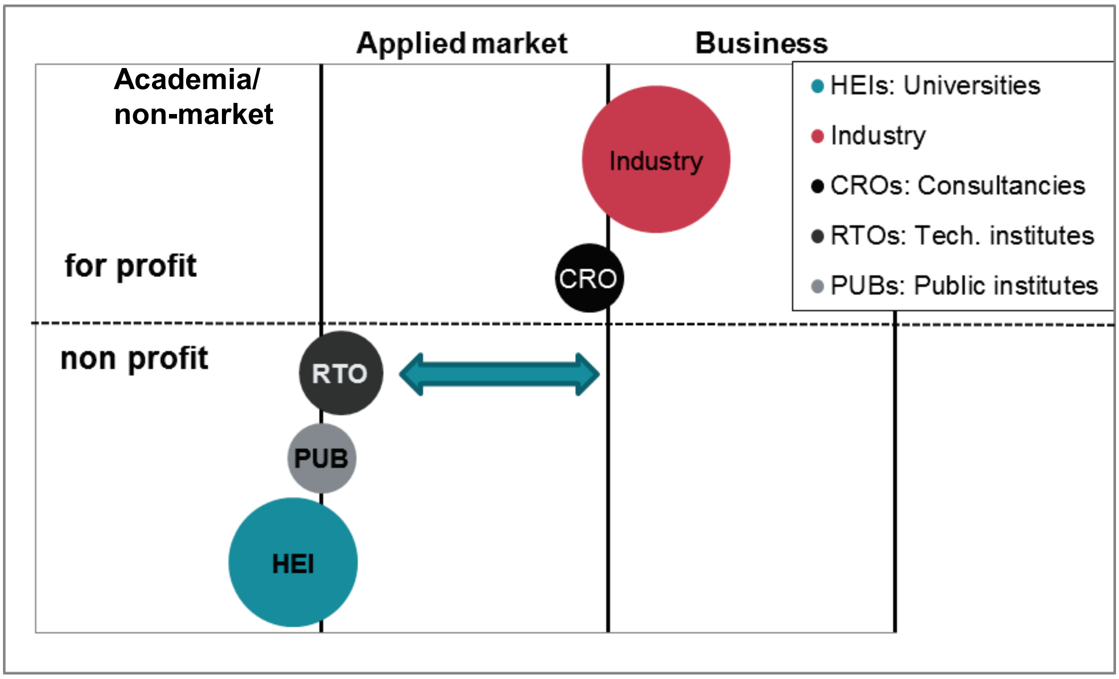

Figure 7.1 Stylised typology of actors on the market for applied research

Source: NIFU

We will now investigate the relative importance of each group of actors in each of the five countries. This exercise is far from straightforward, due to the statistical challenges mentioned in chapter 3. In short, our calculations are built on the following assumptions:

- The role of higher education institutions in applied research may be measured by the share of their funding coming from external sources (HEI)
- Research in the Government sector is kept as a proxy for research by public research organisations (PROs). These include VTT in Finland and TNO in the Netherlands, but the sector also includes regular government agencies etc. performing R&D to a larger or smaller extent
- Technical research institutes (RTOs) may be constructed by extracting non-profit institutes (NPIs) mainly controlled or funded by business enterprises (NACE 72)
- The residue of the Industry sector category NACE 72 (R&D services etc.) is assumed to consist of private research organisations (CROs) and consultancies with R&D as a main activity

In the following we propose a set of typologies of the supply side of applied research in the five countries considered.

7.1 Typologies of supply systems for applied research

Figure 1 shows the distribution of main actors on the Norwegian markets for applied research. A notable feature is the share held by the RTOs serving business enterprises. The Norwegian classification of industrially oriented research institutes, such as SINTEF and Iris, deviates from classification practice in other countries. However, it is also a question of organisation of the institutes and their relationships to Government.

Norwegian institutes in this subsector are typically organised as limited companies or private foundations unlike in some other countries, as we will elaborate on a little further in the following. Norwegian institutes are also, to a large extent, dependent on contract research funding from business enterprises. The flip side of this is relatively low basic funding (cf. Chapter 8). The dominant subsector, however is the Government sector which contains large government institutes, e.g. in the defence sector and ocean research, as well as institutes mainly controlled or financed by Government within the social sciences. Consultancies seem to play a relatively minor role in the Norwegian system for applied research. So do higher education institutions. The PNP sector in Norway is almost negligible.

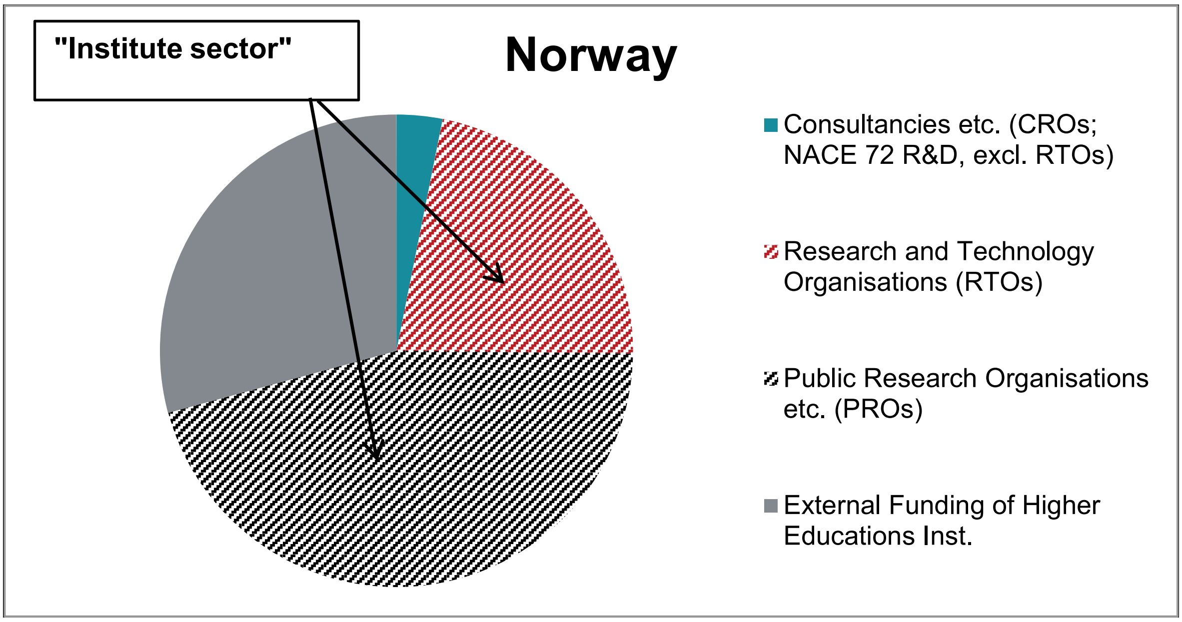

Figure 7.2 Actors in the market for applied research in Norway. Mill. PPP 2009.[1]

1 2008 figures for NACE 72.
Sources: NIFU based on OECD/MSTI 2012, OECD Science, Technology and R&D Statistics (database) and "Det norske forskningssystemet 2010. Statistikk og indikatorer, Norges forskningsråd».

Applying the same method, this analysis shows that the Danish system appears quite different from the Norwegian one. The explanation may at least partly be the Danish integration policies over the past few years, merging public research institutes into the higher education sector. The latter is clearly dominant in Denmark, with consultancies and other R&D intensive firms as a runner-up. As a consequence the Government sector has turned into an almost negligible subsector, which is a distinguishing feature of the Danish system.

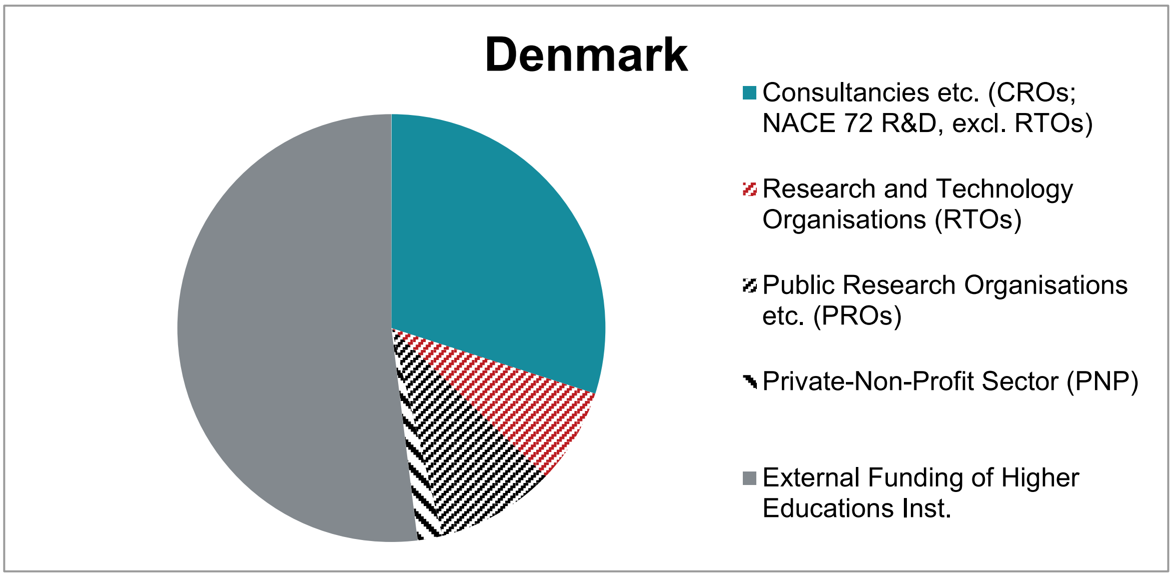

Figure 7.3 Actors in the market for applied research in Denmark. Mill PPPs 2009.[1]

[1] 2007 figures for NACE 72.

Sources: OECD MSTI-database 2012/Science, Technology and R&D Statistics-database, OECD (2011:48), Statistics Denmark. www.teknologiportalen.dk/GTS-Institutter/, OECD: Public Research Institutes. Mapping Sector Trends, 2011

The Finnish and the Dutch systems seem to have striking similarities when compared in this way. The higher education sector is slightly larger in Finland, while the Government sector is slightly larger in the Netherlands. In both countries, though, the Government sector is a prominent subsector, spearheaded by large PROs. In this respect these two systems seem to differ significantly from the Norwegian model. The dividing feature, however, is the reported absence of RTOs in the business enterprise sector in both Finland and the Netherlands. At the national level, independent of different sectoring and organisation, all three countries have large RTOs and PROs with similar functions, i.e. serving business enterprises.

In Finland the VTT is by far the most comprehensive institute with total funds of more than €280m. VTTs R&D and other activities are to a large extent directed towards business enterprises. The VTT itself, however, is, along with approximately 20 other institutes, a Government owned institution. Finland reportedly does not have any RTOs in the business enterprise sector (OECD 2011). However, there are consultancies which participate in competition for contracts, e.g. Pöyry, which is a global consulting and engineering company. Pöyry has about 7,000 employees and net sales in 2011 were €796m – this is 2.5 times the total turnover of VTT.

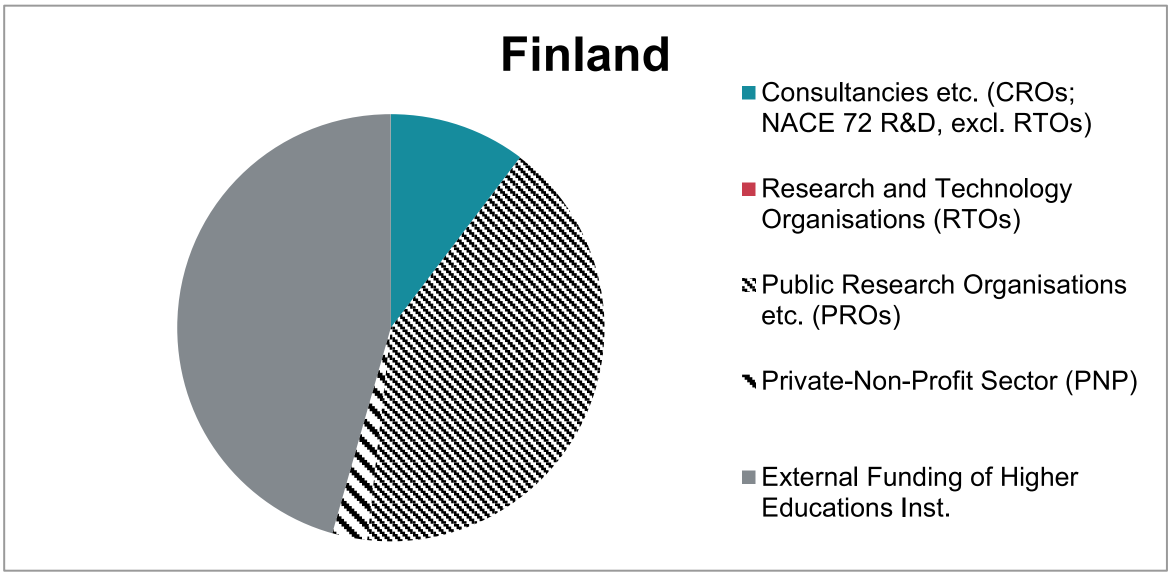

Figure 7.4 Actors in the market for applied research in Finland. Mill PPP 2009.

Sources: OECD (2012) "Main Science and Technology Indicators", *OECD Science, Technology and R&D Statistics* (database), OECD (2011:68).

In the Netherlands, the TNO holds a similar position to that of the VTT in Finland. It is a large, Government steered institution putting a lot of effort into the advancement of industrial R&D. TNO apart, the Netherlands have a quite comprehensive institute sector, largely organised as umbrella systems covering several institutes. One example is the Netherlands Organisation for Scientific Research (NWO), which includes 9 institutes. The Royal Netherlands Academy of Arts and Sciences (KNAW), including 18 institutes, is another. Two even more comprehensive groups in terms of resources are the Large Technological institutes (GTI) and the DLO institutes; the latter covering agricultural research.

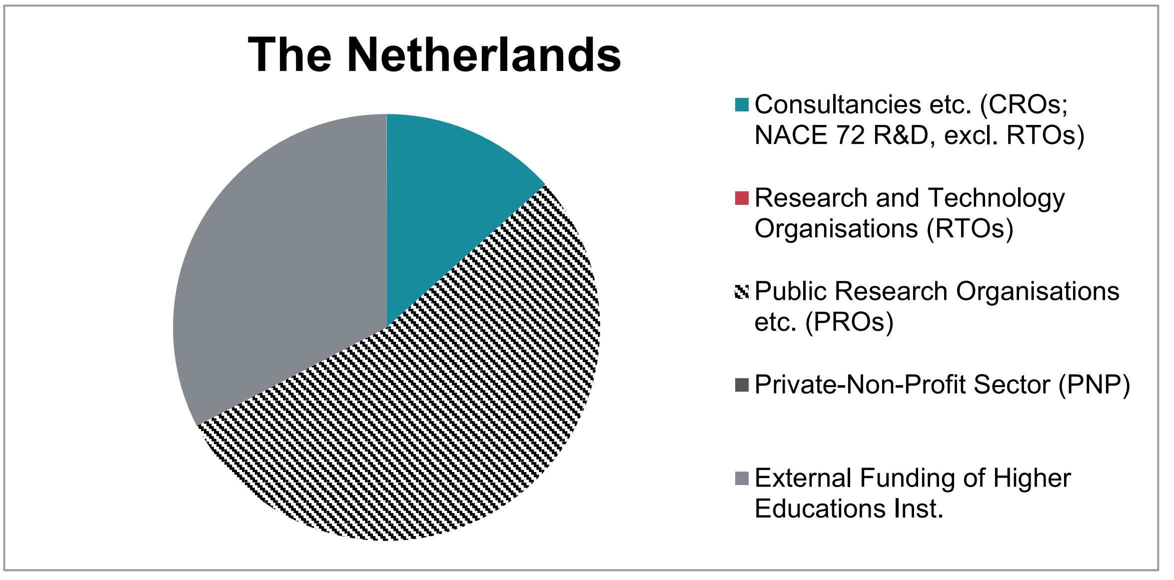

Figure 7.5 Actors in the market for applied research in the Netherlands. Mill. PPP 2009.

Source: OECD (2012) "Main Science and Technology Indicators", *OECD Science, Technology and R&D Statistics* (database), Jan van Steen (2008), National sources.

Sweden has traditionally been considered to have a rather negligible institute sector. This also shows in figure 5. The largest segment by far of the markets for applied research appears to be the higher education sector, indicating that research units have often been established within universities. Runners-up are business enterprises other than RTOs, i.e. consultancies and other R&D intensive firms (CROs). Government institutes have a smaller share. Over the past couple of years there has been a renewed interest in research institutes in Sweden and also a slight expansion of the Swedish institute sector. In particular, this applies to a major reorganisation of industrial R&D institutes and a few others into the RISE organisation. These institutes are classified as RTOs serving business enterprises.

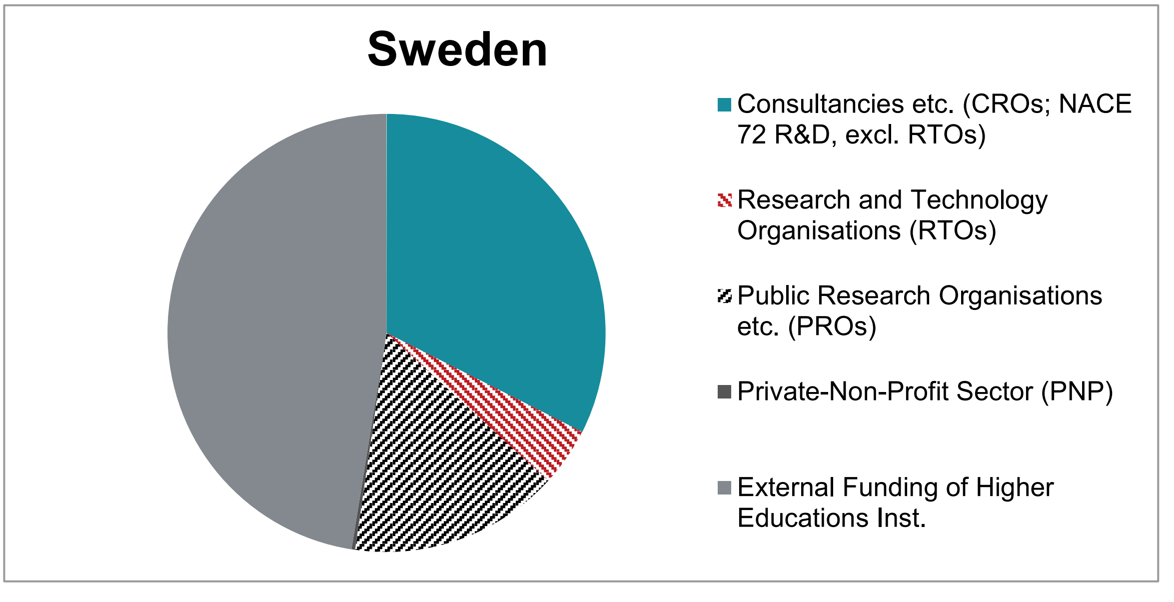

Figure 7.6 Actors in the market for applied research in Sweden. Mill. PPP 2009.

