

1 Norwegian R&D and innovation activities in an international context

Highlights

Economic development and its effect on research and development

- For many countries R&D expenditure as a percentage of Gross Domestic Product (GDP) has increased, however this is often a result of declines in GDP that mask stagnation or even declines in R&D expenditure. Norway is less affected than other countries by the economic crisis and has maintained R&D expenditures relatively well.
- There are uncertainties concerning economic policy actions and their effects on R&D.

Norway in an international context

- Based on the Innovation Union Scoreboard 2010 for the EU, Norway scores lower than the other Nordic countries.
- However, Norway scores relatively highly for the indexes on *Human Resources, An Attractive Research System, Financing and Entrepreneurship*.

Human resources

- In 2008, the share of the population with a higher education was 36 per cent in Norway, compared to an OECD average of 28 per cent.
- In 2009, 238 doctoral degrees per million inhabitants were awarded in Norway. Sweden and Finland awarded more, Denmark less.
- Norway has one of the highest proportions of researchers per capita in the world.
- The number of Full-Time Equivalents (FTE) of R&D performed in the Norwegian business enterprise sector is far below the level of the other Nordic countries.

Resources for R&D and innovation

- The share of the world's R&D resources accounted for by the USA and Europe has decreased in recent years, while the shares for Latin America and Asia have increased.
- Over recent years, growth in R&D expenditure in Norway has been slightly higher than the

world average. However, R&D statistics show that growth in R&D expenditure in Norway has slowed since the financial crisis.

- The business enterprise sector accounted for 52 per cent of all Norwegian R&D expenditure in 2009. In OECD countries the share was almost 70 per cent, which is also typical of the level among the larger R&D actors and the other Nordic countries.
- The higher education sector accounts for a large proportion of R&D expenditures in Norway – almost one third – the share of R&D funding from government sources is also greater than in the other Nordic countries.
- There are signs that Norway's participation in European research is strengthening: so far, Norway has received more EU funding via the EU's 7th Framework Programme, than it did during the 6th Framework Programme.

Results of R&D and innovation

- In terms of reported innovation activity in the industrial sector, Norway is below both the EU average and levels of activity in the other Nordic countries.
- However, the percentage of Norwegian enterprises in the service sector reporting product/process innovation is slightly higher than the EU average; the opposite pattern applies in the manufacturing sector.
- Norway scores lower than all EU countries both in terms of R&D as a percentage of revenues and as a percentage of revenues received from the introduction of new products/services.
- Among the Nordic countries, Norway is second only to Iceland in increases in scientific publishing over the last five years.
- There has been a small decrease in the Norwegian citation index during the last three years, breaking the upward trend that had been established over preceding years.
- Norwegian patenting, as registered by the European Patent Office (EPO) from 2000 until 2008, was modest in comparison to other OECD countries.

Norway's research and innovation profile is presented in this chapter, using the most relevant quantitative indicators available. The indicators are primarily based on R&D and innovation statistics, but other data sources are also drawn on. Updating such international data takes time and therefore some preliminary

figures are presented. The indicators have been selected to provide the most up-to-date overview possible of the contemporary range, development, vitality and quality of the Norwegian research and innovation system, in comparison with other countries. Trends in traditional research indicators are presented, including

those for R&D expenditure, R&D intensity, size of R&D-performing sectors, funding for R&D, and R&D personnel; additionally, more result-oriented indicators of R&D and innovation are presented. Norway is measured against its Nordic neighbours, other small countries and major trading partners. To provide an overview of international trends in the development of national R&D and innovation systems, data on large, international R&D players and key changes in the global distribution of knowledge are also described.

In recent decades, science, technology and innovation have gained attention in national plans and perspectives for progress and prosperity. In line with an increased emphasis on the economic and social importance of research-based knowledge, interest in nations' overall research efforts, and the results of these efforts, has increased. Both the EU and the OECD publish regularly updated scoreboards, comparing member countries' efforts against each other.

The most popular or widely used indicators include long-established measures, but there is also a steady influx of new indicators, offering new overviews and composite indicators. Both nationally and internationally, statistics producers maintain an on-going dialogue about how far current guidelines for data collection, methods and definitions offer the best and most suitable information to members. Norway participates actively in this work.

In 2010 UNESCO examined data from all countries collecting statistics in this area and brought it together to publish the world indicator report. The data included showed that both the distribution of, and results from, investments in research and innovation are changing; while the USA, Europe and Japan dominate this area now, they increasingly face a challenge from Asia, via countries such as China, India and South Korea and from Latin America, particularly Brazil.

In the wake of the financial crisis, the roles science, technology and innovation can play in supporting stable, sustainable development and in meeting major challenges related to demographic change, global health and climate change, have been further highlighted. The OECD concludes that science, technology and innovation have never been more important. It is therefore worrying that some countries are going ahead with cuts in their budgets for R&D and higher education. While it often takes a long time before investments in knowledge come to fruition, such cuts are likely to decrease the human resources required for innovation in the long term. In contrast countries including Austria, Germany, South Korea and the US have increased investment, aiming to improve future prospects for innovation and growth.

1.1 The impact of economic development on R&D

Overall trends in the economy inevitably have an influence on R&D activity, but no clear relationship between growth and R&D investments has been established. The latest OECD figures show that R&D expenditure (in constant prices) grew more slowly between 2007 and 2009 than in the previous two years. Furthermore, these figures are unlikely to capture the full effect of the financial crisis. It is worth noting that while many countries showed an increase in R&D expenditure as a percentage of gross domestic product (GDP) in 2009, this is due to steeper declines in GDP relative to R&D expenditure.

In the 2008 R&D survey of the Norwegian industrial sector the enterprises were asked whether they expected the financial crisis to affect their R&D expenditure in 2009. As these business forecasts suggested a year ago, the financial crisis has had a moderate, negative impact on R&D in Norway. Two thirds of the companies reported that they expected the financial crisis to have no impact on R&D activity. These firms believed they would use a similar amount of resources for R&D in 2009 as previously planned. However, the other enterprises anticipated that the financial crisis would have consequences for their R&D activity: 29 per cent said that the financial crisis would lead to lower R&D investments in 2009 than previously planned, while 6 per cent expected the crisis would result in them spending more than they otherwise would have. It now seems that firms were too optimistic when they made these forecasts, as reported figures for 2009 are lower than such estimates. The survey for 2010 is now underway, but it is difficult to say whether expectations of a stronger economy will help to increase R&D investments enough for R&D expenditure as a proportion of GDP to increase in 2010.

The Norwegian economy is strong compared with most other economies. Figures from Eurostat show that Norway was the European country with the second highest GDP per capita in 2009 (measured in purchasing power parities) behind Luxembourg, but the Norwegian economy has been affected by the global financial crisis, with a fall in production evident during the second half of 2008 and into 2009. GDP growth for mainland Norway was just 1.8 per cent lower in 2009 than the year before (comparing annual averages). This is a smaller fall in growth than that experienced by the USA or by the overall European area, which are Norway's main trading partners.

European and the OECD countries are generally facing major economic challenges, involving both

The OECD's definition of research and experimental development (R&D)

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

The term R&D covers three activities:

- Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
- Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific aim or objective.
- Experimental development is systematic work drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems or services, or to improving substantially those already produced or installed.

The basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty and the resolution of scientific and/or technological uncertainty, according to the OECD (2002): Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development.

government debt and aging populations. Many countries in the Euro area are likely at the start of a period of fiscal austerity. OECD and IMF figures indicate that the financial crisis led to a larger decrease in GDP in the Euro area than in the USA or Norway, and that expectations for growth are also weaker for the Euro area. Statistics Norway has set out figures showing an upturn in the condition of the Norwegian economy. The outlook is for weaker global growth following the crisis and for Norwegian exports to grow only slightly. Growth in Norway will largely be driven by domestic demand. Statistics indicate that no dramatic international economic recovery can be expected until 2013, and that there is a significant downside risk to such forecasts.

1.2 Norway in international comparison

Traditionally, Norway has scored fairly poorly in international comparisons of R&D activity and innovation. Reviews of Norwegian efforts in research and innovation tend to show that Norway invests less in research than the countries typically used as its comparators. In particular, the business enterprise sector conducts less research in Norway than in many other countries. On the other hand, Norway has a relatively large higher education sector and public sources contribute substantially to financing R&D efforts.