Source: OECD (2012) "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database), SCB (2009). Forskning och utveckling i Sverige 2009 (UF 16 SM 1101, korrigerad versjon)

7.2 Main country differences on the supply side

Main conclusions to be drawn from the comparison are:

- In Norway a significantly larger proportion of the supply of applied research is provided by RTOs serving firms than in any of the other countries. Denmark and Sweden also have these kinds of institute structures, the GTS and RISE institutes respectively, but not to the same extent. Neither Finland nor the Netherlands appear to have such RTOs, although the TNO and the VTT may in many respects be considered RTOs (cf. chapter 8 where they are compared with other RTOs)
- The share of PROs is also relatively large in Norway. However, this type of institution accounts for a larger share of the supply side in Finland and the Netherlands than in Norway. This is because large research institutes in these two countries are organised as government institutes and as such classified as PROs. The PROs' share is smaller in Sweden and particularly in Denmark, the latter due to the merger of government institutes with higher education establishment over the past few years
- If we, for a moment, ignore the classification and organisation issues and view across subsectors, we have established the core of a Norwegian style institute sector including both RTOs and PROs. In this perspective Norway has a larger institute sector than any of the other countries, but the structure is not very different from that found in the Netherlands and in Finland. As the difference between Norway and the others is not accounted for by RTOs, one hypothesis would be that other public research institutes, e.g. within the social sciences, constitute a larger segment of the supply side in Norway
- The role of the PNP sector, which is the third component in a Norwegian style institute sector, is quite negligible in terms of R&D resources
- Enhancing the perspective beyond the institute sector we find that consultancies and other R&D intensive firms play different parts in the five countries. The share of such organisations is quite small in Norway, which may be explained by the extensive role of RTOs serving firms. We cannot, however, exclude the possibility that this is also due to different classification practices across countries. Similar tendencies may be found in Finland and the Netherlands, where VTT and TNO respectively, serve many of the same functions as the Norwegian RTOs. In both Denmark and Sweden, consultancies seem to be of greater importance
- Finally, also transcending the institute sector perspective, it may be observed that higher education establishments, as measured by their external financing, are quite significant suppliers of applied research. This is particularly the case in Denmark, but also in Finland and Sweden. Again, this seems a quite logical consequence of the merger between higher education institutions and research institutes. Finland and Sweden, with a comprehensive group of polytechnics, are runners-up here, while such institutions seem less important in the Netherlands and in Norway. However, it should be noted that Dutch figures in this area are underestimates.

8 A case study of technical research institutes

The limited information about research institutes in the R&D statistics makes it necessary to study selected, comparable institutes in order understand further their nature and role. In this case, we look further into the differences and similarities between 6 central technical research institutes. They cover all the five countries considered, with the addition of Germany.

8.1 The technical research institutes in the study

The table below gives an overview of the selected institutes in the five countries considered in this study, including turnover, number of employees, mission statement, legal status and main areas of R&D.

Table 8.1 Mission statements of the technical-industrial institutes included in the study

Country	Name	Mission stated (from project informant group meeting arranged in 2012 and description of institute online)	Legal status	No. Of employees
SWE	RISE	RISE institutes shall be internationally competitive and contribute to sustainable growth in Sweden through the strengthening of the competitiveness and regeneration of industry.	Holding company with limited companies (non profit)	2 277
FIN	VTT	VTT produces research services that enhance the international competitiveness of companies, society and other customers at the most important stages of their innovation process, and thereby creates the prerequisites for growth, employment and wellbeing. The objectives of VTT are to create high level scientific and techno-economic knowledge and know-how and to generate technology and innovations for industry, commerce and society.	Government organisation (non profit)	2 818
NL	TNO	TNO connects people and knowledge to create innovations that boost the sustainable competitive strength of industry and well-being of society. We work for a variety of customers: governments, the SME sector, large companies, service providers and non-governmental organisations. Working together on new knowledge, better products and	Government statutory organisation, established by law (non profit)	4 300

		clear recommendations for policy and processes. As 'knowledge brokers' we advise our customers, moreover, on finding the optimum solutions that are geared precisely to the questions they have.		
DNK	GTS	The mission of the GTS institutes is to convert knowledge to value. We accomplish this by working in the borderline territory between business, science, education and authorities. The GTS institutes aim to develop new, innovative products and services, satisfying the requirements of the business sector and society, and to ensure awareness of new strategically important technologies. GTS aims to maintain and develop the role of the GTS institutes as the core of the technological infrastructure in Denmark.	Network of private limited companies (non profit)	3 700
NOR	SINTEF	The objective of SINTEF is to contribute to social progress by carrying out research in the natural sciences, technology (including building and construction), and the health and social sciences in collaboration with the Norwegian University of Science and Technology (NTNU). This objective is realised by the development of SINTEF's own high-level expertise, close interaction with NTNU, and in collaboration with industry, the public sector and other research and educational institutions.	Foundation, with limited companies and one holding company (non profit)	2 100

(A more comprehensive description of all six institutes is included in annex 1.)

All of these institutes or groups of institutes play a major role in their national market for applied research. Traditionally they have been mostly oriented towards the needs of industry, but are increasingly involved in R&D towards public sector and broader aspects of society. This is also reflected in their recent self-reported objectives (see above).

8.2 Key figures and framework conditions

Measured in total turnover, the six institutes are all large organisations, but with significant country differences. The size of Fraunhofer should of course be seen in relation to the size of the host country, Germany. But for the other institutes, turnover does not correspond to the total level of national R&D. For instance, SINTEF's turnover is considerably higher than the Swedish RISE, although the opposite is the case for total R&D expenditure in the two countries.

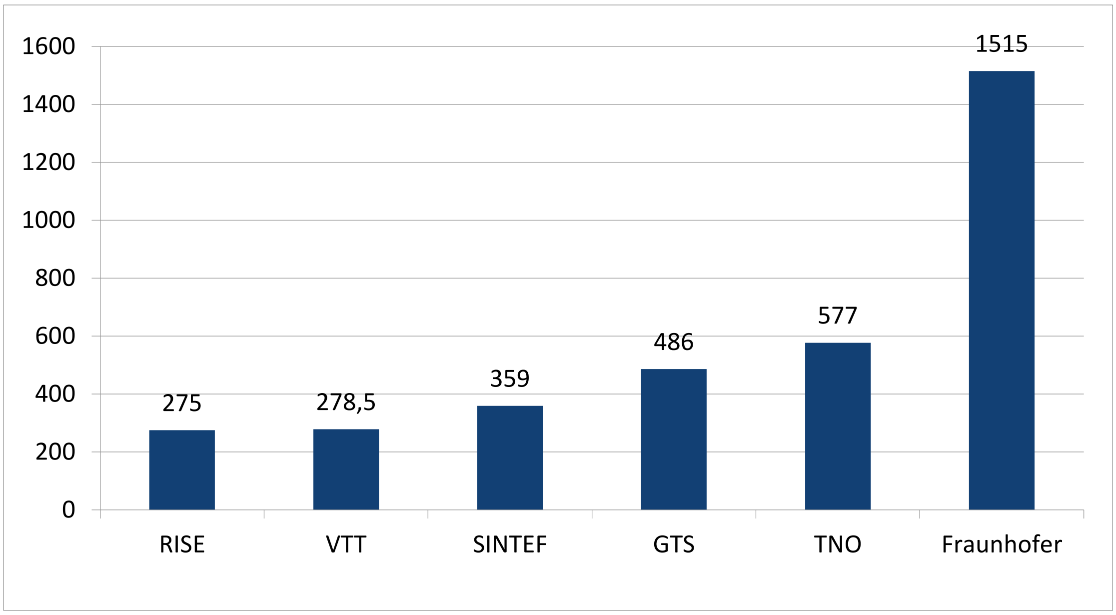

Figure 8.1 Main RTOs by turnover (€m), 2011

Source: Self-reported figures (Informant group)

If we instead compare the institutes' turnover to total R&D expenditures in the respective countries, we see that SINTEF and the GTS institutes have the most dominant roles in their national R&D-systems. On the other hand, Fraunhofer and RISE are less dominant players in Germany and Sweden.

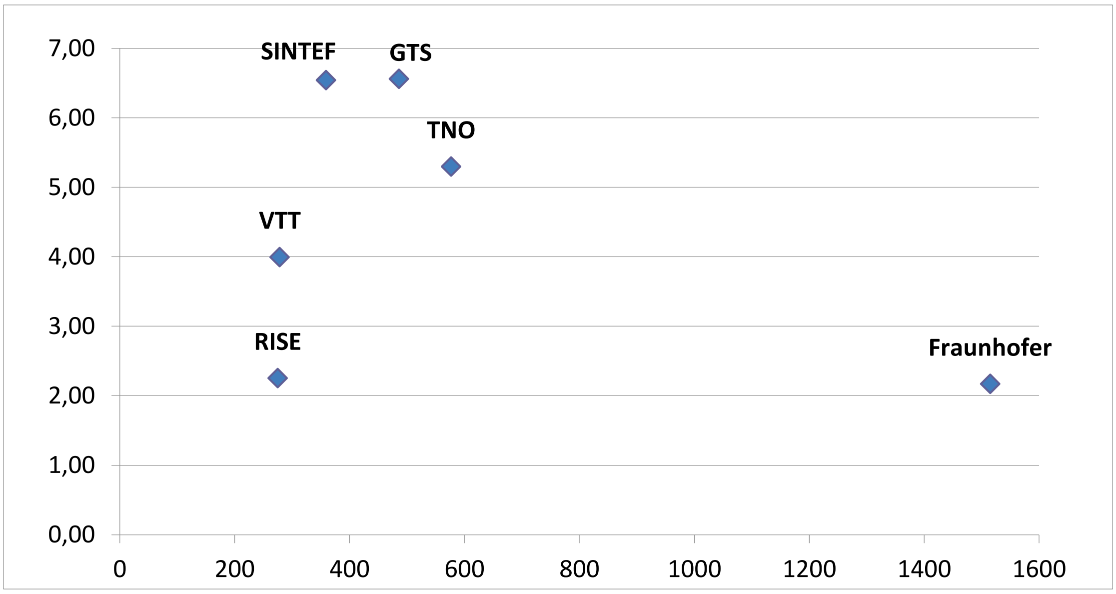

Figure 8.2 Main RTOs by turnover (€m) and share of national GERD, 2010

Source: OECD and self-reported figures (infomant group)

The institutes differ also in terms of funding structure. All institutes are of course reliant on contract research and competitive funding. But the relative importance of funding sources varies a great deal across the institutes. For instance, the level of international funding is by far highest in the Danish GTS institutes. This reflects a deliberate strategy by the GTS institutes during the last decade to increase their international presence.

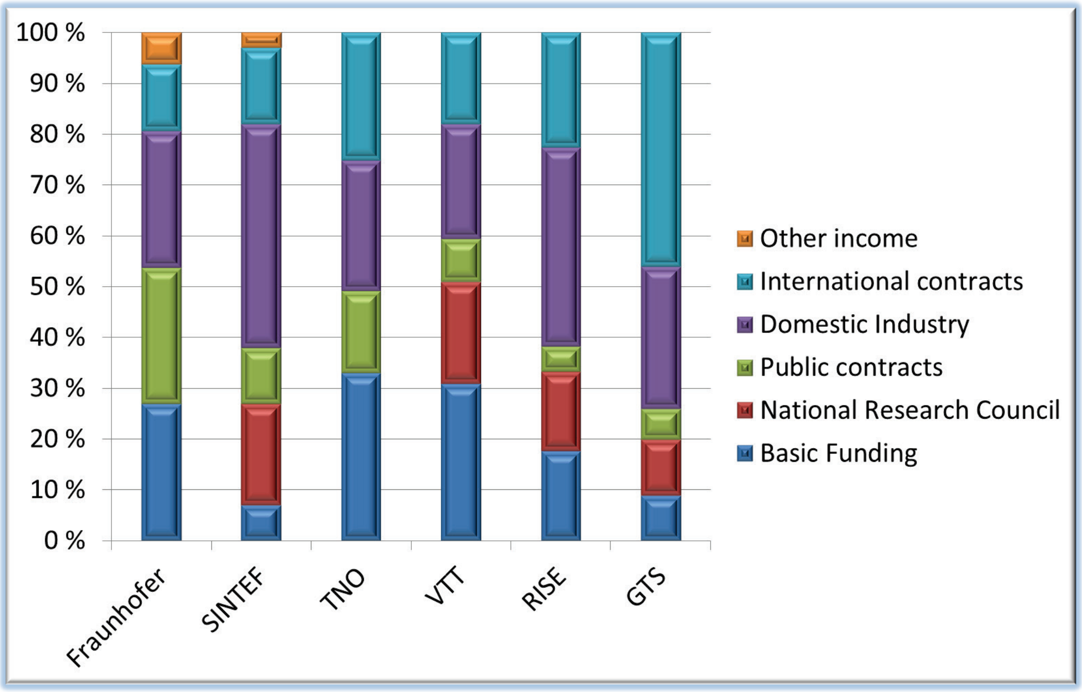

Figure 8.3 Turnover by major sources of income, 2011

Source: NIFU/National sources and self-reported

Another striking difference is in the level of basic, non-competitive government funding. TNO and VTT stand out as the institutes with the highest level of basic funding. This is partly the reason why they are classified in the Government sector in national R&D statistics. Another reason is, of course that these two institutes are formally organised as public institutes, while the others are either private foundations (SINTEF) or limited companies (RISE and GTS). Fraunhofer has a particular legal semi-public status.

Figure 8.4 below shows the level of non-competitive government (basic) funding as a share of total turnover in each of the six institutes since 2003.

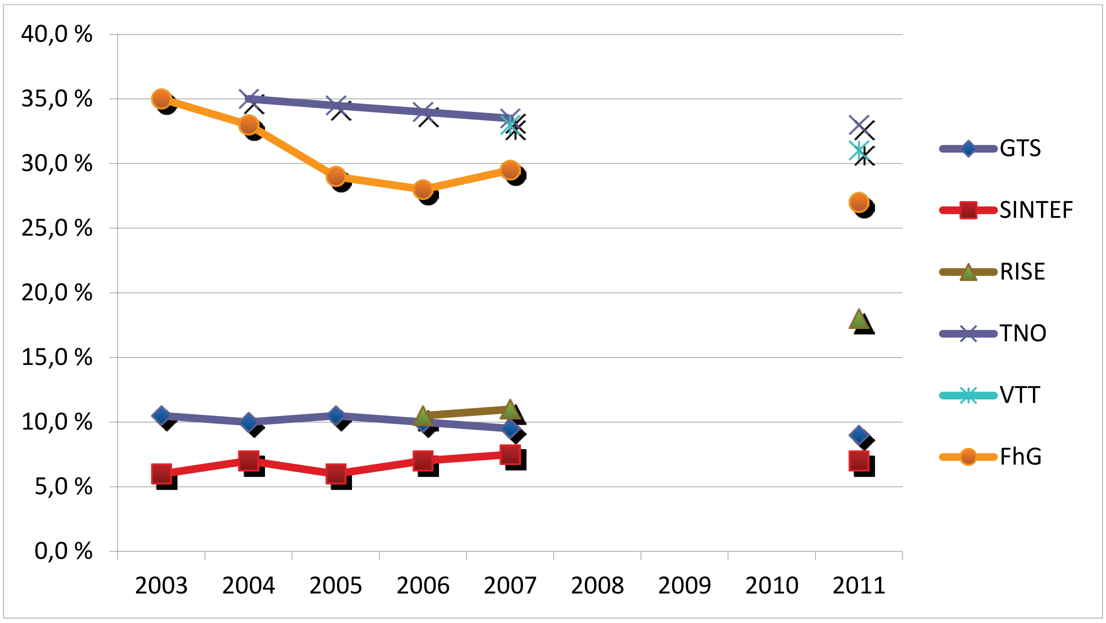

Figure 8.4 Non-competitive, basic funding as a share of total turnover (year 2003-2007 and 2011)

Source: NIFU/National sources and self- reported data from institutes

The most striking thing about this picture is the relatively low share of basic funding in the three Scandinavian institutes, although the basic funding for the RISE institutes has increased considerably and reached the level of 18 per cent in 2011. For both SINTEF and GTS the level of basic funding is well below 10 per cent, and has been so for several years.

However, the differences in basic funding must be seen in relation to the total amount of public funding and steering of the institutes. For instance the large shares of basic funding to TNO, VTT and Fraunhofer do not come without strings attached. The basic funding for VTT is based on a performance agreement with the responsible ministry (Ministry of Employment and the Economy). The same goes for TNO, and in the Dutch case the room for government steering has been even more pronounced following the reallocations connected to the Top sector policy (see chapter 5). In return, the basic funding for SINTEF and GTS are more left to the free disposal of the institute, although requiring annual reporting to the funding authorities.

Comparing the actual performance of these institutes is difficult since they primarily operate in different markets. In the following we will therefore investigate further how the institutes compete and collaborate both internationally and with domestic partners.

All institutes are active participants in the European framework programmes. But they differ in terms of their contribution to the total national R&D funding from the European Union. The table below shows the institutes' share of EU-contribution to their country and the same share when also including projects with domestic partners (excluding Fraunhofer in this context).

	Share of EU-contribution to the country	Share of EU-contribution to the country including domestic partners
GTS	4,1 %	9,5 %
VTT	23,5 %	34,5 %
TNO	5,8 %	11,3 %
SINTEF	19,9 %	27,8 %
RISE	4,7 %	7,7 %

Source: E-Corda/European Commission

In this context, SINTEF and VTT stand out as national "locomotives" in terms of EU participation, while the other institutes have a much more modest role in their countries EU portfolio. On the other hand, SINTEF and VTT have a lower share of total international funding than RISE, GTS and TNO. This indicates that SINTEF and VTT have a relatively strong focus towards the European arena, while the other institutes to a larger degree address other international markets. Fraunhofer's low level of international funding is also partly explained by the fact that Germany constitutes a domestic market of considerable size compared to the other countries.

8.3 Co-operation patterns – a bibliometric analysis

In order to further explore the profile and co-operation pattern of the institutes in the case, we have performed a bibliometric analysis including all institutes covered in this case, excluding Fraunhofer.

In general, the co-authorship data for the Nordic countries show a strong collaboration between institutes and national knowledge actors including technical universities and universities. RISE-institutes show a strong collaborative network with both KTH (The Royal Institute of Technology) and with Chalmers University of Technology. As an example, the number of co-authored papers between these two institutions with KTH was between 60-70 papers (in years 2010-2011). Visual representations of co-authorship data for both RISE-institutes, VTT, GTS, SINTEF and TNO are included in annex 2.

The analysis shows that co-production of scientific publications is largely taken in collaboration with national universities and universities of technology. The long-term collaboration between universities, in technical research and engineering, shared labs and double affiliations of professors are all part of the explanation to these strong ties, shown by co-authorship networks. Moreover it shows that local knowledge production has been and continues to be important. In the case of Sweden, for example, the collaboration also includes PhDs in ongoing research at institutes, actively involved in publishing in scientific journals and also targeting solutions to industrial problems and research questions.

The large share of international collaboration takes place with large countries with a strong science and engineering base (such as US an Germany). The analysis also shows strong co-authorship relations within the Nordic region.

International collaboration, measured by the share of internationally co-authored publications, has been growing, from about 31 percent in 2002 to about 43 percent in 2011. Nevertheless, in Sweden, universities are still the most common collaborators and the network analysis shows that there are extensive knowledge networks between local research partners. In the other Nordic countries, the pattern is also that the national and local co-authorship networks are dominating. Some results from the Nordic countries regarding internationalisation are shown in figure below.

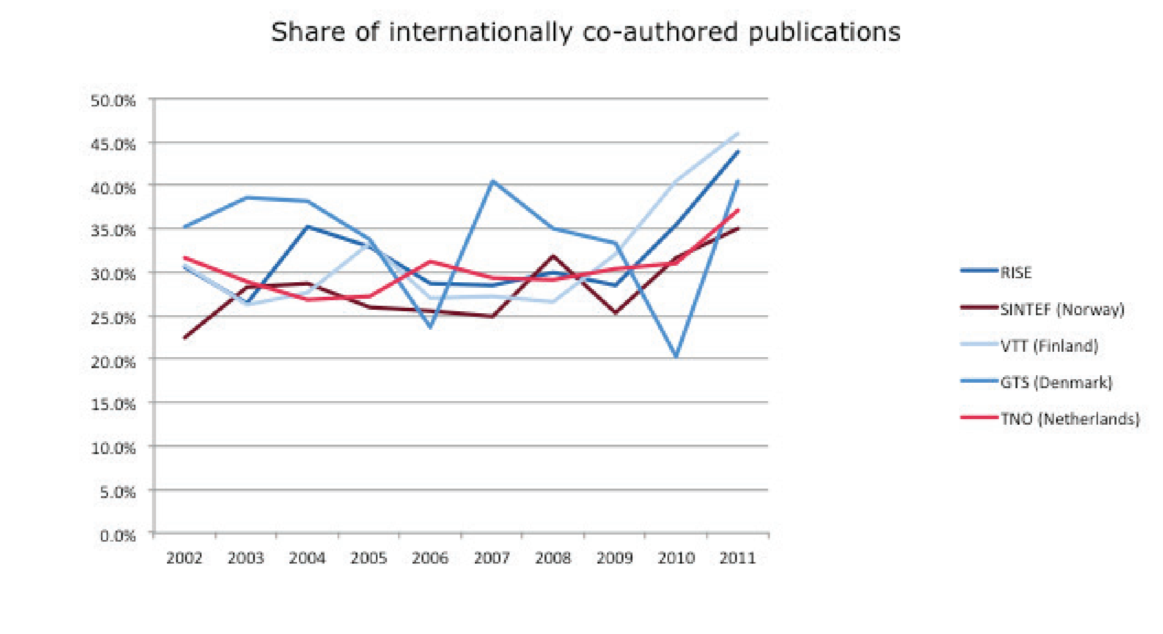

Figure 8.5 Internationally co-authored papers by industrial-technical institutes in Sweden (RISE-institutes), Finland (VTT), Norway (SINTEF), Denmark (GTS) and The Netherlands (TNO).

One comment to the figure, outlining share of internationally co-authored papers, is that the level of internationalisation shown here is based on co-publication, which is one dimension of international collaborative research. Other activities of importance for institutes include contract research for foreign costumers, participation in EU projects (see above) and participation in international conferences and meetings.

Norwegian co-authorship data reveal lower levels of international collaboration for SINTE, but still a rise to 35 per cent at the end of the period. This can be compared to levels of 50-60 per cent internationally co-authored papers for RISE institutes and a strong increase by VTT to above 45 per cent at the end of the period.

Finland: higher levels of international collaboration – including large-scale collaboration networks with many co-authors. This is also relevant to consider when interpreting analysis of citations (VTT 2012)

Sweden: Also showing an increase in international co-authored papers (below 30 per cent in 2009 and above 40 per cent in 2011). Some of the institutes have subsidiaries in other countries – but there is also other international collaboration.

Denmark: The GTS institutes as a whole had an increase in internationally co-authored papers between 35-40 per cent in the period 2001-2011. However, since the publication volume of GTS institutes (see note below about the role of institutes other than research) and fluctuations from year to year in share of publications) does not allow for any strong interpretation of the trend. The Danish GTS institutes illustrate that both publication activities and course activities are considered important. The report “Mapping of the Danish knowledge system” shows both number of publications and dissertations at the institute (years 2000-2007), and number of participants attending the institute’s courses (Forsknings- og Innovationsstyrelsen 2009, p. 109)

The countries included in the analysis show high levels of collaboration with local partners of universities. See figures in end of chapter describing the most frequent national and international collaboration partners such as universities – but also other institutes in the Nordic countries. For example, RISE-institutes have VTT as the most frequent international collaborator and Danish Technical University (DTU) is also among the top 20 collaborators of RISE institutes. The Royal Institute of Technology and Chalmers University of Technology are top collaborators of RISE-institutes in Sweden.

To conclude, these results show that the national collaborative base is important for technical institutes but also indicate an increase in the number of internationally co-authored papers. These results also emphasise the importance of the national science and engineering base for being a strong actor on the international market and for participation in EU programs and other networks where technical institutes are active.

Our co-authorship analysis also shows that the institutes are closely anchored to local collaboration with universities. Other collaborations of institutes (through member organisations, joint R&D programmes etc) involves firms and industry and cover a wide range of activities dealing with technical measurement and testing (standards, materials etc) and also consultancy, which may not to be appearing as scientific publications. Hence, the activities of industrial research institutes need to be understood in a broader context also incorporating their roles in providing innovation infrastructures (including development of pilot machines and testing in demonstrator facilities).

An examination of the Swedish Institutes’ demonstrator facilities (Larsen and Bruno 2012) showed that small-scale customer-specific solutions were at the core of the institutes’ activities. This is the other side of institutes’ collaboration through both large and small research and testing facilities. The many different areas of activity and roles in the innovation system is also expressed in analysis of national GTS institutes and policy discussions about social and economic impact of institutes (GTS 2009, Arnold et al. 2010).

9 Comparing social and working life research institutes

Our second case study looks further into the group of welfare, social and working life research institutes. This field of research lacks a consistent international classification. Hence, the field of research is very broad, and so is the diversity of actors. In order to limit the study to a well-defined group of actors, we have approached the field by using bibliometric analysis.

9.1 Bibliometric framing of the field of social welfare research

Social welfare research was defined by selecting 63 journals covered by the *ISI Web of Science* with a relevant journal classification and/or articles from leading social welfare research institutes in each of the five countries Denmark, Finland, Netherlands, Norway and Sweden. National and/or disciplinary journals were not included.

A total number of 2,595 research articles from 2001-2011 with at least one author's address in one of the countries were downloaded for further analysis. Addresses were grouped into three categories: institutes, higher education institutions and other (mainly hospitals, authorities and private sector). The names of the most active research institutes were standardised.

The basis for a closer look at working life research was established by analysing five journals in a longer timespan 1981-2011: *Economic and Industrial Democracy, Gender Work and Organization, Human Relations, Industrial & Labor Relations Review*, and *Work Employment and Society*.

A list of the 63 journals is given in the *Appendix* along with the number of articles in the data. The five journals for a closer analysis of working life research are highlighted there.

9.2 Results from the overall analysis

Figure 9.1 shows that the number of articles per country was relatively stable until 2005. Thereafter, all countries have had increases, but more so in the Netherlands than in the Nordic countries. Some of the increases can be explained by the addition of new journals to the *ISI Web of Science*.

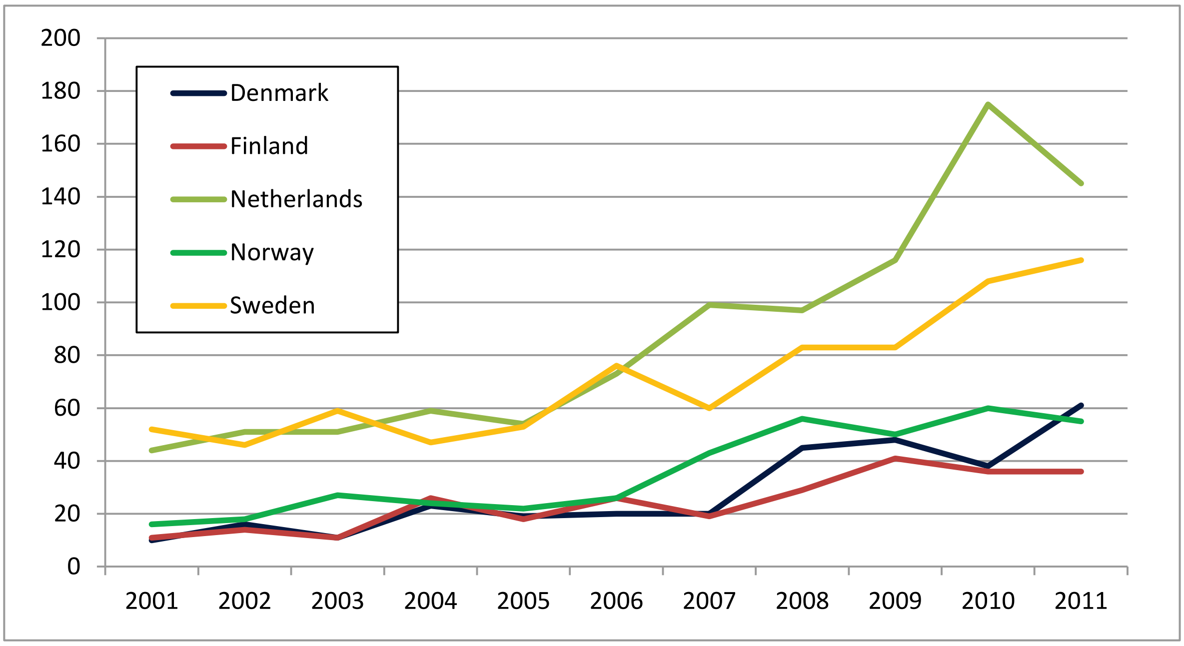

Figure 9.1 Number of articles per year at country level.

There are large variations between the countries in the shares of the country's articles that the institute sector contributes to. The general shares throughout the whole period are: Denmark: 25 per cent, Finland: 25 per cent, Netherlands: 13 per cent, Norway: 41 per cent, and Sweden: 11 per cent. *Table 8.1* shows the shares in the first and second half of the period studied. Overall, the institute sector's share is stable at 19 per cent in all five countries taken together. But there is a relative decrease in the contributions from the institute sector in Norway and Denmark, while there is an increase in Finland. The shares are relatively stable at a low level in the Netherlands and Sweden.

Table 9.1 The institute sector's share of all publications in five countries and two periods, 2001-2006 and 2007-2011.

	Publications in 2001-2006			Publications in 2007-2011		
	Institutes	All sectors	Institutes' share	Institutes	All sectors	Institutes' share
Denmark	28	99	28 %	49	212	23 %
Finland	24	106	23 %	43	161	27 %
Netherlands	40	332	12 %	83	632	13 %
Norway	61	133	46 %	100	264	38 %
Sweden	42	333	13 %	48	450	11 %
Total	195	1003	19 %	323	1719	19 %

Articles from the institute sector and the higher education sector are partly overlapping, as seen below in *table 9.2*. Norway has the largest number of articles from the institute sector, but co-publications with higher education institutions are more seldom.

Table 9.2 Number of articles in 2001-2011 from research institutes and higher education institutions in each county. The number and share of co-publications is also shown.

	Institutes	HE institutions	Co-publications	Co-publications as share of Institutes
Denmark	77	253	26	34 %
Finland	67	213	23	34 %
Netherlands	123	863	71	58 %
Norway	161	264	44	27 %
Sweden	90	716	42	47 %

Table 9.3 shows that about a third of all publications are with international collaboration. Here also, there is slightly less collaboration in publications from Norway. Generally, there is more international collaboration in the higher education sector.

Table 9.3 Internationally co-authored publications in two sectors in five countries.

	All publications		International publications		% International publications	
	Institutes	HE institutions	Institutes	HE institutions	Institutes	HE institutions
Denmark	77	253	19	82	25 %	32 %
Finland	67	213	21	64	31 %	30 %
Netherlands	123	863	28	291	23 %	34 %
Norway	161	264	37	68	23 %	26 %
Sweden	90	716	26	212	29 %	30 %

Table 9.4, on the other hand, shows that publications from the institute sector may be relatively more cited. This is the case in Finland, Norway and Sweden.

Table 9.4 Relative citation rates per country and sector.

	Publications		Total citations		Relative citation rate	
	Institutes	HE institutions	Institutes	HE institutions	Institutes	HE institutions
Denmark	77	253	591	1438	1.59	1.77
Finland	67	213	461	1276	1.55	1.24
Netherlands	123	863	953	6709	2.03	2.07
Norway	161	264	1117	1553	1.72	1.56
Sweden	90	716	613	4920	2.33	1.71

Table 9.5 shows the institutes with a minimum of five publications in the selected journals during the period 2001-2011.

Table 9.5. Most active institutes (in the selected journals in 2001-2011) in each of five countries.

Country	Institute	Publications
Denmark	The Danish National Centre for Social Research	31
Denmark	The National Research Centre for the Working Environment	20
Denmark	Danish Institute of Governmental Research	16
Denmark	Danish Institute for International Studies	14
Finland	National Institute for Health and Welfare	40
Finland	Kela – The Social Insurance Institution of Finland	11
Finland	Finnish Institute of Occupational Health	7
Finland	The Labour Institute for Economic Research	6
Netherlands	Netherlands Interdisciplinary Demographic Institute (NIDI)	66
Netherlands	Netherlands Cancer Institute (NKI)	14
Netherlands	Netherlands Organisation for Applied Scientific Research TNO	11
Netherlands	Netherlands Institute for Health Services Research (NIVEL)	10
Netherlands	The Netherlands Institute for Social Research	8
Netherlands	The National Institute for Public Health and the Environment (RIVM)	8
Netherlands	Netherlands Institute for the Study of Crime and Law Enforcement (NSCR)	6
Norway	Norwegian social research (NOVA)	54
Norway	Institute for Labour and Social Research (FAFO)	23

Country	Institute	Publications
Norway	Institute for Social Research (ISF)	18
Norway	Statistics Norway	15
Norway	The Peace Research Institute Oslo (PRIO)	9
Norway	Ragnar Frisch Centre for Economic Research	8
Norway	The Norwegian Institute of Public Health	7
Sweden	The National Board of Health and Welfare (Socialstyrelsen)	23
Sweden	Institute for Future studies	22
Sweden	Institute for Evaluation of Labour Market and Education Policy (IFAU)	17
Sweden	National Institute for Working Life	11

9.3 Results from an analysis of five journals in working life research

The selected journals for this analysis are Economic and Industrial Democracy, Gender Work and Organization, Human Relations, Industrial & Labor Relations Review, and Work Employment and Society. We study them with a longer time series 1981-2011 to see if there is a change in the role of the institute sector. The total number of articles in this dataset is 462.

There are very few contributions from organisations outside the higher education and institute sectors in this dataset.

This means that we are mainly looking at the relative role of universities and research institutes. In the five countries taken as a whole, the relative contribution of the institute sector decreases from one third of the total publications to a tenth of the publications in the last three decades. In actual numbers, there has been a vast increase in the universities' contributions to the five countries, but almost no increase in the articles from research institutes. Only Denmark's institute sector has a slight increase, but this is only based on 8 articles from the last decade.

The reduction in Sweden is dramatic from the second to the third decade. In the background to these figures, Sweden's most important contributor in the field, the National Institute for Working Life, was closed down in 2007. Table 8.6 shows that this institute has had a large share of Sweden's contributions to the field. A separate search in ISI Web of Knowledge for articles (in all ISI journals) from this institute yields more than a hundred articles per year at the beginning of the last decade. The number is reduced to about fifty at the middle of the decade and to nil at the end of it.

In Norway, the relative contribution of the institute sector mainly decreases between the first and second decade.

Table 9.6 Working life research in five journals: The institute sector's share of all publications in five countries and three periods, 1981-1990, 1991-2000 2001-2011.

	1981-1990			1991-2000			2001-2011		
	All sectors	Institutes	Institutes' share	All sectors	Institutes	Institutes' share	All sectors	Institutes	Institutes' share
Denmark	3		0 %	12		0 %	42	8	19 %
Finland	6	1	17 %	4		0 %	37	2	5 %
Netherlands	9		0 %	25	1	4 %	93	1	1 %
Norway	13	8	62 %	18	7	39 %	42	13	31 %
Sweden	42	14	33 %	55	20	36 %	111	8	7 %
Total	73	23	32 %	114	28	25 %	325	32	10 %

Table 9.7 shows the research institutes with at least two articles in this dataset.

Table 9.7 Research institutes with more than one publication in the dataset of 462 articles in five journals for working life research 1981-2011.

	Institute	Publications
Denmark	The National Research Centre for the Working Environment	4
Denmark	The Danish National Centre for Social Research	4
Finland	The Labour Institute for Economic Research	2
Norway	Work Research Institute	11
Norway	Institute for Social Research (ISF)	6
Norway	Institute for Labour and Social Research (FAFO)	5
Norway	Statistics Norway	3
Norway	Inst Res Econ & Business Adm	2
Sweden	National Institute for Working Life	40

9.4 General conclusions from the bibliometric analysis

From this bibliometric analysis of the broader field of social and welfare research and the narrower field of working live research we can draw the following main conclusions:

- Norway’s scientific activity (measured by publications) is much more dominated by research institutes than is the case in the other countries used for comparison
- When comparing within the group of institutes, Norway also stands out with the highest number of institutes, even regardless of the size of countries. This may indicate a risk of fragmentation and overlap between the Norwegian institutes in these areas
- However, output results both in terms of publications and citations do not indicate that the total Norwegian scientific activity in these areas suffers from the fact that a relatively large share of Norwegian research is carried out by research institutes

10 Strengths and weaknesses of the Norwegian system

So far, our study has mainly dealt with the exploration and understanding of country differences in systems of applied research. But does it all matter? Are systemic differences reflected in corresponding differences regarding the performance of the system? These are the questions which will be addressed in this final part of the study.

Two aspects are important to clarify: First of all, the scarcity of data distinguishing research institutes makes it generally difficult to address and identify strengths and weaknesses specifically related to research institutes. Hence, we are in most cases forced to measure the performance of the total system. This can also prove to be advantageous, since the task of this project in many ways is to assess the performance of entire systems, rather than the specific performance of research institutes. As an example, one could say that a system performs well even with few institutes if the supply of applied research is sufficiently compensated for by other actors, for instance universities. In this perspective we find it both practical and pragmatic to assess the whole system.

A second issue concerns which strengths and weaknesses to assess. The availability of comparable performance data constitutes already a considerable limitation. But apart from that, we will concentrate on the four core objectives for research institutes as stated in the Norwegian framework for basic funding to research institutes. These could be summarised as:

- Providing relevant research based knowledge to users in public sector, companies and society at large
- Performing research of high quality
- International collaboration and competitiveness
- Research co-operation

In the following we will use available indicators in order to compare how the four countries' systems perform in terms of these general objectives.

10.1 Scientific production and quality

Scientific excellence has traditionally been regarded as the role of universities and performers of basic research. This is also the general division of labour in most science systems. However, scientific production and quality are also crucial for the more applied actors in the system. For instance, one of the core elements in the result-based financing system for Norwegian institutes is to reward research institutes for their ability to combine scientific activity with user relevance. Therefore, it makes sense to assess the performance of the applied system by indicators on scientific production and quality.

In terms of scientific publications per capita, we see that the five countries in question are among the top performers in the world.

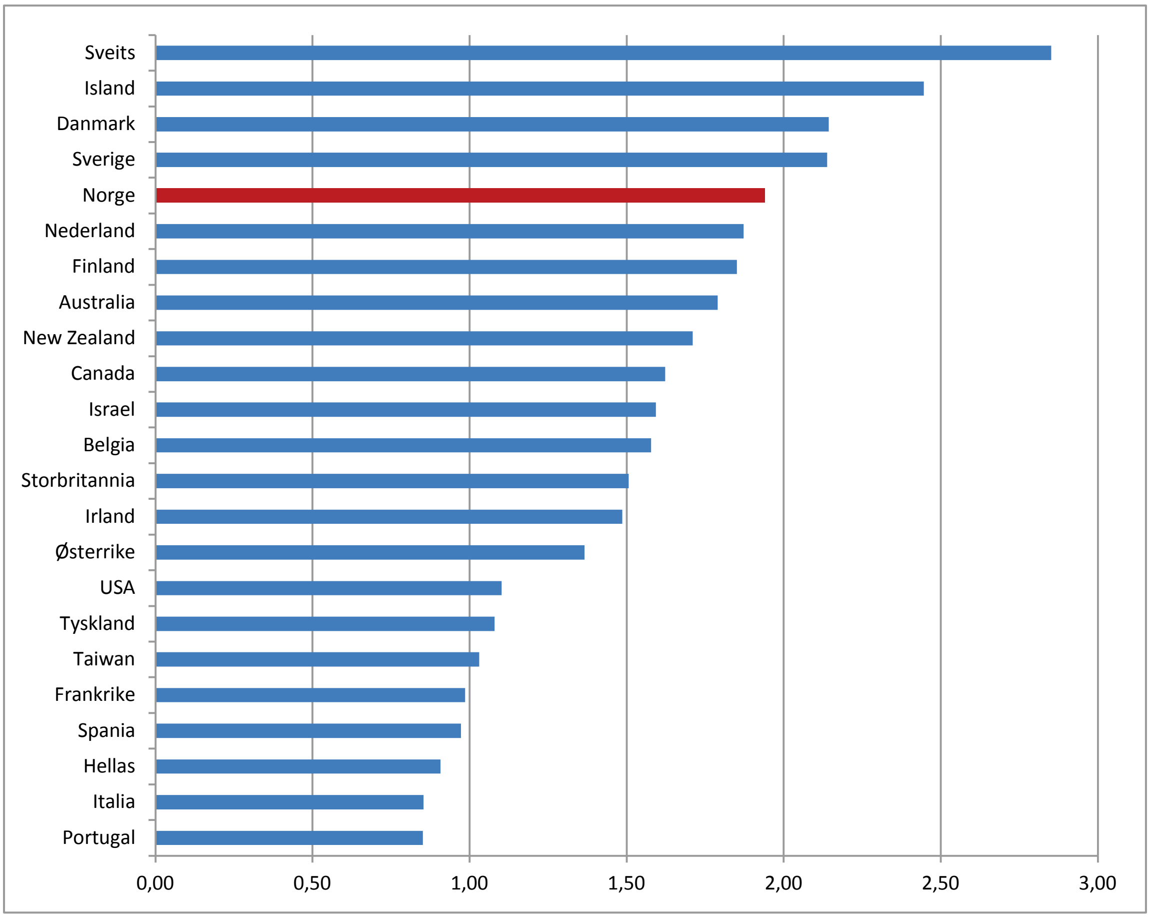

Figure 10.1 Scientific publications per 1000 capita

Source: National Science Indicators/Thomson Reuters/NIFU

Norway is also one of the few western countries to have increased its share of world production during the last ten years. National calculations for Norway show that the research institutes account for 17 per cent of all Norwegian ISI articles. Unfortunately, there are no available data on the share of institutes in scientific production across countries. However, if we compare the Norwegian research institutes' share of national scientific production over time, we find that the picture corresponds to a large degree with the profile of public R&D funding shown in figure 6.1 above. In other words, the share of institutes in national scientific production declines at the same rate as the decline in public funding to the institutes. This indicates a clear correlation between public funding and scientific production, both regarding universities and research institutes.