There are several important background factors that shape a country's research profile. Norway can be broadly characterised as a stable democracy with a well-developed welfare state, high levels of education, extensive cooperation between the social partners, low unemployment, high GDP, solid economic growth and as a country where natural resources contribute heavily to the economy. Norway is also, as described above, one of the countries least affected by the financial crisis, even though estimated GDP has decreased somewhat.

Norway's high level of education is a key factor to consider in describing its research profile. The business structure is also important, being characterised by many small and medium sized businesses (SMEs) and the relatively high proportion of value creation that is driven by primary industries, compared to the other Nordic countries and the EU. These kinds of industries consistently show lower R&D intensity than that found in the service sector. The country has a large petroleum sector and a growing service sector, but relatively low activity in some of the typically R&D intensive industries, such as the electronics manufacturing, pharmaceutical and automotive industries. The country therefore has few, large R&D drivers of the sort found in the neighbouring Nordic countries.

Traditional international R&D indicators are, as mentioned above, gradually being supplemented with new indicators which attempt to measure the results of research and innovation. Efforts to design new, future-oriented research policies have boosted demand for a broad spectrum of detailed and comparable statistics. One set of indicators containing both traditional R&D indicators and a range of other innovation-related variables is provided in the EU Innovation Union Scoreboard (formerly European Innovation Scoreboard). This includes 25 indicators, selected to give the best possible picture of overall national efforts related to research and innovation systems. The indicators cover three main types of indica-

R&D Surveys

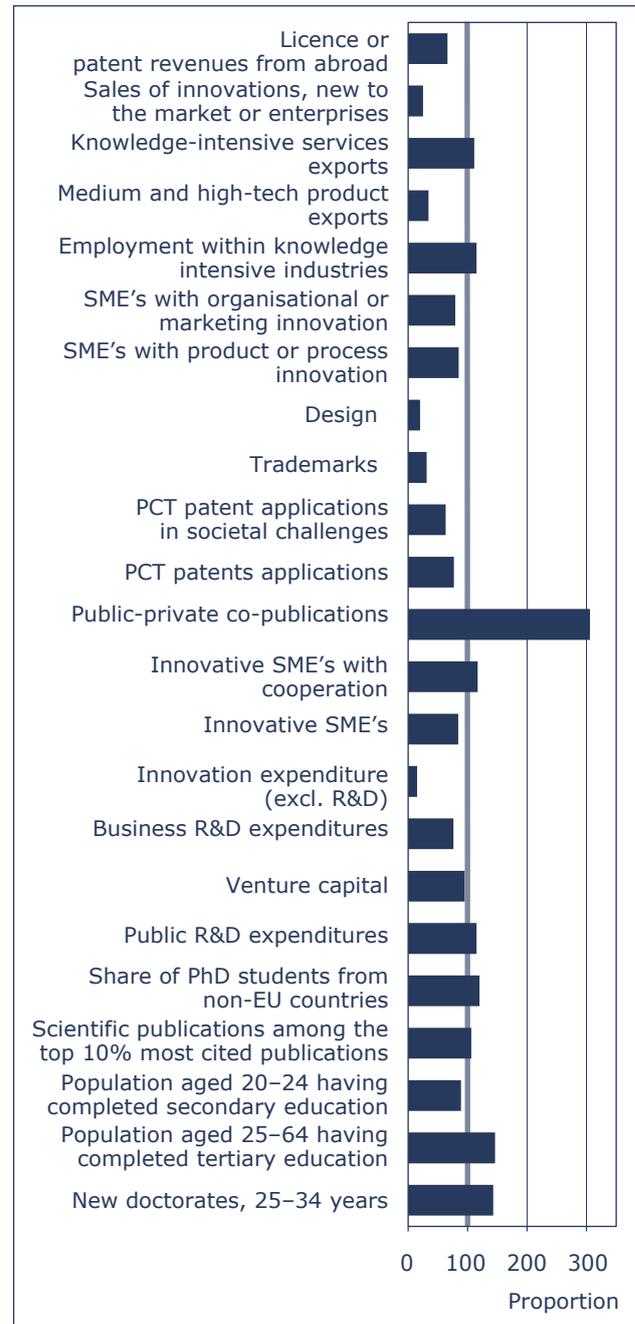
NIFU and Statistics Norway carry out national statistical surveys on resources that are devoted to R&D in Norway. NIFU is responsible for collecting, processing and disseminating statistics and indicators for the institute and higher education sectors, while Statistics Norway is responsible for the industrial sector. NIFU is also responsible for compiling national data into the official R&D statistics for Norway. Annual statistical surveys are carried out for the business enterprise and institute sectors. For the higher education sector, the survey is carried out every second year. Main figures are produced yearly for all three sectors. The statistics are produced using guidelines by the OECD (2002), «Frascati manual».

tors: 1) *enablers* such as human resources, transparency, the excellence and attractiveness of the research system, funding and support; 2) *firm activities*, including business investments, collaboration, entrepreneurship and intellectual property rights; and, 3) *outputs* cover an innovator's dimension and economic effects. This annual indicator set presents an overview of all member countries' efforts within their national research and innovation system. The EU also collects data from several other countries, including Norway, the USA, Japan, China, Brazil, Russia and India.

The EU 27 emerge well from these comparisons overall, although both the USA and Japan score higher. The USA outperforms the EU in 10 indicators, and their lead is gradually increasing. The EU does better in both public R&D expenditures and exports of knowledge intensive services, and has increased their lead in these areas. Japan outperforms the EU on 7 indicators, but scores lower than the EU in terms of numbers of new doctoral degrees, international co-publishing, most cited publications, public R&D expenditure and exports of knowledge intensive services. China, Brazil, India and Russia score far lower than the EU based on overall indicator scores, but countries such as China and Brazil are making serious attempts to close that gap. For China, this is particularly evident in the export of medium-and high-tech products where performance is strong, while Brazil is doing very well in exporting knowledge-intensive services. Russia performs better than the EU when it comes to new doctoral degrees and tertiary education, but overall there is a clear performance lead in favour of the EU.

The EU ranks the countries based on their score in the composite, overall indicator. Norway ends up on the third level in this ranking, grouped as a 'moderate

Figure 1.1
Norway's relative scores¹ for Innovation Union Scoreboard indicators, 2010.



¹ The areas above 100 are those where national performance is higher than the EU average. Those receiving less than 100 show areas where performance is relatively low.

Source: Innovation Union Scoreboard 2010

innovator' with a below average performance. Finland, Denmark and Sweden are placed in the group 'innovation leaders' with a performance well above that of the EU 27 average. Finland and Germany are also in the group of countries showing the highest increases in their scores, while Norway belongs to the 'slow growers' group.

The use and misuse of statistics in research and innovation policy

We live in a culture where numbers inspire confidence and provide legitimacy to decisions. This is evident in the strong emphasis placed on economic arguments for public investment, and in the widespread belief in 'evidence-based policy development'. The prominence given to quantitative knowledge as a basis for policy and decisions is in part a reflection of the idea that more scientific approaches can provide 'objective' knowledge. Such data are often used over experience-based expertise, which tends to be considered subjective and therefore less reliable.

There is no doubt that the availability of good research and innovation statistics is an essential part of the knowledge base required for good policy. However, as both society and our understanding of society undergo changes, there will inevitably be an on-going need for quality assurance and further development of those statistics.

A good example here is the desire to develop statistics for innovation in the public sector. We know that the public sector plays an important role in social development, and that it affects the innovative capacity of the private sector. Yet we know virtually nothing about this sector's ability to adapt and innovate.

Research statistics emerged in a period when great emphasis was placed on research as a source of innovation and new knowledge. It was therefore natural to focus on indicators for factors such as investment in R&D. The focus was primarily on measuring the inputs and less on understanding the links between investment and anticipated desirable effects (in terms of overall welfare, economic growth, cultural diversity etc.).