Citations are generally regarded as a viable indicator of scientific quality. The figure below shows how countries rank in terms of citations per article compared to the world average. The countries considered in this study perform fairly well, although Norway seems to be the lower performer in terms of citations. Over time, Norway has managed to reduce the gap in citations compared to its Nordic neighbors, but is still slightly lagging behind.

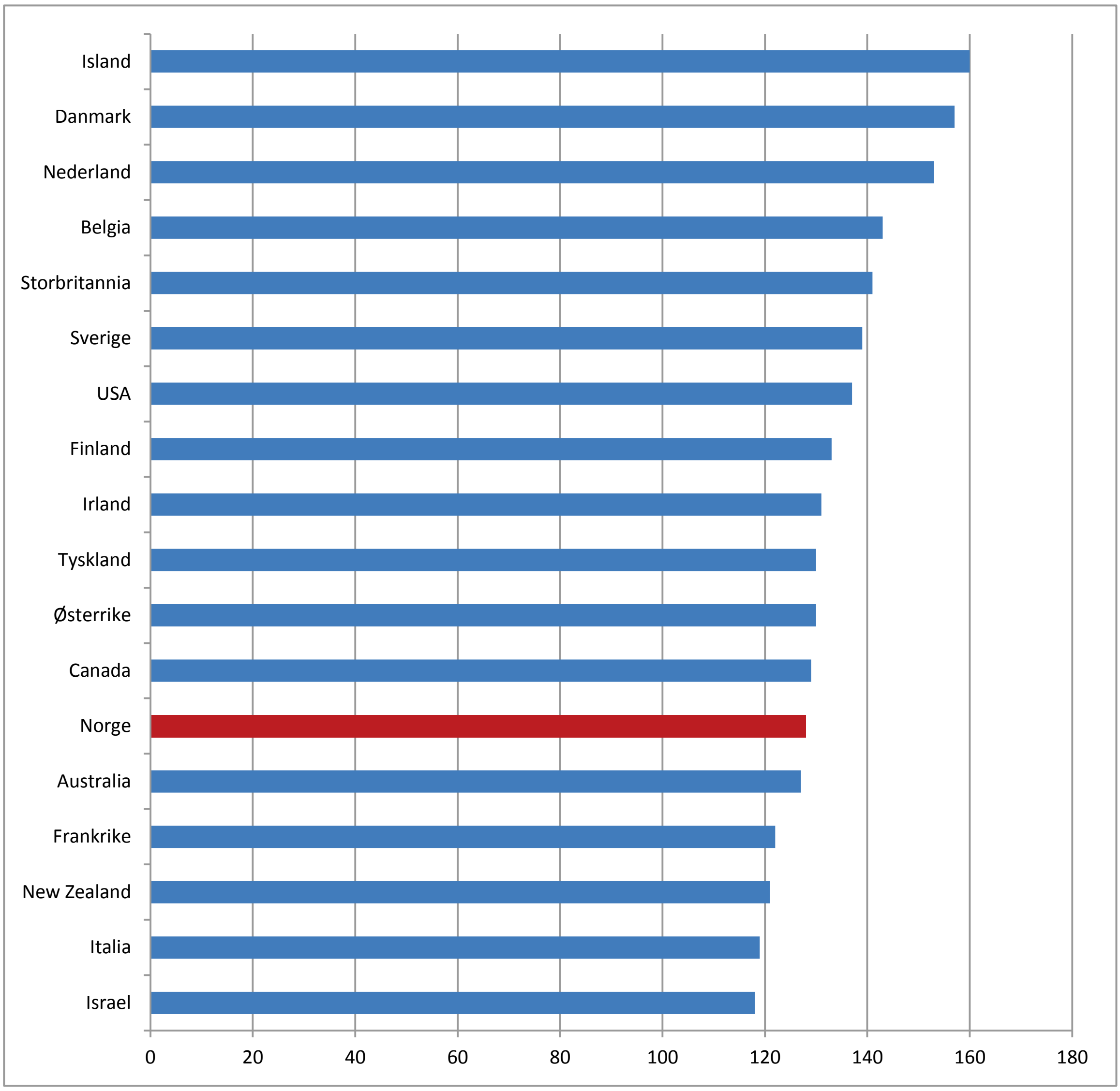

Figure 10.2 Relative citation index 2008-2011 compared to world average (=100)

Source: National Science Indicators/Thomson Reuters/NIFU

Particularly interesting for this project is how articles from research institutes are cited compared to articles from universities and other actors. Again, international comparable data are lacking. But for Norway, the data indicate, perhaps surprisingly, that articles with authors from research institutes have been more cited than articles from higher education institutions over the last 20 years. However, since early 2000, citations from university authors have been generally more cited than articles from research institutes.

In summary, the relatively large institute sector in Norway seems to have little negative effect on Norway's total scientific output, measured by the classical indicators of publications and citations.

10.2 Industry renewal

One core mission of research institutes is to contribute to industrial growth and renewal. This is particularly the case for technological and business oriented institutes (RTOs). It is therefore relevant to see the degree of diversification in industry in relation to the role of research institutes.

The so-called Hanna-Kay-index measures the degree of diversification vs. specialisation in industry by calculating the share of value added in 20 sectors. According to this calculation, countries are considered diversified if the index is above 10, moderately diversified for values between 6 and 10 and specialised for values below 6.

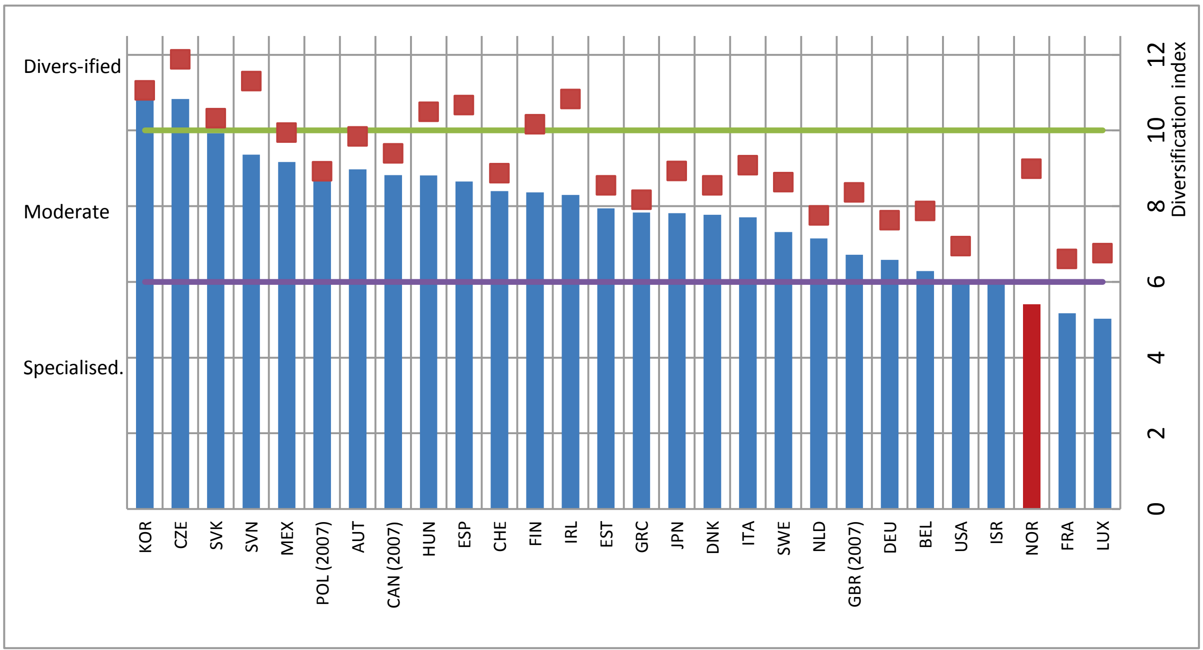

Figure 10.3 Industry specialisation according to the Hanna Kay-index, 2008 and 1998

Source: OECD STAN, 2011

Norway, together with France and Luxembourg stand out with a particularly specialised industry sector. Moreover, Norway is the country where the specialisation has increased the most in course of the last ten years. All the other countries we compare with are in the group of moderately diversified industries. Of course, we need to underline that specialisation is not necessarily a weakness. As the figure shows, many strong economies appear quite specialised, and the general pattern globally shows a tendency towards increasing specialisation. Nevertheless, there might be some sort of inflexion point from where increasing specialisation has more negative than positive effects. Despite Norway's strong economy at current stage, there is reason to raise the question whether the inflexion point of over-specialisation is about to be reached.

Adding to this picture, the Community Innovation Survey (CIS) indicates that relatively few Norwegian companies are innovative. Results from the last two innovation surveys (CIS 2008 and CIS 2010) demonstrate that Norway lags considerably behind its Nordic neighbors when we look at the total share of innovative enterprises.

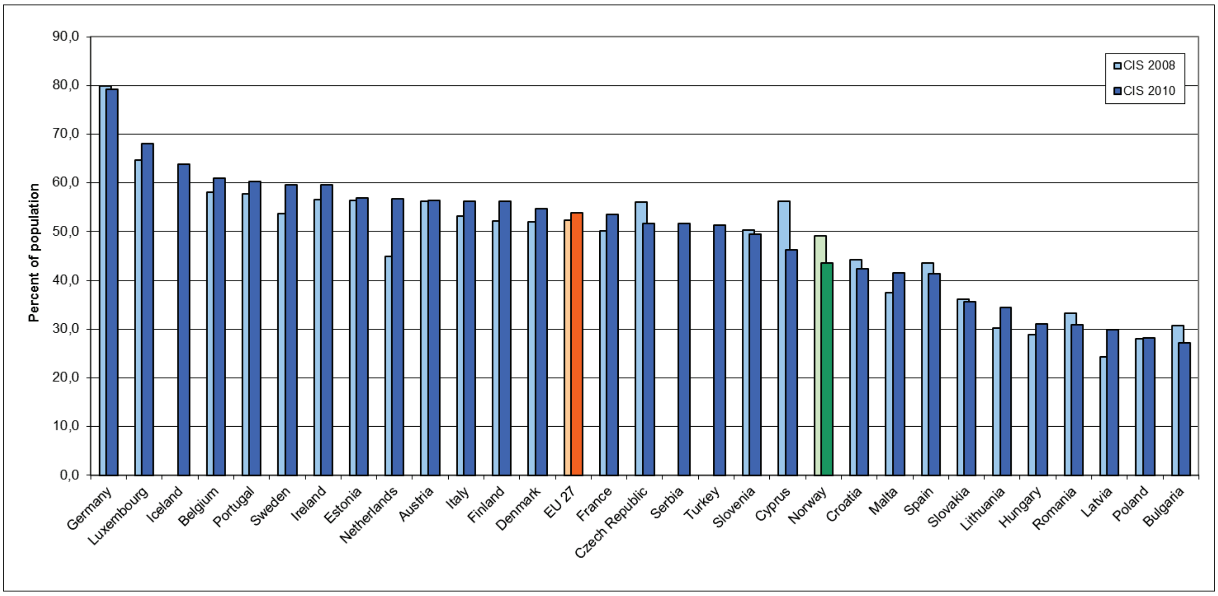

Figure 10.4 Share of innovative companies in European countries, 2008 and 2010

Source: Eurostat/CIS 2010 and CIS 2008

The share of innovative enterprises in Norway is 43.5 per cent, compared to nearly 60 per cent in Sweden, and around 55 per cent in Finland, Denmark and the Netherlands. It needs to be underlined that international comparisons of innovation survey data are highly questionable[6]. Even so, it seems undisputable that the innovation activity in Norwegian companies has shown a declining tendency in three consecutive survey periods.

The apparent mismatch between high economic output and low levels of R&D and innovation is often referred to as “the Norwegian paradox” (OECD 2008). This discussion also relate to the issues of lock-in mechanisms and path dependencies (Fagerberg et al 2009). We will not raise this discussion here. But we observe that Norway experiences both a declining innovation rate and an increasing industry specialisation. Hence, there seems to be a need for industrial renewal in Norway, and the role of research institutes should be taken into account when discussing strategies to cope with that challenge.

10.3 International competitiveness

The increasing importance of the EU framework programmes as a funding source and arena for networking is described above in chapter 6. But since EU funding is based on competition, it is relevant to consider how countries perform in the competition for EU grants. The figure below shows success rates expressed in granted applications as a share of total nation applications.

[6]A special survey conducted by Statistics Norway for CIS 2010 has revealed significant effects of differences in survey methodology. The experiment suggests that innovation in Norwegian companies may be underestimated (Statistics Norway 2012)

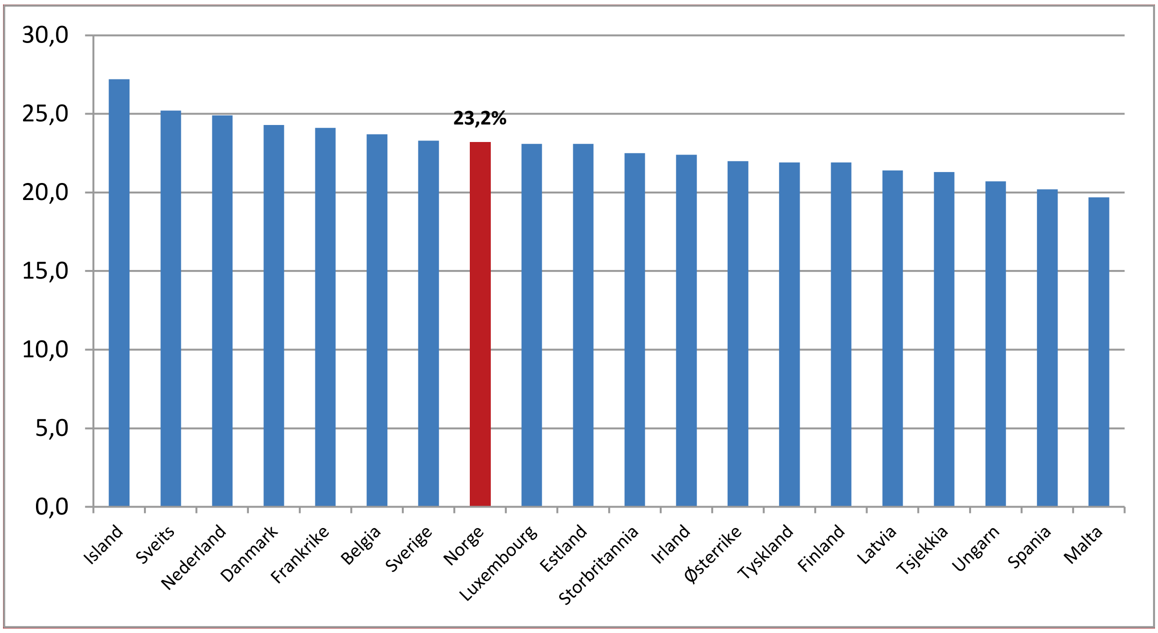

Figure 10.5 National success rates in EU FP7, top 20 countries

Source: European Commission/E-Corda

This is again an area where all the five countries we study perform well, although Norway is slightly behind the other countries we compare with in this study.

If we look at the actors involved in applications from each country, we see that Norway, and to some degree Finland, stand out with a particularly high share of successful applications from research institutes (REC), while institutes in Sweden and Denmark are much less active in the European arena. The high success rates of Sweden and Finland are primarily due to the contribution from higher education institutions (HES).

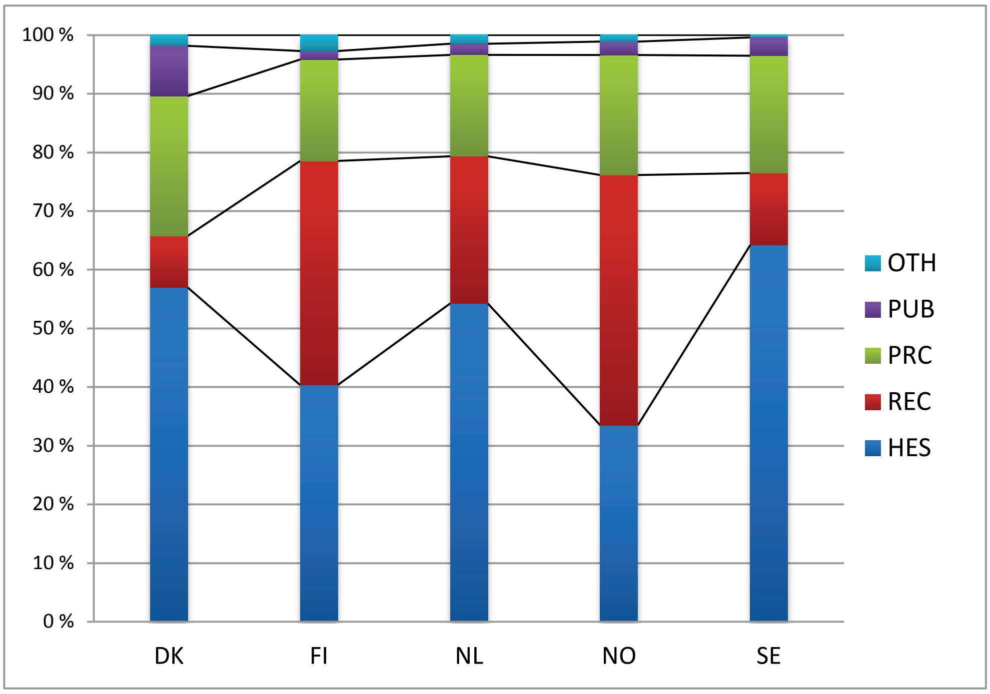

Figure 10.6 Share of innovative companies in Nordic countries, 2008 and 2010

Source: CIS 2010, based on national reports

Note: OTH=Others, PUB=Public institutions, PRC=Private companies, REC= Research institutes, HES= Higher education

10.4 Co-operation

Knowledge flows and knowledge sharing are important dimensions in all R&D and innovation systems. Hence, the ability to cooperate between actors and sectors is crucial for the functioning of the system.

The classical benchmark or proxy for “co-operation-intensity” of a system is to look at cross-sectoral funding streams. In the case of applied research it is natural to look at how much R&D funding the higher education institutions and the government sector receive from industry. This indicator reflects in many ways the degree of co-operation between research institutions and private companies.

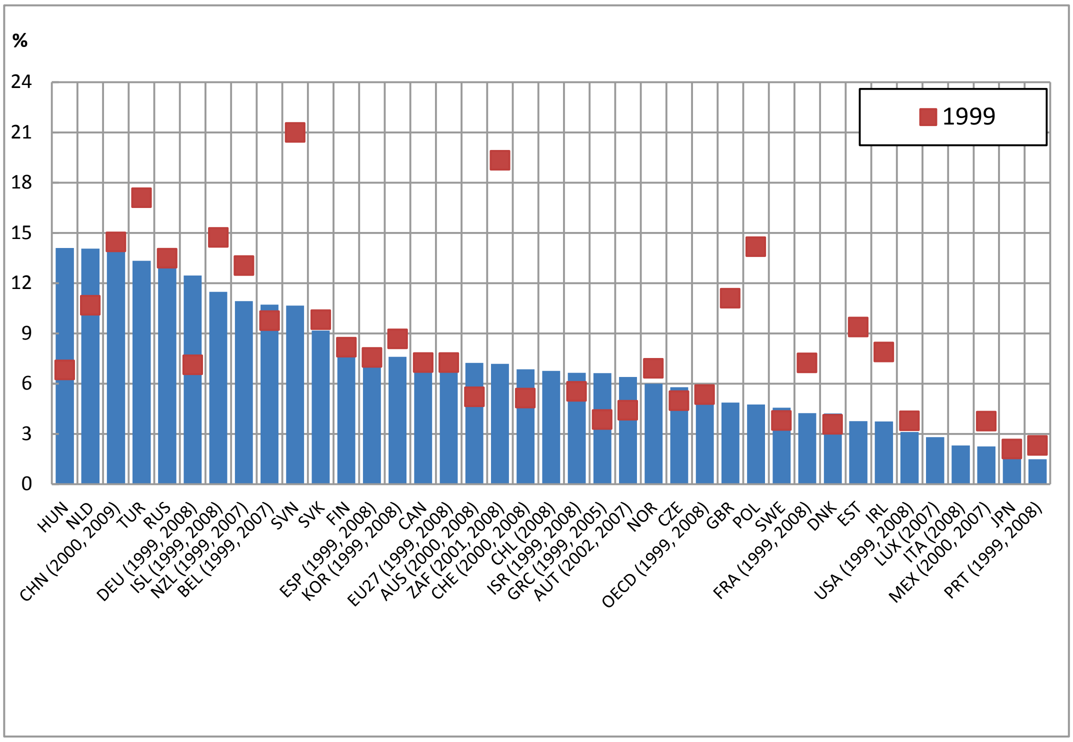

Figure 10.7 Business-funded R&D in higher education institutions and government sector as a share of total R&D in these sectors, 1999 and 2009

Source: OECD, R&D database, 2011

In this context, the degree of co-operation seems low in Norway, but even lower in Denmark and Sweden. On the other hand, Finland and the Netherlands are among the more cooperation-intensive countries. However, the Finnish and Dutch values are skewed by the fact that their large technical research institutes (VTT and TNO, respectively) are classified as government sector, while the most important technical research institutes in Norway, Sweden and Denmark are classified in the industry sector (SINTEF, RISE and GTS). As a result, companies’ co-operation with the latter institutions is not registered as such, since these institutes are classified as industry themselves.

Another comparison which points towards high co-operation is the indicator for public-private co-publishing in the Innovation Union Scoreboard. In this context, Norway and the other four countries are among the top performers. This indicates that softer, non-economic forms of co-operation are widespread in all countries (see chapter 4.2).

The Community Innovation Survey (CIS) also includes information about the role importance of co-operation partners for innovative companies. This information can shed light on the relevance of different actors on the market for applied research. The actual question regarding this dimension is phrased as “did your company cooperate with other enterprises or institutions and, if so, with which institutions?”. The results drawn from national innovation surveys[7] are shown below.

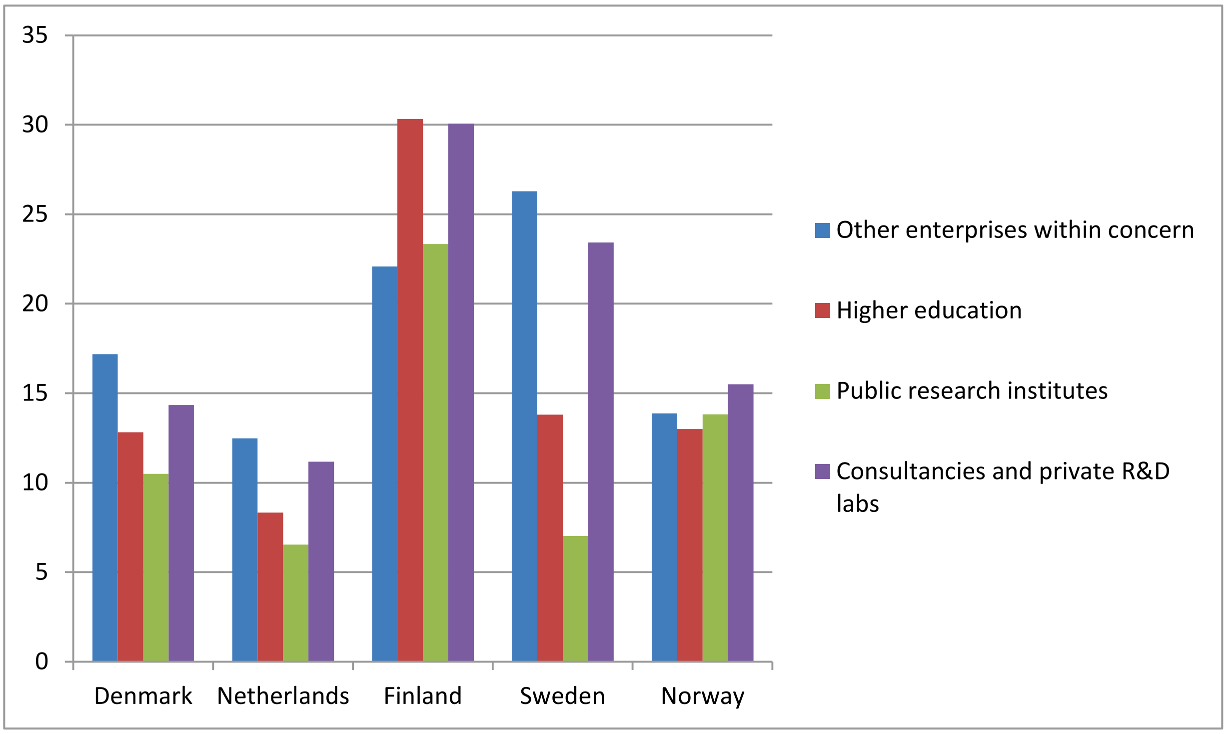

Figure 10.8 Share of innovative companies with innovation co-operation, by partner (2008-10)

Source: Eurostat/CIS 2010

These data give a profile of innovation co-operation patterns and knowledge demand in the five countries. A remarkably high share of Finnish companies report that they have innovation co-operation with external partners. Not surprisingly, enterprises within the same concern appear most important for Swedish innovative companies. In Norway, companies seem to cooperate quite evenly with all four types of partners. Norway is also the only country where public research institutes and private R&D labs are more frequently reported as innovation partners than companies within the same concern. These findings reflect the findings in chapter 6 regarding the extensive use of external partners for Norwegian firms.

As illustrated in figure 10.9 below, Norway is also one of the countries where a relatively large share of companies state that public research institutes are the most important innovation partners for innovative companies.

[7] Eurostat’s official comparable data from CIS 2010 will be available in the autumn 2012. Until then, data must be compiled from national sources and therefore treated with caution.

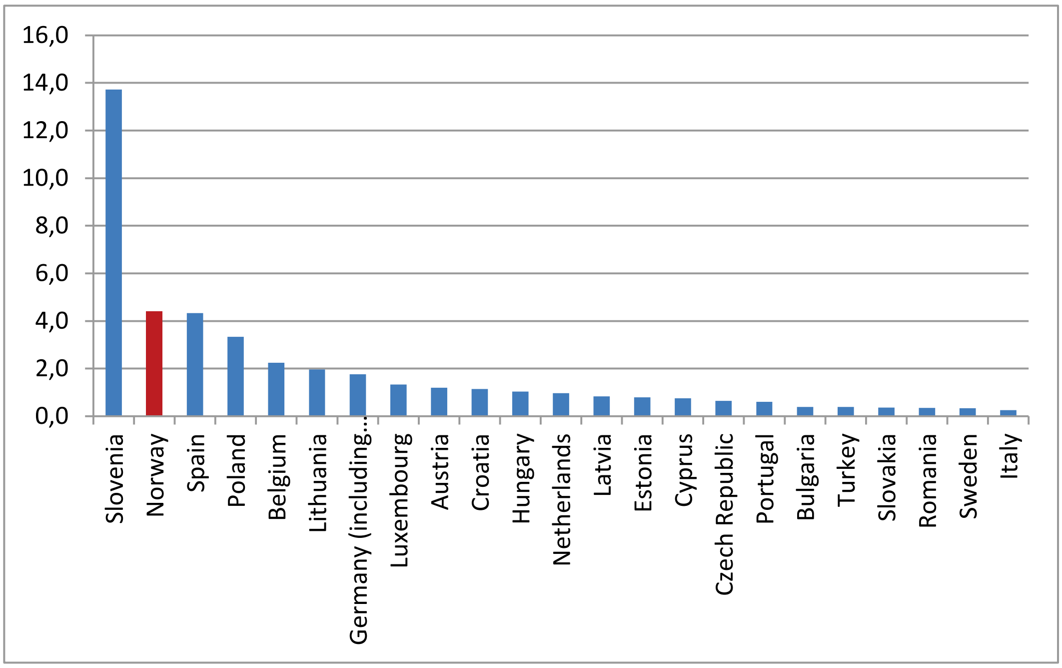

Figure 10.9 Innovative enterprises for which co-operation with Government or public research institutes is the most valuable method, as share of all innovative enterprises (2008-10)

Source: Eurostat/CIS 2010

All in all, these data indicate that research institutes appear more important as innovation partners for firms in Norway than in most other countries. It is, however, important to underline that these data only cover a selected fraction of the business enterprise sector, as they do not include non-innovative companies.

Another dimension is of course co-operation with users in the public sector. This is an area where comparable data is scarce. However, a recent pilot study of public sector innovation in the Nordic countries (Bugge et al 2011) provides some preliminary indicators on innovation co-operation patterns for public sector institutions. The figure below shows from the pilot study for the three Scandinavian countries[8]

[8] Data for Finland not available for this dimension of the study

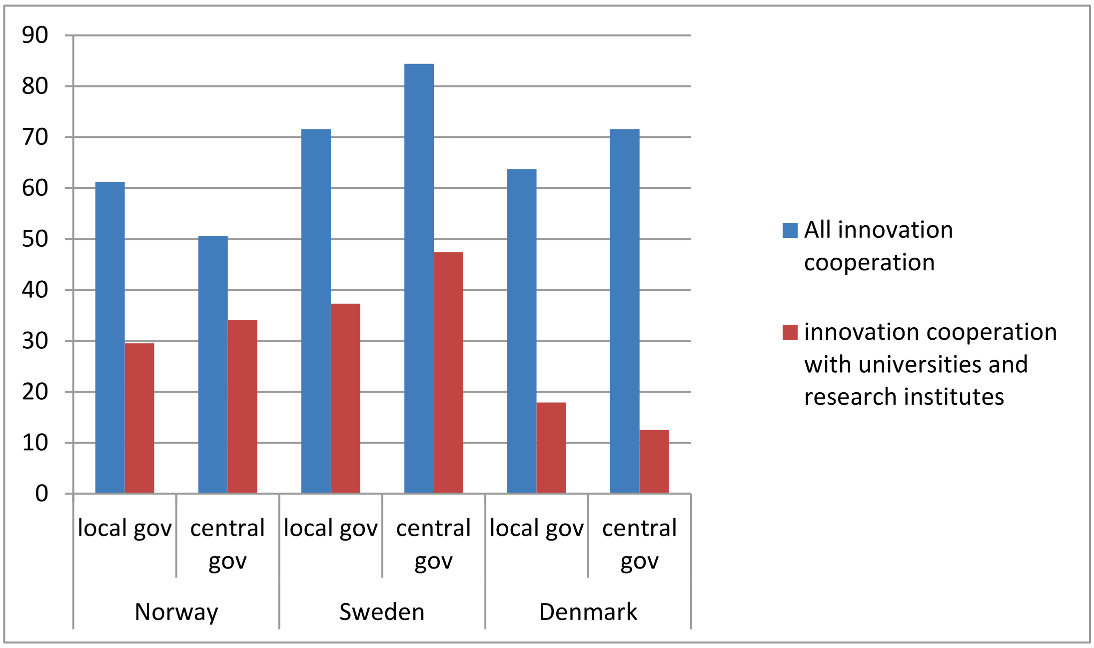

Figure 10.10 Public sector institutions with innovation co-operation/co-operation with universities and public research institutions as a share of all innovation active institutions
Source: NIFU/PUBLIN

The survey did not distinguish between universities and research institutions as co-operation partners for public sector institutions. What can be derived from the study is therefore that public sector institutions in Norway seem to cooperate less on innovation with other partners than do institutions in Denmark and Sweden. However, research institutions seem to be more important for public sector innovation in Sweden and Norway than in Denmark.

10.5 Summarising strengths and weaknesses

Based on this overview of systemic strengths and weaknesses the Norwegian system can be characterised as follows:

Table 10.1 Overview of strengths and weaknesses

Dimension	Strength	Weakness
Scientific production	• High production, but behind the other 4 countries • Very high growth in publications	
Scientific quality	• Fairly high citation rate, but well behind the other 4	
Industry renewal		• High and increasing specialisation
Innovation activity		• Low, but possibly underestimated • Declining rate of innovative companies
EU FP7 success rate	• High success rate, but behind the other 4 countries	• Low participation from higher education institutions
Co-operation	• Very high public-private co-publishing • High share of innovative companies with co-operation with institutes	• Low, but probably underestimated cross-sectoral financing • Moderate share of innovative companies with innovation co-operation

11 Policy dilemmas and options

International comparisons are seldom sufficient as a basis for designing policies and instruments. In the introduction to this project, we referred to Edquist's arguments for the importance of comparative studies. Another central point in his argument is that policies have to address concrete *problems*, and that international comparisons help policy makers identify these problems (Edquist 2011). In other words, an important benefit of comparative studies is to identify problems and challenges.

11.1 Main findings

Based on the analysis and comparisons in the previous chapters, we find that Norway appears to have a rather applied-oriented system in terms of public R&D funding. Roughly half of all public funding in Norway is considered to have an applied focus. Furthermore, we find that a relatively large share of public R&D funds in Norway is allocated according to competitive mechanisms. Although private funding for research is less abundant in Norway, Norwegian firms seem to have a high propensity to purchase R&D from actors outside the concern. In summary, this leads us to conclude that Norway has a relatively large domestic market for applied research.

We also find that research institutes play a more dominant role in this market than in the other countries. Yet, when comparing the countries according to mainstream output indicators, we find little evidence indicating that the Norwegian system suffers from its applied and institute based orientation. On the contrary, Norwegian research institutes appear to enhance overall performance of Norwegian research in several respects, notably in the competition for EU funding.

A common concern for all countries seems to be the need to ensure that the R&D and innovation system is able to produce research which is oriented towards meeting societal challenges and securing future sources of growth.

In light of these challenges and objectives, we will emphasise three particular challenges for the Norwegian system of applied research: Firstly, we identify a general need for renewal of the business sector. Secondly, policies should aim at developing appropriate instruments for addressing grand, societal challenges. Thirdly, we point to the international arena as a way of expanding the Norwegian domestic market for applied research.

11.2 Renewal of the business sector

As clearly demonstrated in the above sections, Norway has a low R&D intensity in the business sector, at least compared to its Nordic peers. This is not necessarily a problem in itself, especially in view of Norway's strong economic performance (see for instance table 4.1). It appears, however, that Norwegian industry is highly specialised in low R&D-intensive sectors. Moreover, we find that Norway stands out as one of the most specialised economies among all OECD-countries, and that Norway is the one country where the specialisation has increased the most during the last ten years. To this picture, we could also add the moderate and declining innovation intensity among Norwegian firms. In sum, it appears that the need for industrial renewal is definitely an issue for policy.

Research institutes are important actors in this respect, in particular the technological and business oriented institutes, the so-called RTOs. One of their main roles is precisely to contribute to industrial renewal and innovation through research. So, have the Norwegian institutes failed, or have policies failed in equipping the institutes with the necessary means to trigger R&D activity in Norwegian enterprises? Or has Norway relied too much on the role of institutes instead of building R&D capacity in firms?

A number of studies of Norwegian institutes, as well as the last Government white papers on research policy, seem to reject previous allegations against the Norwegian institute sector. The role of research institutes is nonetheless relevant to discuss in light of the need for industry renewal in Norway. The Norwegian model relates in many ways to the theories of *open innovation*, which i.a. emphasises the need for firms to "open up" and innovate through and together with external knowledge sources (Chesbrough 2006). The strong alliance between companies and institutes in Norway could be seen as a system of open innovation, and to a large extent this model has proved to be a success story.

However, a recent study of the effects of open innovation practices finds that outsourcing innovation to external partners such as research institutes actually has negative effects on firms' product innovation (Herstad and Ebersberger 2011). On the other hand, they found that the sourcing of R&D had positive effects for firms which already had an internal R&D activity of their own. This raises the question whether too much R&D outsourcing reduces the internal learning processes of firms. The policy dilemma is therefore to find the right balance between, on the one hand, institutes as a supplementary knowledge source for firms (adding to firms' own innovation process) and, on the other hand, their compensatory role (conducting R&D on behalf of companies).

Based on the findings of this study, we will argue that Norwegian technological research institutes are insufficiently equipped to act as real change agents for Norwegian firms. A low basic funding combined with a relatively competitive public funding system draws technological research institutes to serve the needs of established structures instead of acting as change agents for Norwegian industry. The role of institutes should be to *supplement* the R&D performed by firms and not *compensate* for their lack of R&D activity. As a consequence policies should both aim to increase R&D and absorptive capacity in firms and at the same time increase the basic funding of institutes so that they are equipped to provide firms with the more forward looking and high risk research which is not so likely to be carried out by firms on their own.

11.3 Addressing grand, societal challenges

Our brief survey of current policy trends in the five countries (see chapter 4) reveals a common trend in all countries towards prioritising so-called grand, societal challenges. This trend is also confirmed by other recent policy surveys, i.e. OECD's most recent Science and Technology Outlook (OECD 2012). Furthermore, as shown in chapter 6, the upcoming EU Horizon 2020 programme will devote the lion's share of its budget to research addressing such grand challenges. This "megatrend" represents a policy shift towards more focus on the societal effects of R&D and hence a more applied orientation of policies and funding. Research institutes should therefore have a major role in this shifting landscape.

The main question for policy is how to translate these ambitions into concrete action. One particular challenge is how to transcend established borders between sectors and research disciplines. This is crucial, since the complex nature of the challenges in question calls for more multidisciplinary and cross-sector research. In other words, there needs to be some kind of "thematic bundling". But how and where should this bundling take place?

The recent Finnish reform proposal described in chapter 4 is quite explicit in this respect. The radical mergers between sector-specific institutes are to a large extent motivated by the need to address broader themes and complex challenges. The proposed strategy is therefore to merge public research institutes into larger units with broader thematic coverage. In addition, they seem to move from ministry-specific funding to a system more funding from one common pot. In other words, the thematic bundling seems to be addressed both at the funding level and at the performance level.

The Danish model consists of extensive mergers of public institutes into larger universities. Although this reform was justified by a number of reasons, the need to address broader challenges was definitely one of them.

The Dutch model is more dualistic, with on the one hand a declared hands-off and generic policy, and on the other hand a strong element of strategic steering through substantial reallocations of funding from research institutions to the so-called Top sectors (see chapter 4). However, the steering in this case is primarily left to the companies, rather than the government.

In the Norwegian model, the heaviest responsibility for action towards societal challenges is left to the Research Council of Norway (RCN). The RCN receives funding from sixteen ministries and has, in turn, a financing and strategic responsibility for more than fifty research institutes in various fields. With this degree of diversity on both funding and performing level, the RCN has to play a major role in the thematic bundling. This is quite the opposite of the proposed Finnish model, where the strategic level (TEKES, Finland's Academy) is more or less bypassed in the planned efforts to design R&D policies and instruments for tackling grand challenges.

11.4 Increased internationalisation

Our study has confirmed that research institutes in Norway are among the drivers behind the internationalisation of the Norwegian R&D-system. This is particularly the case for the technical research institutes and their performance in the competition for EU funding. Nevertheless, there is still scope for improvement and for further exploiting the potential of international markets for research. For instance, the case study of RTOs in chapter 8 shows that SINTEF is a champion in terms of EU funding, but at the same time, funding from international sources in general is low compared to the other institutes.