Innovation statistics have been further developed through the Oslo Manual – which collects information from companies to see how they go about collecting and making use of knowledge – an approach which broadened perspectives considerably. However, it is still difficult to connect companies' use of knowledge to overall effects of R&D or innovation on wider society. While this latter aim may not be fully realizable – the outcomes and influences are likely too large and complex – these must at least be considered when designing overall policy strategies. However, when an area lacks clear data or numbers, less attention is paid to that area.

This is where we have arrived with these issues: years of significant research have advanced our understanding of knowledge, learning and innovation in society; but these attempts to devise easily understandable statistics have led to measurements that still offer a description of what is going on that, at best, can be described as being of very limited value.

The EU Commission has placed great emphasis on the development of statistics for research and innovation, and deserves credit for this. However, all too often such statistics are used in ways that are plainly misleading. The clearest example of this is the most commonly used indicator of all: R&D as a share of GDP. In itself, this is a useful indicator. It says something about how much of a country's wealth creation is being used in research and development. In political rhetoric it is widely used as a measure of a country's innovation capacity; input is interpreted as output. In this way, investment in research is re-framed as the primary objective, instead of innovation and learning as the basis for welfare and wealth creation.

The Commission has reviewed the development of the European Innovation Scoreboard, now called the Union Innovation Scoreboard, and has tried to respond to such criticism by presenting a composite indicator that takes many different forms of learning and investment in knowledge and innovation into account. This gives the impression of being more objective, but it is not. The choice of indicators and the weighting between them reflects a vision of innovation where research and high technology activities are given greater weight than other forms of learning.

For Norway, this leads to particular problems, as we have an industry structure dominated by industries that invest relatively small amounts in R&D compared with so-called high-tech industries. The oil and gas industry, for example, is by definition 'low tech', as the companies' turnover is so high that even considerable research investments seem relatively modest. The strong focus on research also means that other important forms of innovation become less visible.

We find similar problems with fraction-based indicators in the discussion of R&D as a share of GDP: having one of the world's richest and most productive economies makes it much more difficult to reach the EU's three per cent target. Furthermore, as this target simply focuses on investments in R&D and not on the factors that influence a nation's ability to make use of research, technologies and other forms of knowledge, the social and cultural framework that makes Norway successful is often overlooked. Similarly, Norway has an egalitarian culture that most likely contributes to learning and welfare by offering social security that reduces risk for both individuals and companies. This is not captured by the standard statistics.

There is therefore a need for more realistic narratives that put all the numbers into a larger context, one that does not reduce the 'knowledge society' to a few basic indicators. Norway is leading the way here: this indicator report is considered by many as offering best practice when it comes to placing research and innovation statistics in a broader context. The Ministry of Education aims at something similar through its Research Barometer. In contrast, the EU Commission has decided to close down the Inno-policy TrendChart, that were to give these numbers more meaning in a national context.

Per Koch, The Norwegian Ministry of Education and Research

Figure 1.1 shows Norway's position relative to the EU 27. The Norwegian system's relative strengths are, unsurprisingly, in human resources, an open, excellent and attractive research system, financing and support and entrepreneurship. Areas of relative weakness are found within private sector investments, pat-

ents, innovators and results. Changes in scores for some specific indicators have not altered Norway's overall position, compared to the European Innovation Scoreboard from 2009.

Despite the fact that Norway does not score particularly highly on the EU's selected innovation indica-

tors, the country still has good economic results, with a high GDP, high growth and low unemployment. The phenomenon has been termed ‘the Norwegian puzzle’ and presents a challenge regarding the usefulness and relevance of these indicators. Possible explanations have been sought in terms of high workforce adaptability and the role played by the Norwegian welfare state. However these factors are, to a greater or lesser extent, also present in the other Nordic countries, which scored higher on innovation indicators.

1.3 Human resources

The available human resources in a country are of crucial importance for efforts and achievement in science, technology and innovation. Another important background factor influencing Norway’s R&D profile is the country’s size: a country with a small population cannot perform very strongly in all areas, industries or fields of research. However, it is important that small states possess a certain level of knowledge within central areas, so that important research findings outside national borders can be exploited. As a high-cost country Norway has focused on ensuring it has highly educated workers: it has a well-developed national system of free education and has retained

generous funding for post-compulsory studies. Such large public investments have contributed to today’s population having a very high overall level of education. In 2008, the proportion of the adult population with higher education stood at 36 per cent in Norway, compared to an OECD average of 28 per cent.

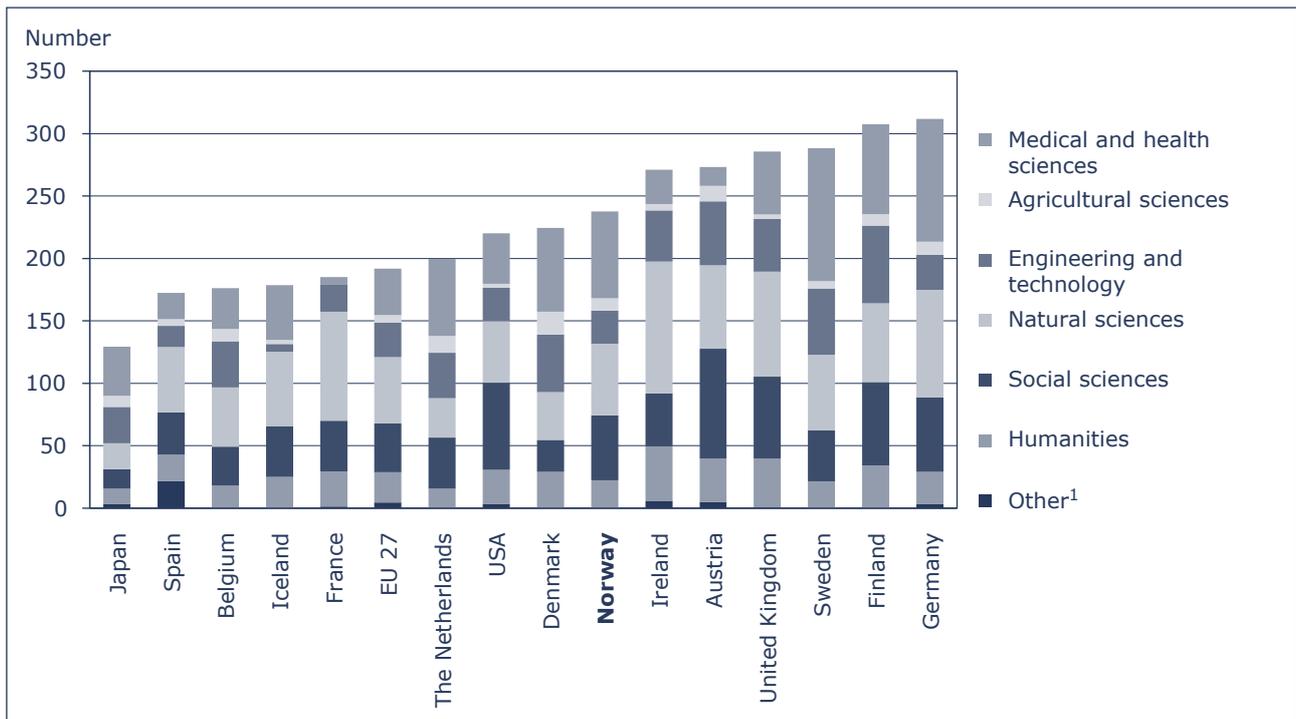
The unemployment level in Norway is low compared with most other countries. Data from the OECD shows that unemployment levels tend to decrease as the proportion with higher education rises.

The OECD has estimated that among the 59 million immigrants living in OECD countries, 20 million have higher education. Norway is one of the countries that benefits from these migration flows. The share of non-Norwegian citizens has increased more among researchers than the general population in Norway (see chapter 2 for more details). In some cases, over-qualified labour may be a sign of a dysfunctional economy. At the same time, the expectation is that economic growth will tend to take place in knowledge-intensive industries, meaning the demand for highly-educated workers should continue to rise.

Statistics Norway have produced projections showing an acute need for people with bachelor-level education in areas including business, health care and nursing, and needs for more post-graduate trained people in areas such as civil engineering and science

Figure 1.2

Number of doctorate degrees per million inhabitants, for selected countries by field of science, 2009.