The domestic market for applied research is by nature relatively limited in Norway. There is also reason to believe that the competition for EU funding will be strengthened in the forthcoming Horizon 2020 programme. Confronted with these challenges, a stronger international strategy, beyond the EU framework programmes, might be advisable in the Norwegian policies for research institutes.

The remarkable growth in the international funding for the Danish GTS institutes could be inspirational in this respect. An international evaluation of the GTS institutes in 2009 found that there is no trade-off between serving national industry and delivering knowledge intensive services to costumers abroad (Sörlin and Arnold 2009). Given the increased focus on societal challenges in most countries, the potential of the international market for knowledge intensive services should also be exploited by institutes other than technological and business oriented institutes.

We therefore see a general need for policies which aim at increasing Norwegian research institutes' presence in the international market for research based knowledge services.

11.5 Policy options

As argued in chapter 3, the roles and missions of the institutes need to be rearticulated in the light of changes in the R&D landscape as well as in the light of emerging R&D challenges. Above, we pointed out two clusters of challenges which seem particularly important when discussing the roles and missions of Norwegian research institutes. With this as a backcloth, what are the policy options?

Merging research institutes into larger entities is clearly an alternative and an option discussed in several countries. This strategy could, in principle, be an answer both to the need for industrial renewal and to the need for addressing grand challenge. However, experiences from the Danish mergers seem to indicate that the conditions for policy oriented research have worsened considerably as the former sector institutes have become more deeply integrated into the universities. Furthermore, unlike the Danish and Finnish institutes most Norwegian institutes are organised as independent bodies not controlled by the state. The devolution from the state of formerly public institutes in the '80s and '90s was a conscious decision to create arm's length distance to the institutes. The state no longer has the same opportunity as in Finland and Denmark to direct steering of the institutes' strategy. Instead the state has to relate to the institutes as autonomous actors, respecting their governing bodies and their strategies.

Incentives through competitive funding channeled through the research council is the second obvious strategy, and the one most used today. One question however is to what extent a low basic funding combined with relatively short term competitive funding is sufficient to change the landscape to create the desired concentration and quality of research, as well as the conditions for cross disciplinary and grand-challenge driven research that is aimed for by Swedish, Danish, Finnish and Dutch institute policies.

One line of argument in organisational studies (DiMaggio and Powell 1983) is that similar institutional pressures on actors in a field can lead to conformity and similarity among actors (isomorphism). In the context of research institutes this raises the question of whether a system dominated by competitive funding could lead to industry lock-in and "frozen" thematic areas lacking incentives for renewal and competence development in areas that could be relevant for innovation within traditional industries and creation of new business opportunities.

Furthermore, as shown by Gulbrandsen et. al. (forthcoming SAK report) only the large scale projects, such as centres and other very large projects have the potential to release cooperative efforts between universities and institutes. The institutional landscape seems to be only modestly affected by this funding mechanism, as seen e.g. in the social science institutes which have the highest share of funding from the research council, but still the lowest degree of concentration and the lowest degree of work division. A pure market mechanism thus seems to be a poor instrument in terms of stimulating concentration and a clear division of work.

Incentives through the basic or strategic funding is a third alternative. As pointed out in the evaluation of the research council (Arnold and Mahieu 2012), steering through quasi-markets in the form of performance-based reallocation of the basic funding may stimulate productivity, but is hardly a good way to make progress towards concentration and relevance, and needs to be complemented by a more visible hand in the form of strategic dialogue.

This study has revealed that the other four countries in this study have a more extensive use of strategic dialogue and steering of their research institutes. The recent evaluation of the Norwegian basic funding of institutes also points towards the need to increase the dialogue between the state, the research council and the institutes (DAMVAD 2012). *Strategic funding and dialogue* may thus be explored further as an instrument to create concentration, work division and co-operation towards multi-disciplinary and challenge-driven research, as well as providing the industrial institutes with sufficient resources to avoid market driven over-specialisation and lock-in.

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Annex 1: Further description of RTOs

Sweden: RISE-institutes

Most Swedish institutes have previously been run as foundations, with certain limitation on actions and financial freedom. Today, many institutes have been transformed into limited companies with partially private and partially public ownership. At the same time, the public ownership of the Swedish institutes has been organised into a holding company, IRECO, which more recently changed its name to Research Institutes of Sweden Holding AB. RISE consists of four corporate groups with a total of 17 RTOs and their subsidiaries. In 2011, the RISE RTOs had altogether 2114 employees and a total turnover of 2.49 billion Swedish kronor. Today, the RISE-institutes account for about two thirds of the Swedish institute sector (Gov Bill 2012). The predecessor to RISE was called IRECO was established in in 1997 to organise the governmental ownership of institutes. In the following years, several restructuring of institutes took place to incorporate institutes in the four groups of institutes; SP, SWEREA, Swedish ICT and Innventia. The names of the subsidiary companies were included in the bibliometric analysis (also including names of institutes merged into existing institutes, such as STFI and Packforsk, now included in the institute Innventia).

The formation of an industrial research institute sector in Sweden started during the 1920s, in part inspired by earlier European examples, e.g. institutes in Germany and the UK. The first Swedish research institute was created following a private initiative from steel-producing firms; this institute was active in the field of metallography. In the 1940s, during World War II, came the first public initiative to start several new institutes while reorganising the Institute of Metallography into a semi-public institute (Sörlin 2006). The newly formed institutes were dedicated towards applied research in strategically important fields where Swedish firms were active, i.e. forest products, food and textiles respectively. These institutes were given considerable support from public funds already from the start while also considered having an important role for Swedish industry. Below is an outline of areas of R&D activities of the four institute groups and their Swedish subsidiaries. In addition to the Swedish subsidiaries listed below

SP – Science Partner	**Swerea**	**Swedish ICT**	**Innventia**
6 business areas (energy, ICT, Life science, Risk-Safety-Security, The built environment, Transportation) ***6 subsidiary companies: Name (R&D areas)***	Areas of activity include: materials, process, product and production technology. ***5 subsidiaries: Name (R&D areas)***	Areas of activity include: embedded intelligence, security, nano electronics, distributed systems design and energy saving electronics. ***5 subsidiaries: Name (R&D areas)***	Innovations based on forest raw materials. 3 business areas: Biorefinery, Material processes and Packaging solutions
CBI (Cement, concrete)	IVF (polymers, ceramics production engineering)	Santa Anna (applied IT, eHealth)	
Glafo (Glass research)	KIMAB (materials and process development)	Viktoria Institute (automotive, transport)	
JTI (Agriculture)	SWECAST (cast metals)	Interactive Institute (art, design and energy)	
SIK (Food research)	SICOMP (composites)	SICS (computer and communication science)	
SMP (Testing, certification)	MEFOS (metallurgy)	Acreo (microelectronics, optics)	
YKI (Surface chemistry)			

Industry member organisations are active in a wide range of activities at institutes ranging from defining areas of research, consulting, PhDs (Bienkowska et al. 2010). The analysis of governmental bills and reports in Sweden in 1940-50s describe institute policy historically, showing a separation of basic and applied research organisationally but also stressing interaction between basic and more applied research and institutes as an arena where industrial needs and scientific attitudes towards knowledge production were supposed to meet (Pettersson 2012). During the 1950-60s several new institutes were created and governmental funding of their activities grew rapidly. The institute sector became larger and more diversified during this time. But from the early 1980s and onwards, research policy shifted to prioritise universities as research performers with diminishing relative funding of institute-based research as a result. The end of the Cold War and deregulation of several important markets further exacerbated this development (Sörlin 2006). Also during the late 1990s public support for the institutes diminished substantially. However in the two recent Governmental Bills for Research and Innovation (2008 and 2012), the roles of the institute sector has been strengthened. In the time period following the guidelines of the Bill from 2008 the funds allocated to the holding company RISE was 355 MSEK (in 2009) and the annual funds for years 2010 and 2011 was 468 MSEK. In 2012, the institute funding of strategic competence development at institutes are set to be 473 MSEK.

Finland: VTT

VTT has a pure military background and was established during World War II to provide the Finnish armed forces and civic defence authorities with scientific competence within the measurement and testing fields. Only by the end of the 1950s did VTT start to provide services to private industry as well. It grew steadily after the war and already by the mid-1960s it was the largest research institute in Finland. Today VTT is the largest research performer in Finland, significantly larger than any single university, and like TNO it is organised as a polytechnic research institute (Sörlin 2006).

Looking ahead from today towards 2020, VTT's vision is focused on the concept of sustainability. In this regard, six impact areas have been chosen as focal points for VTT work. These are bioeconomy, low-carbon energy, resource-efficient industries, clean globe, people's wellbeing, and digital world (VTT 2011).

One of VTT's main roles is the provision of services to companies although is described as combination between a traditional service provider and a technology push institute (Sörlin 2006; Arnold 2007). More concretely, its services range from forecasting future developments through strategic technological developments, development and testing of solutions and implementations, to commercialisation activities (VTT 2011).

As stated by the organisation itself, the main tasks of VTT are research and development, technology transfer, and technology testing. In practice, three main project types are used: self-financed projects (self-funded in the sense of not being co-funded by other actors; the money ultimately comes from the government), which are strategic research projects that aim to be competence-building for the institute; joint projects, which are funded and/or carried out in co-operation with other actors such as companies or specialised research funders; and finally commercial projects, which are contracted specifically by one client in a more consultancy form (VTT webpage).

The official mission of the institute is: "VTT produces research services that enhance the international competitiveness of companies, society and other customers at the most important stages of their innovation process, and thereby creates the prerequisites for growth, employment and well-being." (VTT, 2011, p. 3)

VTT is state-owned and is the responsibility of the Ministry of Employment and the Economy. Its organisation is somewhat complex, but its structure matches the three types of research projects: there is a strategic research division that manages the self-financed projects, a R&D division that manages the joint projects, and a business solutions division that manages customer accounts and the contract research activities. The entire organisation is governed by a board of directors and a management team (VTT webpage). There are presently eight technological focus areas of the institute: Applied materials, Bio- and chemical processes, Energy, Industrial systems management, ICT, Microtechnologies and electronics, Services and the built environment, and Business and innovation research.

VTT turnover in 2011 was €278m, of which external revenue made up 69 per cent, or 193 million, and basic government funding 31 per cent, or 87 million. Of the external revenue, about 80 million came from Finnish public sector sources, and about 2/3 of this came from Tekes, the Finnish Funding Agency for Technology and Innovation. 18 per cent of the total turnover came from sources outside of Finland (VTT webpage).

About 79 per cent of VTT employees are university graduates and 25 per cent have either a PhD or a licentiate degree. The institute further reports that 63 VTT scientists were on working assignments abroad at the end of the year, and 252 foreign scientists were visiting at VTT (VTT webpage).

The customers of VTT come both from domestic and international industry, as well as from the public sector. Of its 1520 customers, 930 are domestic companies, 360 are foreign companies, and 230 are public organisations from Finland or from abroad (VTT webpage).

Apart from its customers, VTT also has extensive co-operation with other actors. It considers its participation in the EU framework programmes and European strategic alliances as very important. It also has foreign research units, presumably with their own regional networks, in Brazil, Korea and US (Berkeley, California). It also participates in many national research programmes with partners coming both from industry, universities and other national research institutes, and it has established research alliances with both industry and universities in Finland. VTT also has an active regional network, with representatives in 14 locations in Finland. There is intensive local networking and collaboration with universities, research institutes and universities of applied science (VTT 2011).

As with most similar research institutes, one of VTT's appointed tasks is to provide services specifically for SMEs. The relationship between VTT and its SME clients has been the subject of a specific study (Pesonen et al. 2008) showing that about 11 per cent of all Finnish SMEs had some sort of interaction with VTT during 2005, indicating that the institute is quite active in its collaboration with smaller firms. VTT also serves SMEs from a variety of sectors and of various sizes (many collaborators are manufacturing companies, but there is no concentration in particular sectors). The broader objectives of VTT are to create high level scientific and techno-economic knowledge and know-how and to generate technology and innovations for industry, commerce and society.

In the analysis referred to above (Pesonen et al. 2008), about half of VTT's SME collaborators conduct consecutive collaboration with the institute, i.e. they have a stable, long-term relationship in which VTT is seen as an external resource that continuously can be drawn on. The other half of the collaborators has a more on-off kind of relationship with VTT. Larger SMEs are relatively more active in their collaborations (Pesonen et al. 2008).

Another recent policy directly concerns the institutes and suggests a new structure by merging public research organisations and institutes (Research and Innovation Council 2012). This policy reform suggests for example, that VTT is to be merged with research centres in Geology (Geologiska forskningscentralen, GTK) and Measurement techniques (Mätteknikcentralen) to form a multidisciplinary research and technology centre (Forsknings- och utvecklingscentralen för mångteknologi).

The Netherlands: TNO institutes

TNO, the applied research institute of the Netherlands, was established by legislation in 1932, with the intention that it should support industrial development through the performance of applied technical research. The reason can be described as an increasing concern over the prospects of companies with no in-house knowledge production, a concern further exacerbated by World War I (Van Rooij

2011). Its structure has in the past been somewhat divided, reflecting that TNO came to incorporate various smaller government laboratories into its organisation (Van Rooij 2007), but it has now a more composed structure as a polytechnic research institute (Sörlin 2006). One way in which TNO still stands out compared to many other polytechnic institutes is that it retains the responsibility for Dutch defence research through its 'Defence, Safety and Security' theme. In size and orientation this roughly corresponds to the Swedish FOI institute (Sörlin 2006).

More recently, TNO has re-organised itself according to a new strategic plan, shaped not least by the current economic crisis. Another factor that has recently impacted the institute is the creation of a government ministry responsible for innovation (The Ministry for Economic Affairs, Agriculture and Innovation). In terms of Dutch research policy, this means that applied science now is the responsibility of a ministry with an explicit focus on innovation. For TNO, which aims to include also more basic scientific work, this is a new challenge. Also, the new ministry is part of the cabinet of prime minster Mark Rutte that recently fell, and so its future after the elections in September is presumably unclear (TNO webpage).

In the classification scheme used by Erik Arnold and colleagues (2007) and by Sverker Sörlin (2006), TNO is considered as a service institute, implying the provision of broad services to companies, but also as having moved more upstream towards research and a 'technology push' function. Like most large institute concerns, it has a rather broad range of competences, combining knowledge-generating research with development projects and service provisions directed at particular customers. The range of clients is broad as well: governments, the SME sector, large companies, service providers and non-governmental organisations. Its official mission is stated as follows: "TNO connects people and knowledge to create innovations that boost the sustainable competitive strength of industry and well-being of society." (TNO webpage).

Management of the institute is handled by the Board of Management, whose three members are appointed by royal decree on the recommendations of the Minister for Economic Affairs, Agriculture and Innovation (Chairman + 1) and the Minister for Defence (1). Furthermore, the seven-member Supervisory Board supervises the policy and provides advice to the Board of Management. The policy for the defence research part of TNO is handled by the separate TNO Council for Defence Research.

The research organisation of TNO is, after a recent reorganisation, divided into seven research 'themes' (Healthy Living, Industrial Innovation, Defence, Safety and Security, Energy, Transport and Mobility, Built Environment and Information Society) and three expertise areas (Technical Sciences, Earth, Environmental and Life Sciences, and Behavioural and Social Sciences). The seven themes are further subdivided into twenty so-called 'innovation areas', for example "Food & Nutrition" within the Healthy Living theme, or "Sustainable Chemical Industry" within the Industrial Innovation theme. As is clear from this structure, the scope of the institute is very broad both in terms of societal sectors and in terms of scientific disciplines.

TNO reports that the workforce is growing more international, with about 15 per cent of new employees being non-Dutch (TNO 2011). Their competences are broadly classified into three expertise areas: technical sciences (e.g. material scientists and mechatronics engineers, physicists, electronic engineers, experts in fluid mechanics, and chemists), earth, environmental and life sciences (molecular biologists, more physicists and chemists, food and food safety specialists, and earth scientists), and behavioural and societal sciences (e.g. psychologists, industrial designers, mathematicians, and business scientists). The technical expertise area is the biggest, about the size of the two others put together.

TNO also works together with other Dutch research institutes. Recently the "TO2" federation has been created to strengthen the co-operation between TNO and the so-called Large Technology Institutes (LTI's). This aims to create a knowledge infrastructure that will boost the innovativeness and competitiveness of the Netherlands. The institutes included in this federation are Deltares (working with the Dutch specialty of water infrastructure), the Energy Research Centre of the Netherlands, Maritime Research Institute of the Netherlands, and the National Aerospace Laboratory (TNO 2011).

As for industry, in addition to working with its clients, TNO also considers it important to have good relationships and communications with important stakeholders. One expression of this is the so-called “TNO Round Tables”, to which the institute invites CEOs and other industrial stakeholder, as well as government representatives, to discuss subjects relevant for TNO’s strategy. During 2010 the theme considered was ‘scarcity’, which is also a central concept in the new strategic plan (TNO 2011).

Strengthening competitive and innovative capacities of small and medium sized enterprises (SMEs) is considered an important mission for TNO, in line with the prevailing paradigm which holds that innovations within SMEs are a driving force behind economic development. Therefore supporting innovations within the SMEs and strengthening their competitive capacity is an important mission for TNO (TNO 2011).

TNO is able to provide assistance to SMEs in the different stages of product and process development, from the first impulse or idea to the implementation and testing stages, using both technological knowledge but also process competence. There is also a policy of establishing new companies as part of the TNO group. This is handled by TNO Bedrijven, the holding company for the start-ups (TNO 2011).

Denmark: GTS institutes

Advanced Technology Group has nine members. The members work within different fields and provide different services and are not-for-profit organisations.

The GTS institutes are private independent consulting firms, which develop and sell state-of-the-art technological services to private enterprises and public authorities. They offer knowledge, technology and consultancy, co-operation on technological and market-related innovation, testing, optimisation, quality assurance, certifications and benchmarking - all of which contribute to enhancing the international competitive position of the business sector and benefit society in general.

The GTS institutes sell their services on commercial terms in Denmark and abroad. At the same time, the GTS institutes collaborate closely with the Danish Ministry of Science, Technology and Innovation on technology-based promotion of trade and industry that increase Denmark’s international competitive strength. The following nine institutes are included in GTS:

Name of institute	Area of activity
AgroTech	Primary production of agricultural and horticultural products, competencies value chain from primary produce to final consumption
Alexandra Institute	Application-oriented IT research
Bioneer	Drug development, biomarkers, protein manufacture, immune targeting, probiotics etc
DBI	Danish Institute of Fire and Security Technology
DELTA	Danish Electronics, Light & Acoustics
DFM	Danish Institute of Fundamental Metrology
DHI	Advance technological development, governance and competence in the fields of water, environment and health
FORCE Technology	Materials and analysis, certification and testing, energy and climate etc
Danish Technological Institute	Building and Construction, Chemistry and Biotechnology, Energy, Transport and Logistics, Environment, Working Environment and Health, Food Technology, Industrial Production, Microtechnology and Surfaces Analysis, Productivity and Management

The evaluation of GTS institutes that was carried out and appointed by the Danish Ministry of Science, Technology and Innovation (GTS 2009) concludes that the Danish GTS institutes help companies to go a step beyond what their own capabilities let them do. Furthermore, the reports states that "that the growing knowledge intensity of production means that it is time for the institutes themselves to increase their capabilities by doing more R&D so as to be able to support increasingly sophisticated companies in their innovation efforts". The evaluation also emphasised the importance of institutes in their role toward small and medium-sized companies and the wide range of activities and roles of the Danish institutes. Customers using GTS institutes were identified in a number of different areas of activities, to a great extent including activities of product testing and product development. Other areas of activity indicate relevance for both larger risk sharing activities and experience exchange as well as activities dealing with certification, quality systems, market analysis and new service development.

Norway: SINTEF

SINTEF business development strategy is characterised by a strong emphasis on co-operation with the universities, especially NTNU and University of Oslo (UiO), aiming at long term interaction between university, industry and SINTEF institute. The SINTEF Group comprises the SINTEF Foundation, four limited companies and SINTEF Holding. The following units describe the areas of activity:

SINTEF Building and Infrastructure
SINTEF Energy Research
SINTEF Fisheries and Aquaculture
SINTEF ICT: applied research in information and communication technology
MARINTEK: The Norwegian Marine Technology Research Institute
SINTEF Materials and Chemistry
SINTEF Petroleum Research
SINTEF Technology and Society: build social into the national technology projects

SINTEF has three main strategic tools to support its scientific advancement:

1. Centre for excellent innovation/research (SFF/SFI)

These national centres are selected, among several competing research groups, and funded by the Norwegian Research Council. A research group, which gains this status will maintain it for about 8-10 years.

2. Corporation efforts

These are internally funded projects between two or more research divisions with a clear objective to either reach a market or develop technology (3 years duration).

3. GEMINI Centres

18 Centres are established between SINTEF and the collaborating universities in selected areas where SINTEF wants to develop scientific excellence and build critical mass together. The researcher can be appointed for 3 years, but could be continued for a new 3 year period. The areas of activity for these centres include areas such as materials and spectroscopy, electricity and energy systems, marine technology, medical microbiology and health services (Gemini 2011).

The business development strategy is based on the way SINTEF understands its own role in society, as outlined below in four areas:

To create value via knowledge, research and innovation (to generate knowledge and develop technology adopted by users; to be a R & D partner for private industry and the public sector; and to develop new industrial and commercial companies)

- To supply solutions for sustainable development
- To build and operate research laboratories
- To supply premises for social debate and policy design

During recent years, SINTEF has developed and followed an international strategy based on academic co-operation, participation in the EU research programmes, delivery of contract research to international customers, international presence in selected areas (Denmark, USA, Chile and Brazil) and recruitment of international scientists. Oil and Gas, Energy and Environment, Maritime and Biomarin are the four strategic areas in the international strategy.

Annex 2: Co-authorship patterns for technical research institutes

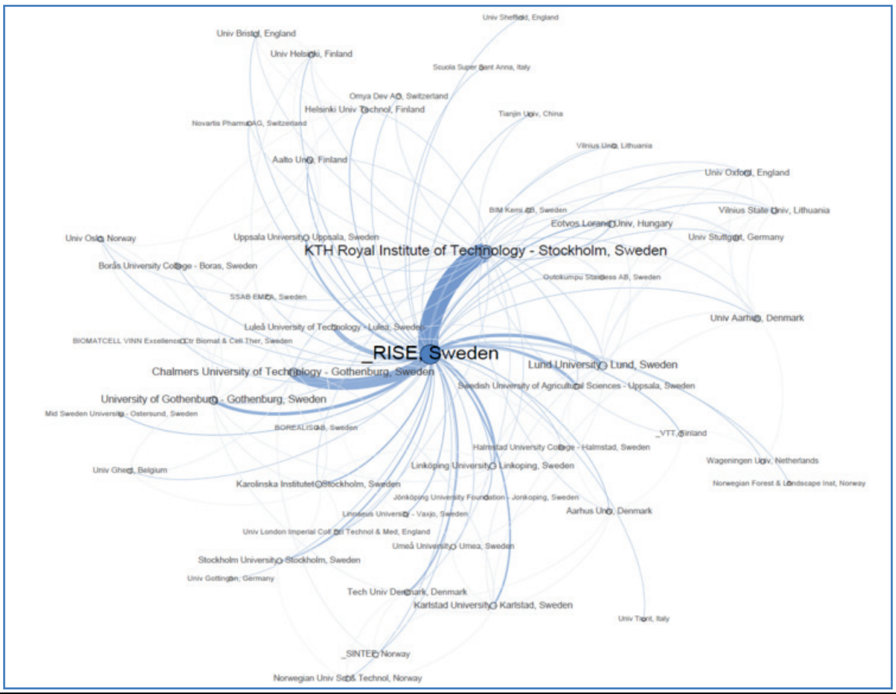


Figure 1. Co-authorship network 2009-2011 for RISE-institutes.

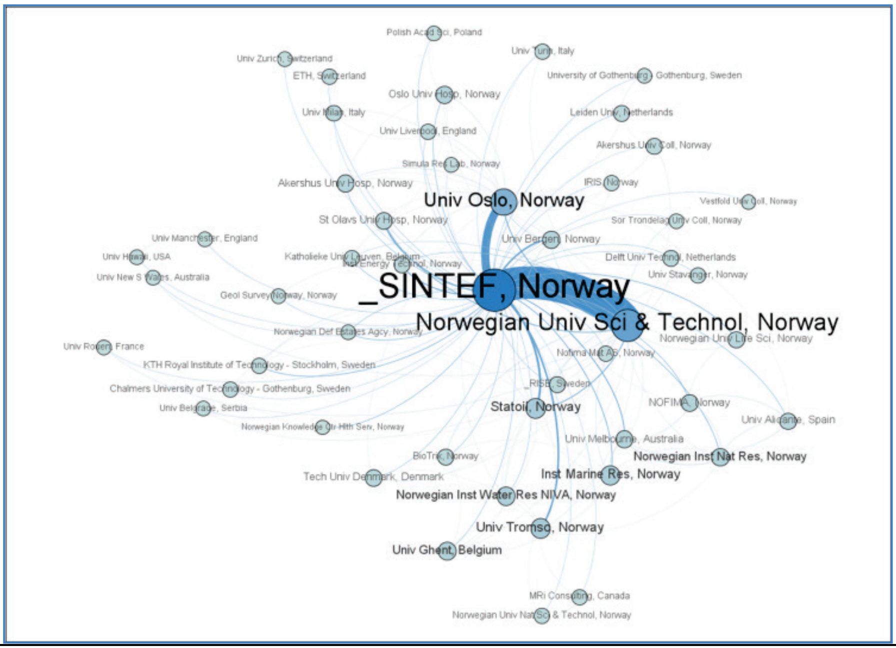


Figure 2. Co-authorship network 2009-2011 for SINTEF

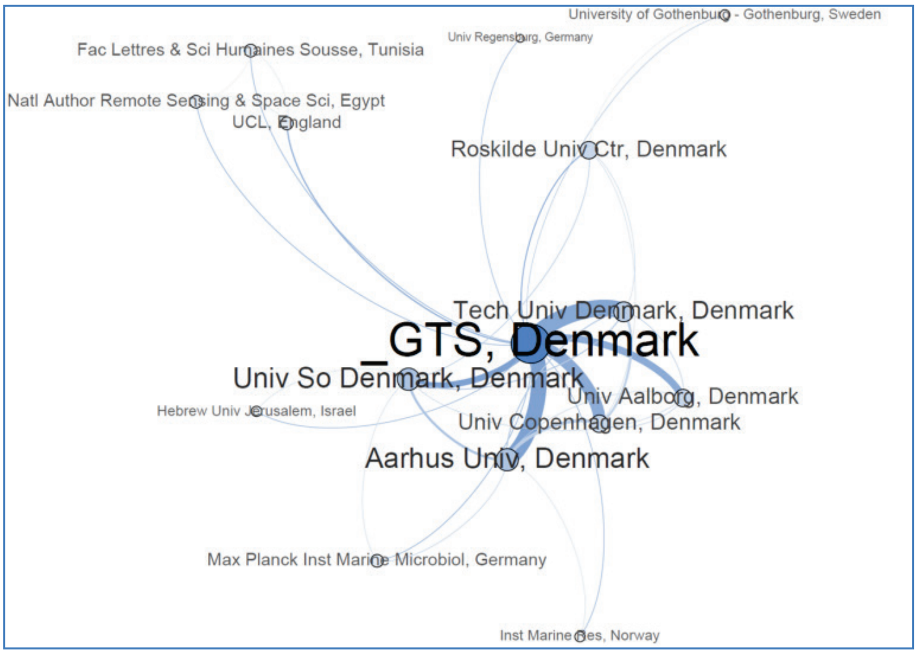


Figure 3. Co-authorship network 2009-2011 for GTS

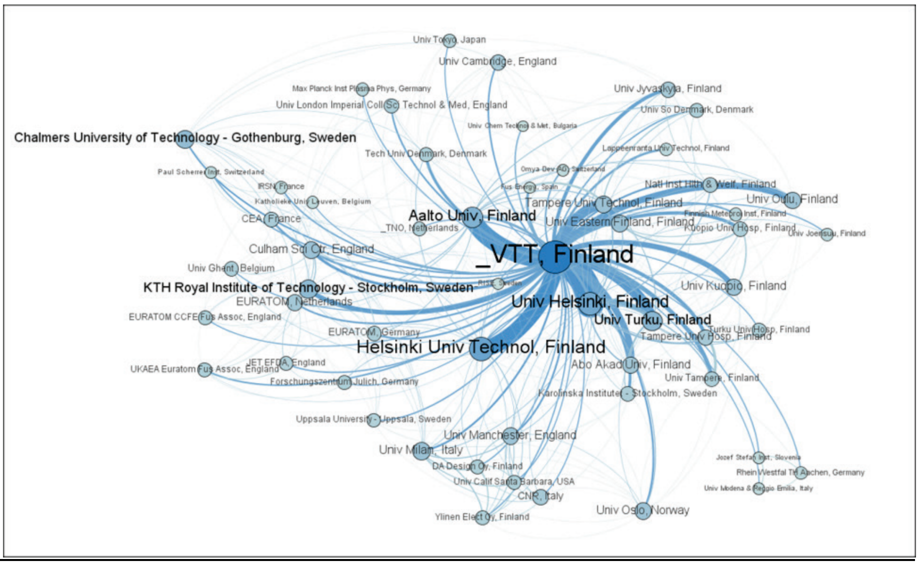


Figure 4. Co-authorship network 2009-2011 for VTT (excluding large scale physics collaborations)

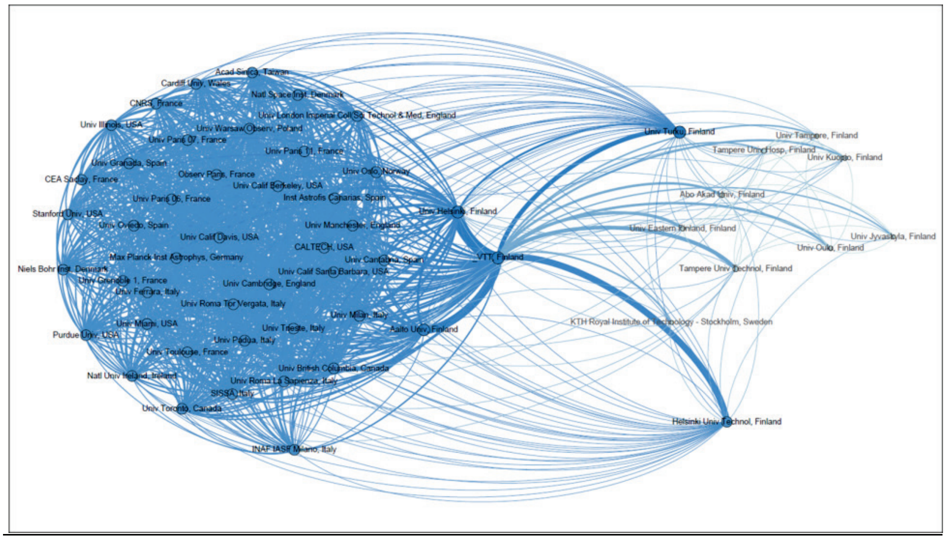


Figure 5. Co-authorship network 2009-2011 for VTT (including large scale physics collaborations)

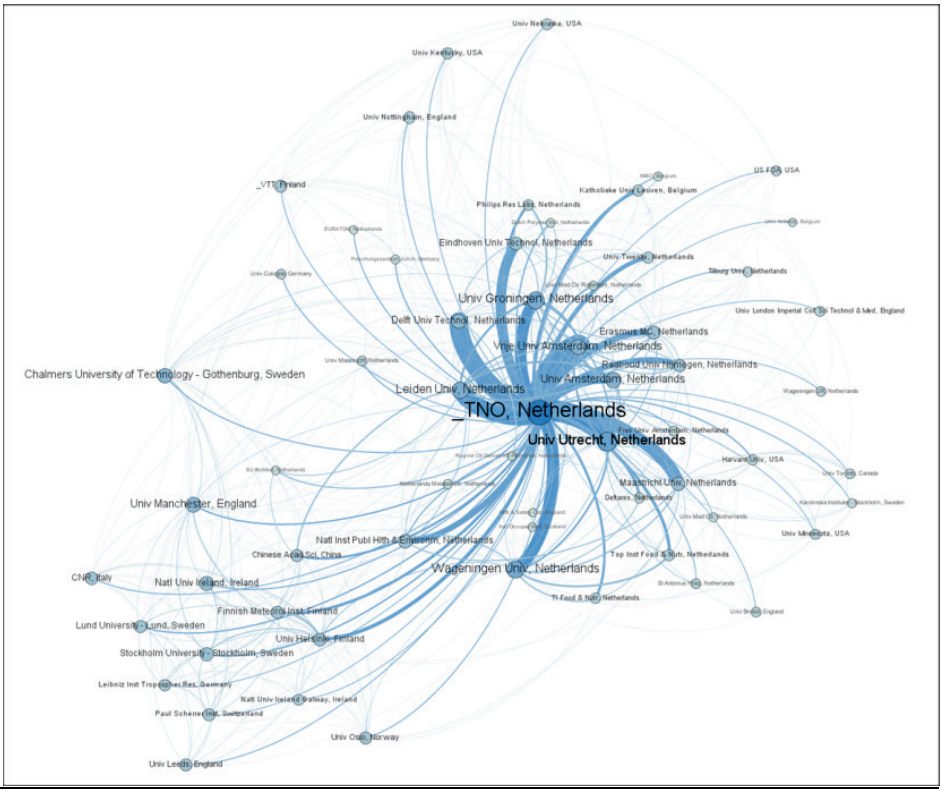
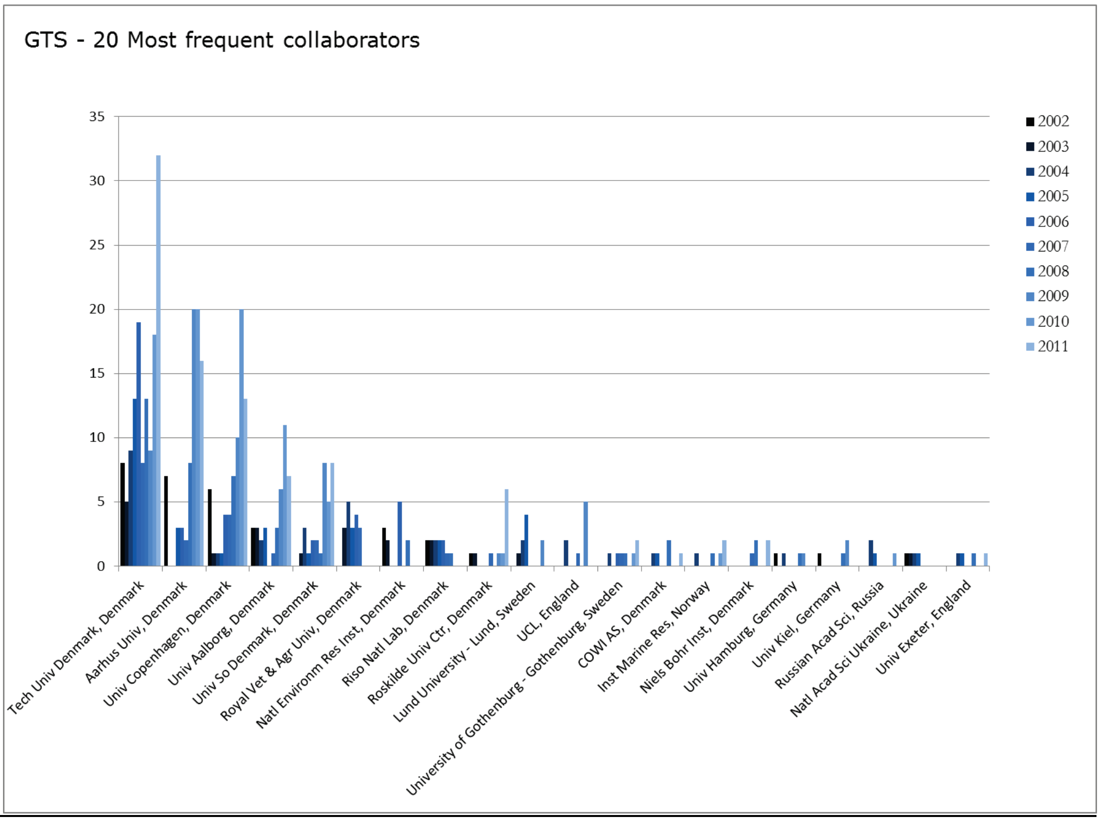
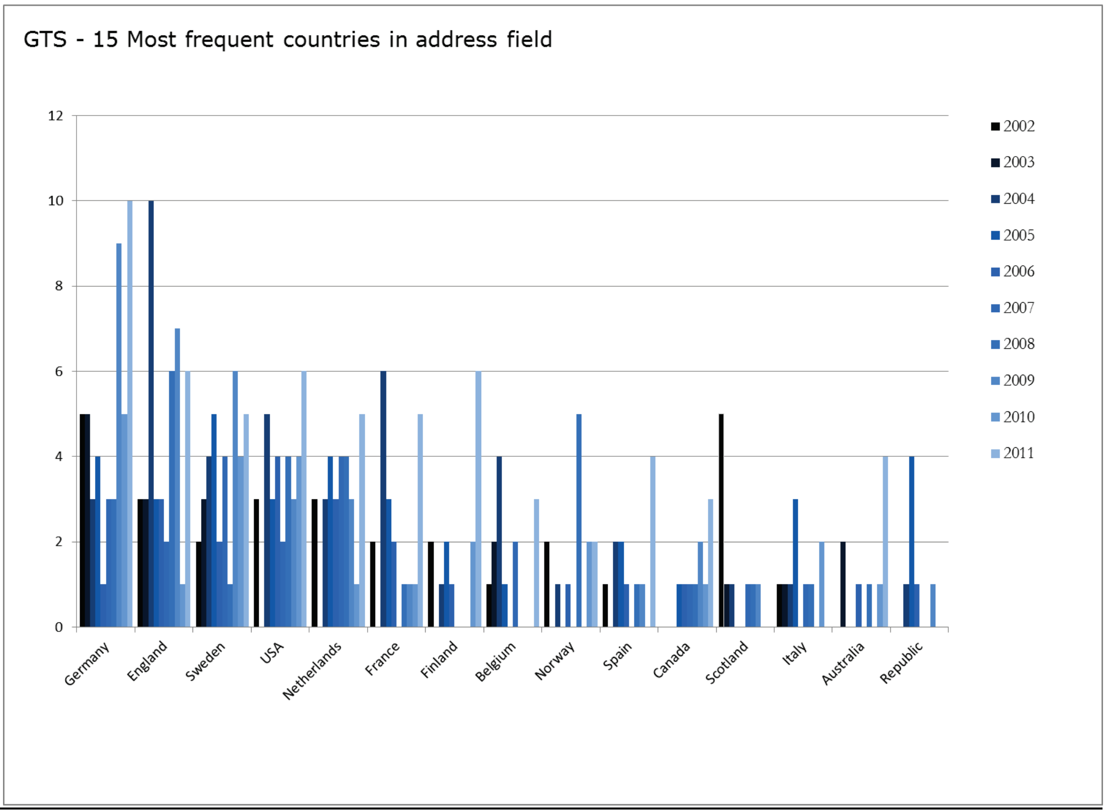