¹ Incl. services and others not classified elsewhere.

Source: OECD/NORBAL

subjects. The natural sciences have proved to be a particularly challenging area in terms of meeting demand for skilled workers. As shown in section 2.1.1, although there has been an increase in the number of people taking higher degrees, this has been accompanied by a decline in the proportion of students taking a science subject; from around 50 per cent in 1990 to fewer than 30 per cent in 2008 (although actual numbers of science graduates have risen, they have not matched overall expansion).

1.3.1 International comparison of human resources

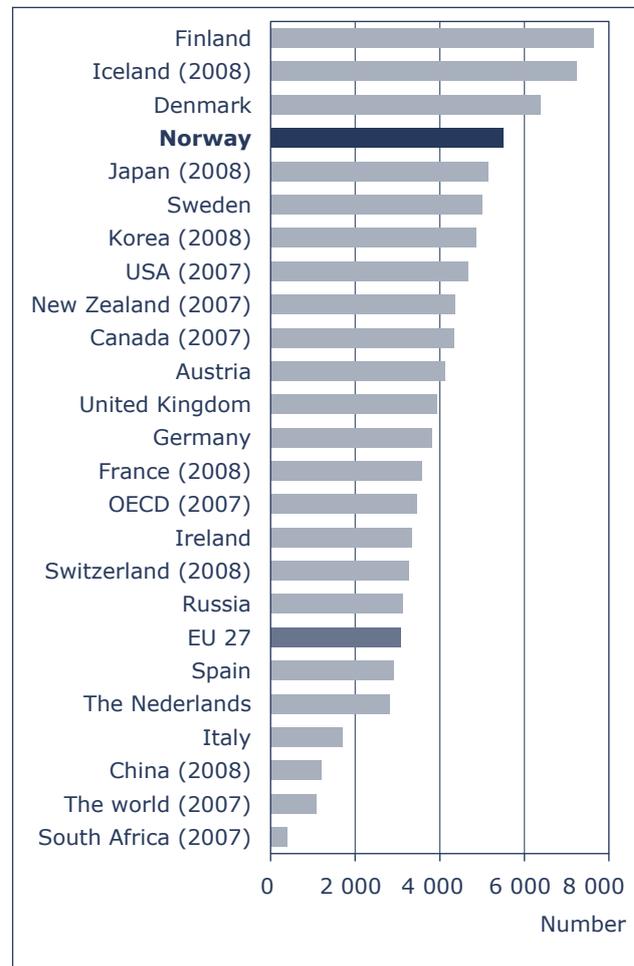
Norway invests the equivalent of 5.5 per cent of its GDP in its education system (across all levels) slightly less than the OECD average of 6.2 per cent. These figures include only public investment, as private investment in education is very low in Norway compared with other countries where the OECD collects such statistics. Among OECD countries 90 per cent of primary and secondary education is paid for through public funds. However, private financing is increasingly significant in university and college education, with the proportion of private funding varying considerably between countries, from under 5 per cent in Norway, Denmark and Finland to over 75 per cent in Chile and South Korea. Norway also scores highly on annual public investment in higher education per student.

A doctorate marks the highest level of research training, and the concentration of such qualifications can therefore be seen as an indicator of the level of competence in a country's research population. It is important to note that there are some national differences in the regulations, content and level of PhD programs.

Norway saw relatively high numbers of new doctorates in 2009, with 238 new doctorates awarded per million inhabitants. The leading countries in terms of the production of new doctorates were Finland and Germany, with over 300 new doctorates per million inhabitants. As figure 1.2 shows, the Norwegian discipline profile for doctorates includes a higher share of degrees in medical and health sciences, a slightly higher proportion of social sciences and a slightly lower proportion in technology, mathematics, natural sciences and humanities. The other Nordic countries (except for Iceland) have a much higher proportion of doctoral degrees in technology.

If we compare national R&D efforts in terms of the number of researchers (measured as full time equivalents of R&D work conducted) the picture is clearly dominated by China, the EU and the USA.

Figure 1.3
R&D full-time equivalents of higher education, per million inhabitants, 2009 (or last year with available statistics).



Source: OECD – Main Science and Technology Indicators 2010:2

Together, these three giants account for about 60 per cent of the world's research workers. The USA contained about 20 per cent of all researchers working in 2007 (down from 23 per cent in 2002). In terms of absolute numbers, China overtook the USA and the EU recently, with an increase in the number of researchers from 1.42 million in 2007 to 1.59 million in 2009. However, while research is concentrated in wealthier regions, the global proportion of researchers based in developing countries increased from 30 to 37 per cent in the period 2002–2007.

Figure 1.3 shows that Norway, despite relatively low R&D investments, has one of the highest levels of researchers among the population. The world average stands at almost 1 100 researchers per million inhabitants, the OECD average is nearly 3 500, while the Nordic countries and Japan have between 5 000 and 7 500 researchers per million inhabitants.

In the Norwegian business enterprise sector, the number of employees are distributed across the largest industries in a relatively similar pattern to that found in the other Nordic countries. However, when it comes to full-time equivalents (FTEs or person-years) of work conducted by these employees, large differences emerge. Norway sees 18 000 R&D FTEs conducted in the business enterprise sector, around half the number performed in Denmark or Finland, and about a third of the Swedish total. Norway also seems to spend less time on the areas of *industry, energy, plumbing, building and construction*, when compared with Finland and Sweden. Although the energy sector contributes heavily to GDP, this has not resulted in large investments in research and development as measured by FTEs. The Norwegian service sector, in contrast, shows a relatively high total of FTEs compared with the other Nordic countries. Furthermore, when we relate total full-time equivalents in R&D to the size of the population, Norway ends up with 3.9 FTEs in the business enterprise sector per 1 000 of the population for 2009, a higher result than the EU 27 average of just 3.0. On this measure Norway remains behind the other Nordic countries, whose 2009 results were 4.6 in Iceland, 5.8 for Sweden, 6.0 for Finland and 6.8 for Denmark.

1.4 R&D and innovation resources

1.4.1 International developments in R&D resources

The global distribution of R&D resources is changing. From 2002 to 2007 global investment in R&D grew from 790 to 1 145 PPP \$ billion:¹ this equates to nominal average annual growth of just under 8 per cent, as shown in Table 1.1. Spending data show that the dominant positions are still held by the USA and Europe, but that Asian investments are rapidly catching up and both Europe and the USA's overall share of world R&D decreased between 2002 and 2007.² Norway has maintained its overall share of world R&D investment, and is showing stronger annual growth in R&D expenditures than Europe or the USA.³ To explain these changes in the distribution of R&D efforts, the UNESCO World Science Report

points out several factors, including the rise of cheap and readily available digital technology, broadband, internet and mobile phones, resulting in new parts of the world having more opportunities to participate in international research.

The full effects of the financial crisis are not yet reflected in such R&D data, and the UNESCO report argues that the crisis will accentuate the decline in Western dominance in science and technology. It stresses the increasing role of emerging economies such as Brazil, China, India and South Africa in activities further up the value chain, and their development from locations for cheap outsourcing of production, to autonomous developers of process technology, product development, design and applied research.

While global investments are changing, the uneven distribution of research and innovation is emerging in new, sub-national forms. In Brazil, 40 per cent of all R&D expenditure was linked to the Sao Paulo region, while South Africa's Gauteng province accounts for 51 per cent of the national total.

Investment in R&D as a share of GDP is widely used as an indicator to describe a country's R&D effort. From 2002 to 2007 the world's R&D spending grew slightly faster than overall GDP. Globally, R&D expenditure as a share of GDP was 1.7 per cent both years. China has performed particularly well on this measure, with R&D spending as a share of GDP at 1.54 per cent in 2008, up from 1.07 in 2002.

The EU has also focused attention on R&D investment as a share of GDP. This was the main indicator selected when launching a vision for "smart, sustainable and inclusive growth" in the EU's growth report and the Green Paper.⁴ There are concerns within the EU about the region's R&D investment compared to that of the USA and other advanced economies, particularly in terms of private investment. The EU wants to achieve the overall goal of 3 per cent of GDP going to R&D by 2020, and all member states have been asked to set their goals to support this outcome. Many countries are aiming high with targets approaching 3 per cent, while Austria, Finland and Sweden have gone further to set a 4 per cent target.

Norway's R&D investment is well above the OECD average in terms of per capita spending (see Figure 1.4). Norway spends just under 9 000 NOK per capita, well above the OECD average of under 7 000 NOK, and the country has remained above the OECD average on this measurement since 2001. However, Norway is below the OECD average of R&D spending as a share of GDP. The countries

¹ PPP stands for Purchasing Power Parity. This is a conversion to a common unit on the basis of U.S. dollars to make all countries R&D efforts comparable regarding currency and purchasing power.

² See the UNESCO World Science Report 2010.

³ OECD – Main Science and Technology Indicators 2010:2.

⁴ European Commission (2011): Green paper and Annual growth survey.

Table 1.1

R&D expenditure by continent and selected countries: 2002–2007. Absolute amounts PPP \$, growth and share of global R&D and world GDP.

Part of the world/ country	R&D (Bill. PPP \$)		Average yearly growth	Per cent			
	2002	2007		Proportion of the world's R&D		Proportion of the world's GDP	
				2002	2007	2002	2007
North America	297.8	399.3	6.0	37.7	34.9	24.7	22.8
Latin America	22.1	34.6	9.4	2.8	3.0	8.1	8.5
Europe	238.5	314.0	5.7	30.2	27.4	31.1	29.0
Africa	6.9	10.2	8.1	0.9	0.9	3.6	3.9
Asia	213.9	369.3	11.5	27.1	32.2	31.0	34.5
Oseania	11.2	18.3	10.3	1.4	1.6	1.5	1.4
The world	790.3	1 145.7	7.7	100.0	100.0	100.0	100.0
China	39.2	102.4	21.2	5.0	8.9	7.9	10.7
USA	277.1	373.2	6.1	35.1	32.6	22.5	20.7
Japan	108.2	147.9	6.5	13.7	12.9	7.4	6.5
Brazil	13.0	20.2	9.2	1.6	1.8	2.9	2.8
India	12.9	24.8	14.0	1.6	2.2	3.8	4.7
Norway	2.8	4.3	8.8	0.4	0.4	0.4	0.4

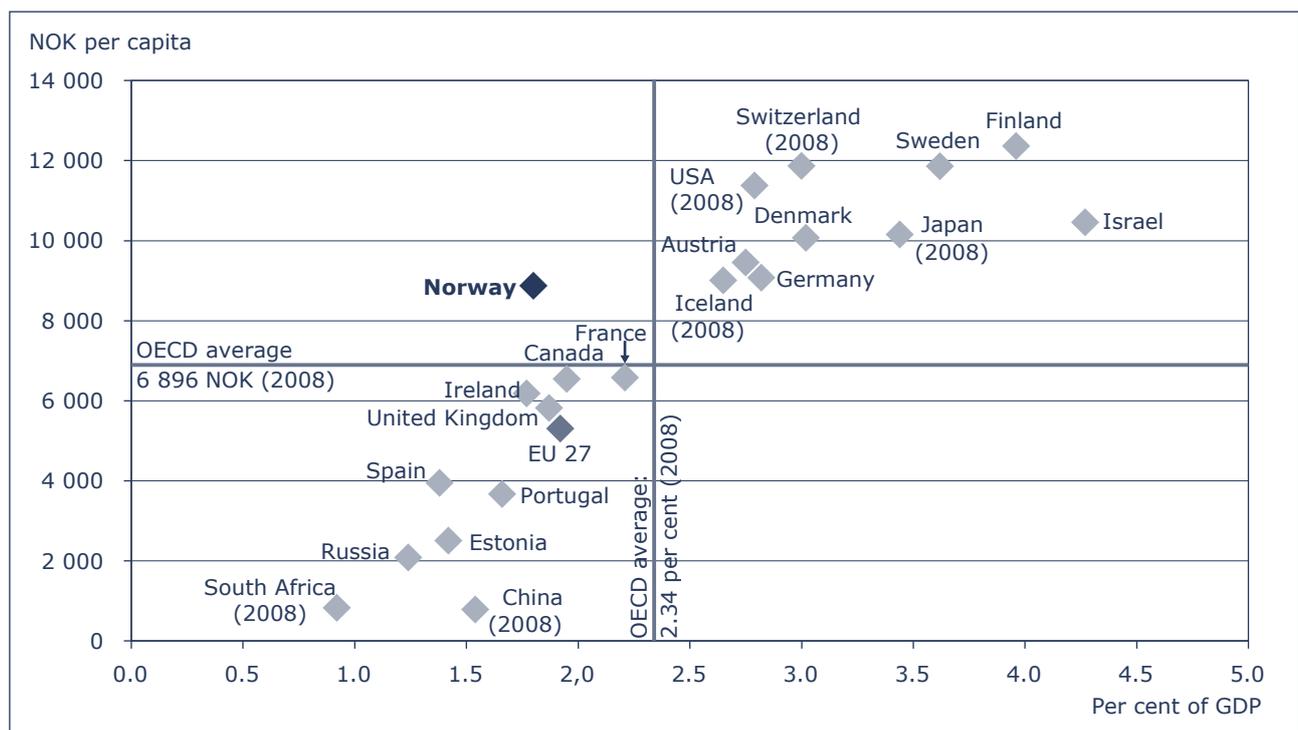
Sources: UNESCO World Science Report 2010 and OECD MSTI 2010:2/National R&D statistics for Norway

where R&D spending makes up the largest shares of GDP are Israel, Finland, Sweden, Japan, Denmark and Switzerland; all invest more than 3 per cent of GDP in R&D.

For a number of years Norway has had an explicit national goal to achieve the OECD average result in terms of R&D investment as a share of GDP. This target has now been placed on the back burner, but re-

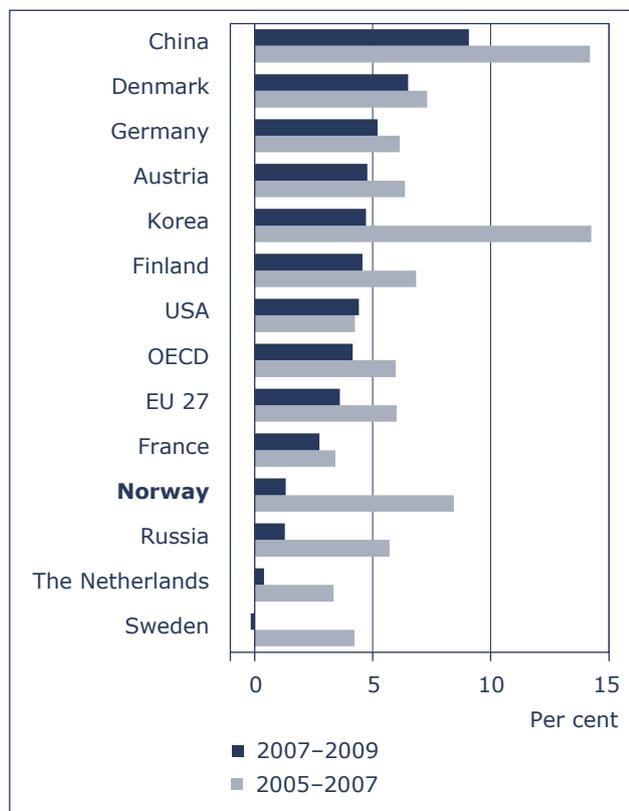
Figure 1.4

R&D expenditure per capita and as a share of GDP for selected countries, 2009.



Source: OECD – Main Science and Technology Indicators 2010:2

Figure 1.5
Increases in R&D spending for selected countries:¹ 2005–2007 and 2007–2009 (average annualised real growth).



¹ For the OECD, China, South Korea and the USA figures from the period 2007–2008 are used for the second period.