Figure 6. Co-authorship network 2009-2011 for TNO

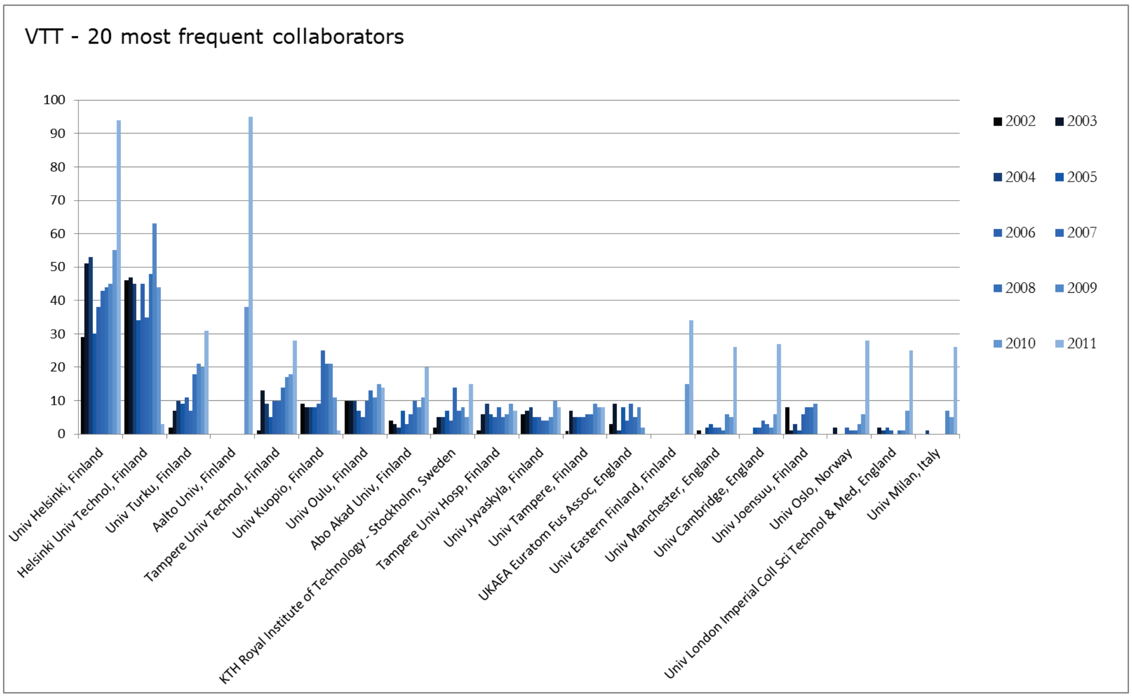
Co-authorship analysis: collaboration with national institutions and other countries

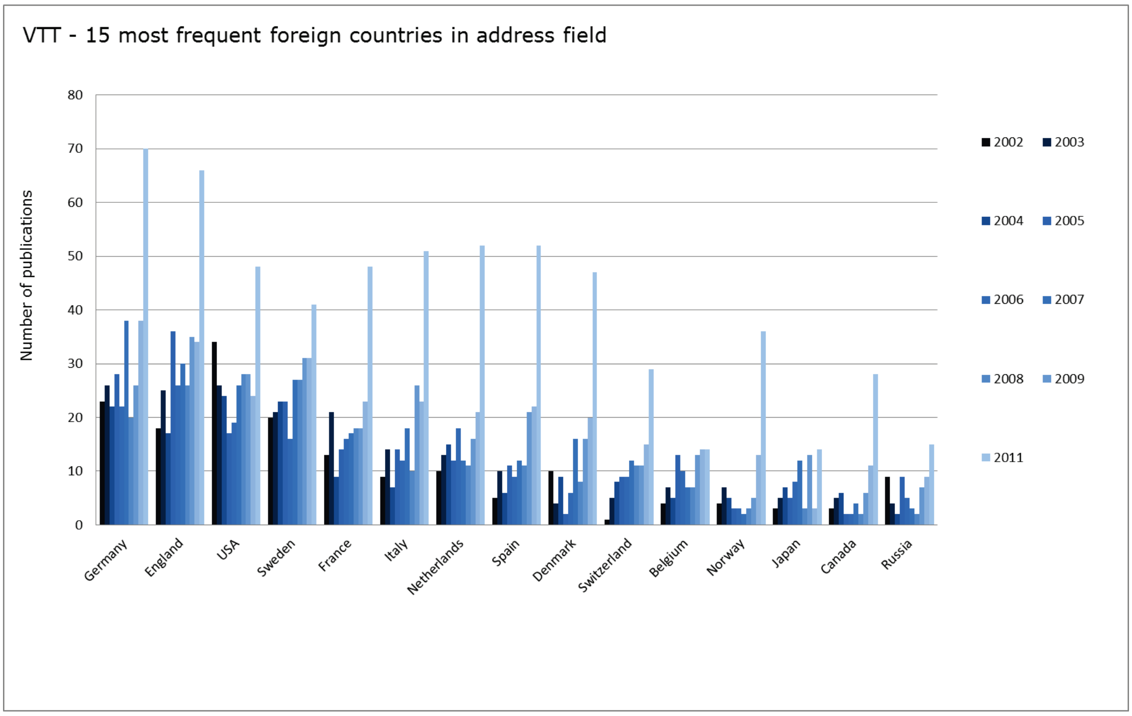
Denmark, GTS most frequent collaborators: national and other countries



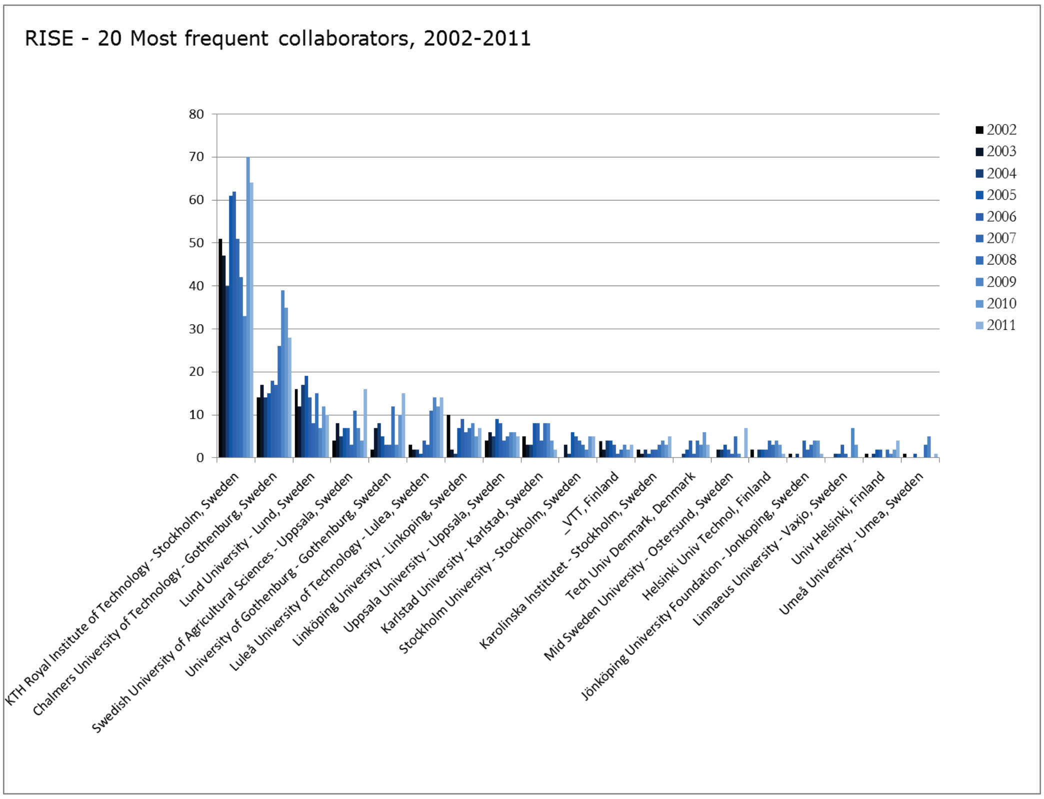


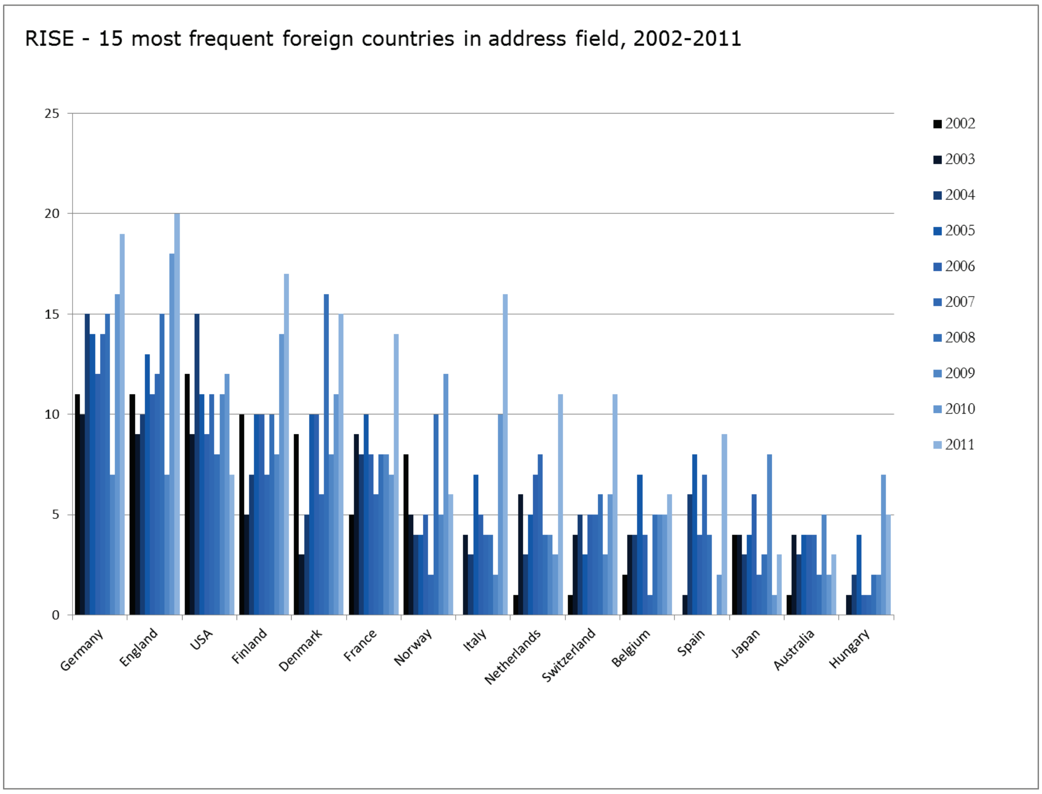
Finland, VTT most frequent collaborators: national and other countries



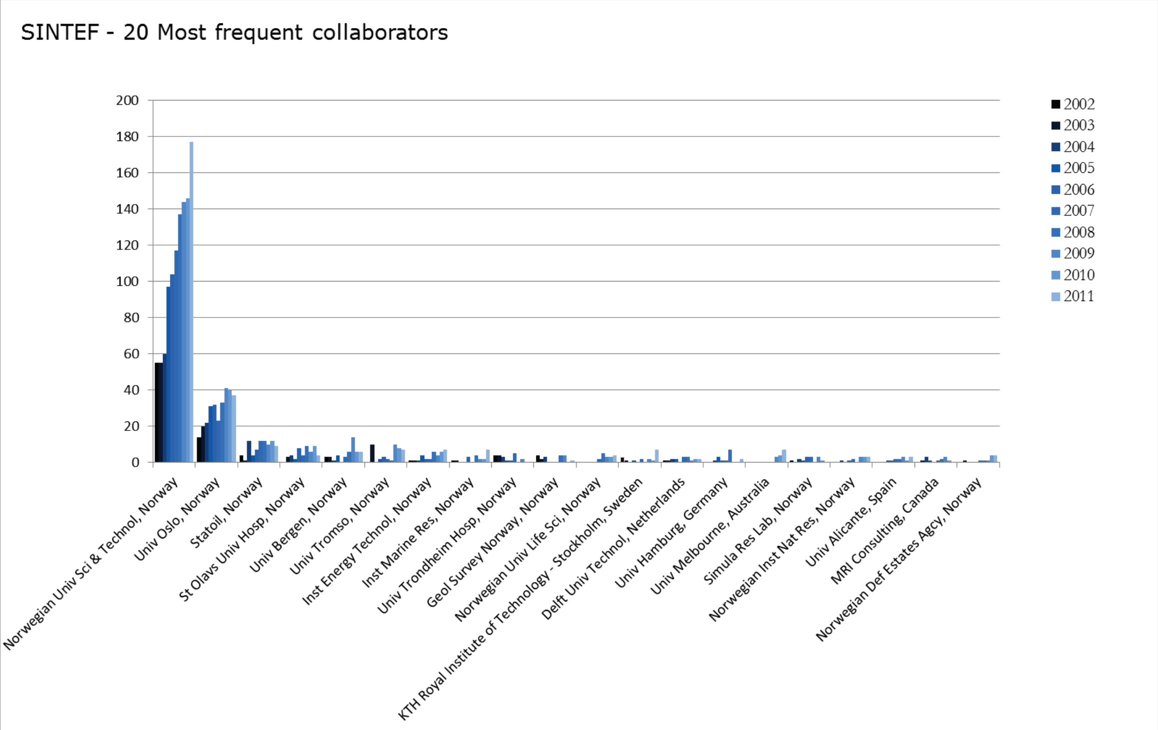


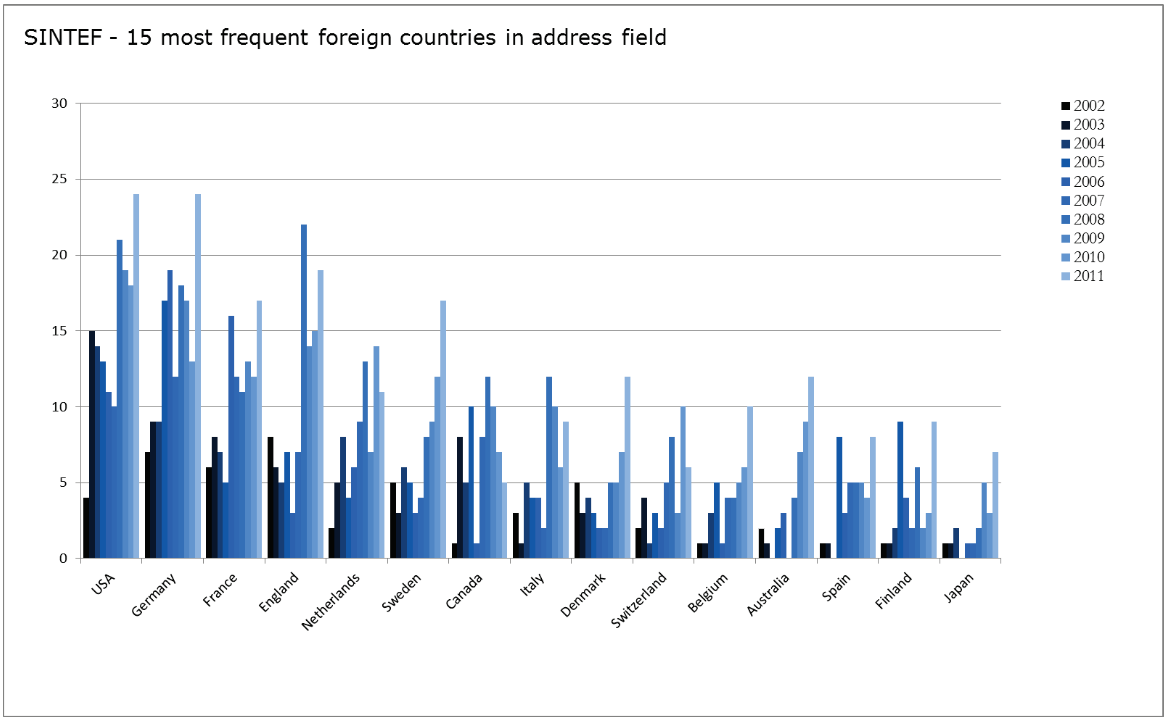
Sweden, RISE institutes' most frequent collaborators: national and other countries



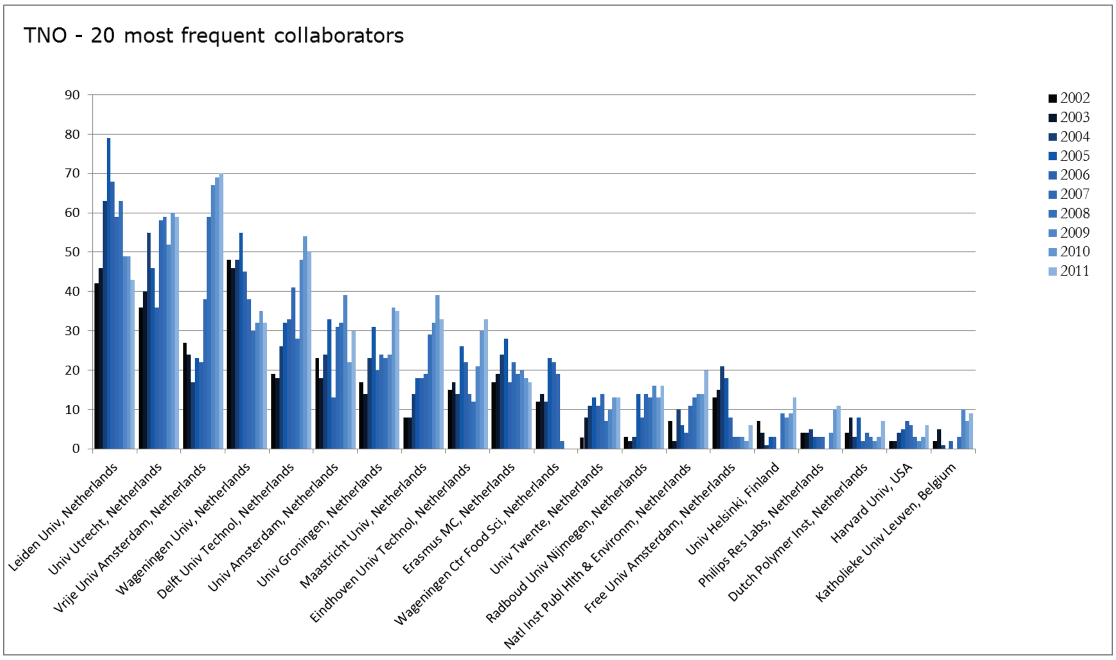


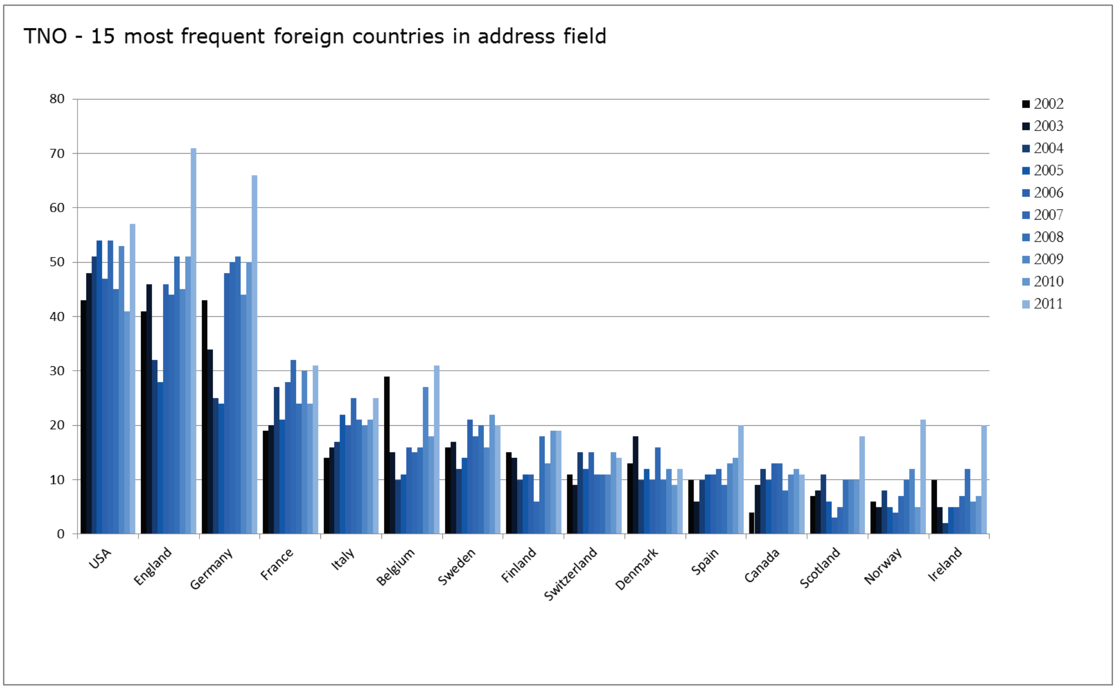
Norway, SINTEF most frequent collaborators: national and other countries





The Netherlands, TNO: **most frequent collaborators: national and other countries**





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