Source: OECD – Main Science and Technology Indicators 2010:2

mains a long-term goal. In the recent white paper “Climate for Research” the government relaxed their focus on this target, and suggested this indicator should be linked to several others in target setting, including R&D full-time equivalents.⁵

To look for signs of the impact of the financial crisis on R&D investment, statistics from the OECD are the best option currently available. There was growth in R&D expenditure in real terms (in average annualised growth) from 2007 to 2009, but the rate of growth has slowed when compared with growth in the two previous periods of 2005–2007 and 2003–2005. However, these changes are very recent, and data for 2009 are still preliminary in many cases, and perhaps present over-optimistic estimates. In the EU, average annual real growth in expenditure was just under 3 per cent from 2003 to 2005, 6 per cent from 2005 to 2007, and was below 4 per cent from 2007 to 2009. Figures

⁵ See the white paper “Klima for forskning”, St.meld. nr. 30 (2008–2009).

International comparisons

International comparisons are based on R&D surveys conducted by each country but standardised according to the OECDs «Frascati Manual». This manual contains definitions, classifications and guidelines on how to treat data in order to measure R&D activity. According to the OECD guidelines, several performing sectors form the basis of the mapping of R&D effort. The four performing sectors are:

- Business enterprise sector
- Government sector
- Private Non Profit sector (PNP sector)
- Higher education sector

These four sectors do not fit the Norwegian situation neatly. The higher education sector is the only performing sector that is identical for both national and international statistics. In addition to industry, the business enterprise sector in Norway also includes some units in the institute sector. These institutes mainly serve the industrial sector and include special branch institutes and task-oriented industry institutes. The government sector includes institute sector units that are related or directly connected to Departments, in addition to other public or semi-public institutions and government-directed, task-oriented institutes. In Norway the institute sector is monitored and measured in addition to the sectors set out above. The Norwegian PNP sector contains relatively few, and typically small, units. In reports to the OECD and in other international efforts to collect statistics, these institutions are therefore included under the government sector.

from 2008 to 2009 suggest a substantial change has occurred in this region, with this latest period seeing an increase of just 0.8 per cent. There are no updated results available for the whole OECD area, but countries own statistics suggest a slow-down took place in 2008 to 2009. Decreases in R&D expenditures have been reported by Norway, Belgium, Finland, Israel, Italy, Romania, Spain, UK, Sweden and Austria. Iceland has not updated their figures for 2009, but has experienced a real decrease in R&D expenditure in recent years.

Almost all countries shown in Figure 1.5 experienced slower growth in R&D expenditure from 2007 to 2009 than in the previous two year period. China has shown the strongest growth since 2007, but even there, growth has clearly slowed. While Norwegian R&D expenditure showed real growth of 4.6 per cent from 2007–2008, the period 2008–2009 saw a decline

of 0.3 per cent, giving an average annual real growth rate of just of 2.1 per cent for 2007–2009.

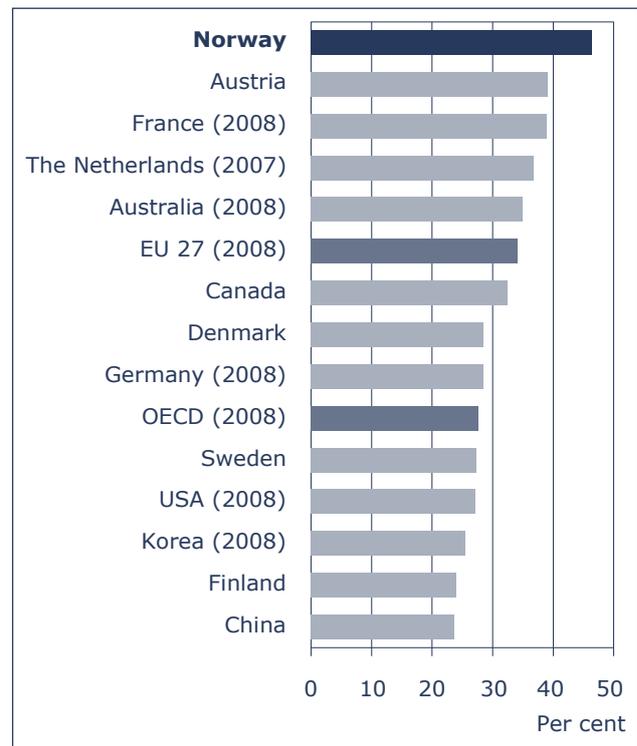
The importance of various research-performing sectors varies between countries. There are many reasons that influence the range of research performers, such as industry structure, historical conditions, economic conditions, and educational and political priorities. In Norway, the role of the public sector in R&D is relatively strong. Policies to increase private sector R&D efforts have been pursued for several years. The EU also sees this as a key objective, as one possible measure to increase R&D efforts in the competition with Asia and the United States. However, neither the EU nor Norway has managed to increase the business enterprise sector's share of R&D activity over the last few years. Indeed, in 2009 the EU and Norway saw this share drop slightly, from 62 per cent to 61 per cent in the EU, and from 54 to 52 per cent in Norway. Meanwhile, the largest R&D actors, the USA, Japan and China, all have a pattern of R&D efforts where the business enterprise sector accounts for over 70 per cent of total expenditure. Other Nordic countries also have business enterprise sectors responsible for large shares of R&D expenditure: Finland, Sweden and Denmark have shares of 71, 71 and 67 per cent respectively.

The business enterprise sector in Norway consists of businesses and the business-oriented part of the institute sector (see box on international comparisons). Norwegian businesses are commodity based, but knowledge intensive. Although R&D measured as a percentage of sales is low in many places, many companies use advanced technologies.

The share of R&D expenditure drawn from Norwegian universities and colleges is high compared to other countries. In Norway the higher education sector accounted for 32 per cent of total R&D expenditure in 2009, while the OECD average was 17 per cent (in 2008). Denmark also sees a high proportion of investment from the university and college sector (30 per cent), while this sector is smaller in Sweden (25 per cent) and Finland (19 per cent). The high share of spending in the Danish university sector is partly explained by institutional changes which have seen research units from the government sector merged with universities.

If we compare R&D expenditure in the higher education sector per capita, the differences between the Nordic countries are small: Denmark and Sweden's higher education sectors spend nearly 3 000 NOK per capita, Norway's result is just slightly lower, and Finland and Iceland stand at just under 2 500 NOK per capita. Among the Nordic countries Norway had the highest proportion of higher education funded by pub-

Figure 1.6
R&D expenditure financed through public sources. Selected countries, 2009 or latest available year.



Sources: OECD – Main Science and Technology Indicators 2010:2

lic sources, at just over 90 per cent.⁶ This includes the general university funding, other funding from ministries and government bodies, funding from the Research Council of Norway and from the counties and municipalities. Among the Nordic countries, Norway also had the lowest proportion of funding from abroad (2.5 per cent) and from enterprises (less than 4 per cent) in the higher education sector in 2009.

The overall proportion of R&D expenditure funded by public sources is also relatively high in Norway. Among the countries shown in Figure 1.6, Norway had the highest proportion of public funding of R&D, at nearly 47 per cent. The OECD average was 28 per cent in 2008, and the other Nordic countries are fairly close to this result. In both the business enterprise sector and higher education sector in Norway, the share of public financing is particularly high, while the balance of funding in the government sector itself is in line with, or lower than other countries in Scandinavia. The government sector in Norway includes a high proportion of publicly-oriented research institutes (see box on International comparisons).

⁶ Sweden, Denmark, Iceland and Finland have shares between 77.2 and 81.8 per cent.

Table 1.2
Key results for Norwegian participation in FP6 and FP7.

Indicator	All programs	
	6RP (2003–2006)	7RP (2007–dec 2010)
Number of projects with Norwegian participation	849	728
Rate of success for Norwegian projects	27.1%	23.7%
Proportion of projects with norwegian participation of all cancelled projects.	8.4%	6.7%
Number of Norwegian projects	1 299	1 059
Number of Norwegian coordinators	148	170
Estimated EU funding to Norwegian participants (NOK)	2.3 bill.	2.7 bill.
	1.7%	1.8%

Source: E-Corda/EU-Commission

1.4.2 The EU Framework Programme

The EU's Framework Programme for Research and Technological Development is seen as having a key role in meeting the objectives of the EU Lisbon strategy for competitiveness, growth and employment. It is also regarded as Norway's most important arena for building international cooperation, internationalisation and for steps to improve the quality of Norwegian research. Participation provides opportunities for networking, opportunities to collaborate with leading scientists in Europe and contributes to knowledge-based innovation and innovation in Norwegian industry and society. Success rates for participation in the programs can be considered as indicators of the quality of the country's research.

Norway's participation in the EU Framework Programme is in line with that of EU member countries (it is part of the EEA Agreement). Member countries' funding contribution to the Framework Programme is calculated as a share of GDP. The 7th Framework Programme (FP7) runs for seven years (2007–2013) while the previous Programme lasted just four years. Norway participates in the following specific programmes:

- 1) Cooperation (10 major programmes);
- 2) Ideas (frontier research);
- 3) People (researcher mobility);
- 4) Capacities (7 capacity-enhancing activities);
- 5) The EU Joint Research Centre.

At the end of 2010, the fourth year of FP7 was completed. However, only just over a third of the total FP7 budget of 50.5 billion euros had been allocated by that time. The FP7 budget is therefore set to increase significantly in the programme's second half. During the first four years of FP7 Norway participated in 3 071 applications, resulting in 728 projects. The 728 approved projects are expected to provide Norway with overall funds of 331 million euros (approx. 2.7 billion NOK). Estimates suggest this puts

Norway's share at about 1.8 per cent of all competitive funding allocated under FP7 so far.⁷

Norway is particularly well-represented in some of the specific Framework Programme areas. Under the Environment Programme, 28 per cent of all projects include Norwegian participants. Participation is also high in the programs for Energy, Science in Society (SiS), SME, Space, Research Infrastructure (RI) and Security. Norway has the highest success rate of any of the EU member countries and associate countries in both the Energy program and SiS, and has the second highest success rate in the SME programme.

At the end of 2010 there had been a total of 4 271 Norwegian participants in FP7 applications and 1 057 in recommended projects. The Research Council of Norway estimates that the recommended projects which include Norwegian participation will involve almost 3 200 scientists in total. However, participation in these projects is quite concentrated: the ten most active Norwegian actors account for nearly 40 per cent of all Norwegian participation in FP7. The same actors tend to have coordinator roles, both in applications as well as recommended projects.

Over a third of all Norwegian participation in FP7 comes from the institute sector. Research institutes are also the group with the highest success rate for applications. Universities and colleges are the second largest sector in terms of numbers of applications, but come out third, after companies, in recommended projects. Government departments have increased their participation in FP7 compared to FP6, up by 4 percentage points, while companies have reduced their share of participants accordingly.

Norway's most common partner countries for FP7 projects are the United Kingdom, Germany, Italy, France and Spain. These are also the larger European

⁷ See data on applications and projects under FP, compiled by The Research Council of Norway/ E-Corda (The EU Commission).

The future of EU's Framework Programme

The EU's 7th Framework Programme will run until 2013, but the preparation for the next programme, and comprehensive restructuring of these policies, is already in full swing. Participating countries have been asked to provide input for changes, visions, challenges and solutions. In Norway, the Ministry submitted input based on feedback from 19 different environments. The Norwegian proposal highlights the continued importance of public spaces for research and where researchers' voices can be heard, innovation in the public sector and the important role played by the education system in innovation and demonstration activity. It also stresses the need to make the system more accessible and user friendly, and urges caution in increasing the framework budgets. The Norwegian Ministry has also already chosen two of the thematic areas central to the Grand Challenges: marine and maritime research and Arctic research. The expectations are that the EU will simplify application procedures and rules about the application process and participation in research and that additional investment will be made in the areas of renewable energy, a new energy program, ICT and connected medicine.

countries, which tend to dominate the Framework Programme; indeed, of the 199 countries participating in FP7 applications so far, these five together account for half of all participation. If we weight the number of joint applications by population size for each partner, then Denmark, Sweden and Finland are the most important countries for Norwegian cooperation.

Table 1.2 compares Norwegian results under FP7 so far (up to the end of 2010) with results from FP6. The results for both periods cover four years of activity, with comparable budgets: FP6 distributed approximately 16.7 billion euros, while FP7 distributed approximately 18.4 billion Euros in the period 2007–2011.

Norway participated in fewer projects for the first four years of FP7 compared with FP6, despite the fact that FP6 involved fewer (and larger) projects than FP7 so far. There is also slightly less Norwegian participation per project in FP7, compared to FP6. Furthermore the Norwegian success rate is lower in FP7 than in FP6, although part of this follows from lower average success under FP7 as a whole. While Norway has received more support in total from FP7 projects than it did in 6RP, this can partly be explained by changes in funding whereby the EU finances up to 75 per cent of project costs in FP7, compared with 50 per cent in FP6.

1.5 The results of R&D and innovation

1.5.1 Results from the European Innovation Survey

The Norwegian industrial sector's innovation activity appears to be lower than the EU average.⁸ The European Community Innovation Survey (CIS) for 2008 illustrates this, both when we look at the proportion of enterprises reporting innovation activity overall, and the proportion of enterprises that have introduced new products or processes (PP-innovation) in the period 2006–2008. As Figure 1.7 shows, the Norwegian results are also below those of Sweden, Denmark and Finland.

Norway has the lowest innovation activity of all the Nordic countries. Only around half (49 per cent) of Norwegian enterprises reported some form of innovation activity in the period 2006–2008.⁹ This is three percentage points below the EU average. When countries are ranked in ascending order, Norway is number 16 out of 28 countries, while Sweden, Finland and Denmark are in positions 10, 12 and 13 respectively (with 52 per cent, 52 per cent and 54 per cent).

Germany's result on this indicator really stands out, with 80 per cent of surveyed enterprises reporting innovation activity. However, there may be reason to treat this result with some scepticism. Germany had the lowest response rate of all countries participating in the survey, at just over 20 per cent in 2006.

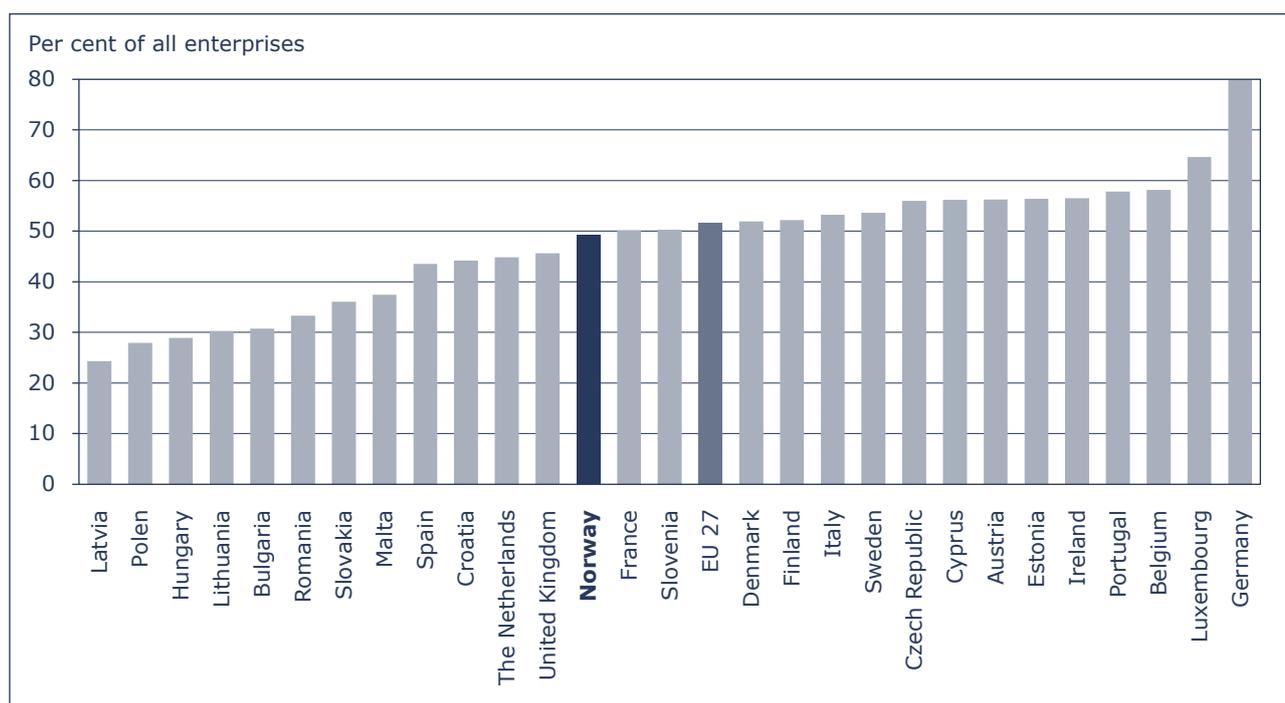
Germany also reported the most substantial methodological deviations from the standard survey procedures. As it is, this German result has a powerful effect on the EU average: if the German result is excluded the EU average drops to 46 per cent.

Norway stands out from other countries most clearly when it comes to the proportion of companies that have introduced innovative processes, but which have not been completed or which have not led to some innovation by the end of the period: 10 per cent of Norwegian enterprises are in this situation, com-

⁸ EU averages (EU 27) are calculated on the basis of the available data for the individual indicators. This means there can be missing data for many cases from countries; it is not mandatory to submit all data to Eurostat. Greece has not provided data for CIS 2008 and is therefore not included in any totals.

⁹ Innovation activity refers to firms that have done one or more of the following: companies that have introduced new products or new processes; that have introduced organisational changes or changes in the way the company markets itself or its products; that have interrupted or delayed activity with a view to introducing new products or processes; or, have begun such innovative activity even if it was not completed at the end of 2008.

Figure 1.7

Proportion of enterprises reporting innovation activity in EU 27 and Norway: 2006–2008.

Source: Eurostat

pared to an EU average of only 3 per cent. Part of the reason for this high level of aborted or incomplete innovation may be explained by Norway conducting a combined R&D and innovation survey. This has a high response rate and a large number of items that recur from survey to survey. This broader information base provided by the Norwegian study (compared with most other countries) may have influenced results by including units that would probably not have been included in an innovation-only survey.

If the results from CIS 2008 are broken down into broad sectors,¹⁰ it does not change the picture substantially (see Figure 1.8). While Norwegian companies in the service sector scored higher than the EU average, the results for industrial firms are below average.

Norway's poor ranking is also related to the Norwegian industrial structure. In particular, larger enterprises are less often located in industries with high innovation density. A joint Nordic study has attempted to correct for the effect of varying industrial structures across different countries, and this resulted in significant increases in the relative innovation activity in Norway.

When it comes to the proportion of business turnover that is derived from the introduction of new products (goods or services) introduced in the last three years, Norway again ends up at the bottom of the rankings for Europe. Again, these results are explained by Norway's industrial structure to a large degree. Different business sectors show very varied results on this variable, and these results also vary substantially from survey to survey. For example, Norway has only a small number of enterprises in high-turnover sectors, which typically involve consumer-oriented technology products, which are rapidly replaced by updated new models. The Norwegian industrial sector is dominated by the oil industry and related industries that are undoubtedly technology heavy, but are not typically classified as high-tech industries in European comparisons. Such industries are also rarely involved in innovative activities involving new products: continuous improvements in industry are not reported as innovations, even though they can involve substantial and innovative change over time.

When we try to exclude the effects of national industry composition, by looking at innovation as measured by the percentage of sales only in those enterprises with product or process-oriented innovation activity, the picture changes. On this basis, Norwegian product or process innovators are performing better than those in Sweden. This indicates that Norwegian

¹⁰ Industry here includes industry codes B05–09, C10–33, D35 and E36–39, while the services sector includes codes G46, H49–53, J58, J61, J62, J63, K64–66 and M71. Together, these two groups constitute the required range of sectors set out for CIS 2008.

innovators do well when measured against other innovators based in comparable countries and industries. Norway simply has too few of these kinds of enterprises to perform well on many of these indicators, both due to a small pool of firms in the relevant industries, but also as the specific kinds of firms and industrial areas that are stronger in Norway seem to have a lower tendency to innovate than those in neighbouring countries.

There is widespread agreement across countries about the main purpose of innovation activity. When firms are asked about possible purposes that drive innovation, a set of common issues emerges. Improving the quality of goods produced or services provided is most often seen as a very important reason driving innovation. Expanding the range of goods or services on offer is the second most commonly reported purpose in most countries, although Denmark stands out with a relatively small share of companies who say that this is a very important aspect. The third most frequently reported objective is to increase the company's market share.

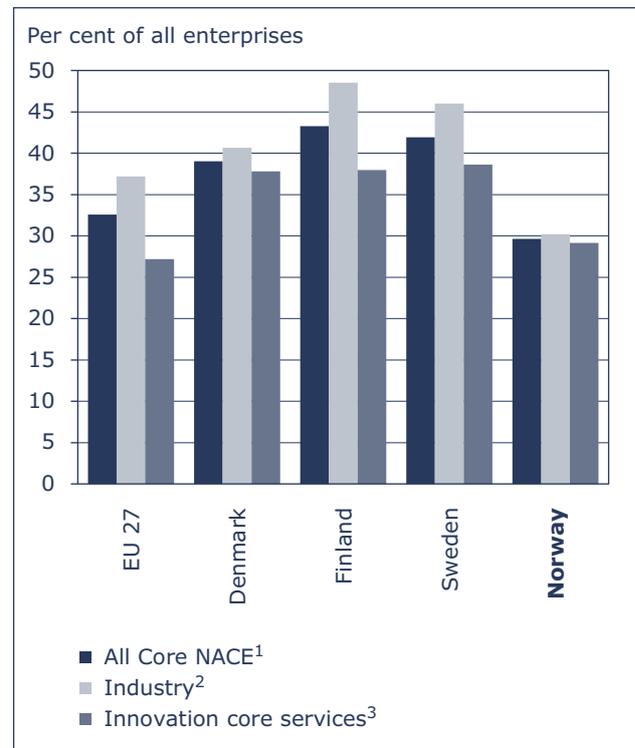
However, there are differences in the range of aims or factors that are seen as important. Norwegian enterprises cite a high number of factors as being 'very important', and are focused on more factors than the average for firms across the EU. The greatest difference is apparent when it comes to improving health or safety, which is the factor that is least likely to be reported as driving innovation in the EU overall, but which is reported by 49 per cent of Norwegian respondents as being very important; almost twice the EU average.

1.5.2 Scientific publishing and citation

Publication and citation data are widely used as indicators for the results of research. The basis for the use of such 'bibliometric indicators' is that new knowledge, which is the fundamental goal of all basic and applied research, is typically disseminated to the scientific community through publications. Publication can therefore be used as an indirect measure of knowledge production. The number of publications can be seen as representing the extent of scientific output in countries or disciplines, while the numbers of citations can be seen as an indirect measure of the impact published research has had. This chapter provides a comparative international analysis of Norwegian research based on these perspectives.

In the period 1981–2010 more than 22 million scientific articles were published worldwide. Global publication production increased throughout the period, from 460 000 articles in 1981 to nearly 1.2 million articles in 2010. Norwegian production has also

Figure 1.8
Share of enterprises reporting product and/or process innovation, by industrial activity group in EU 27 and the Nordic countries: 2006–2008.



¹ All NACE core industries related to innovation activity (B, C, D, E, G46, H, J58, J61, J62, J63, K and M71).

² Except building and construction businesses.

³ NACE G46, H, J58, J61, J62, J63, K and M71.

Source: Eurostat

increased. In 1981 Norwegian scientists published almost 2 400 articles. In 2010 that number had increased to just over 9 300. This reflects the huge expansion in the production of knowledge over this period, but also that the number of journals included in monitoring has increased. A significantly increased proportion of the articles with a Norwegian author also feature author addresses from other countries. Of all the Norwegian articles from 2010, 55 per cent involved international co-authorship.

There are large differences between countries' article production, as Table 1.3 shows. Figures from 2010 show that the USA accounted for 22 per cent of the world's scientific knowledge production, measured as a sum of all countries' output. China is now the next largest knowledge producer, with a share of 8.9 per cent, followed by the UK and Germany, with shares of around 6 per cent. Of the Nordic countries, Sweden is the largest knowledge producer. Norway's share was 0.61 per cent, but the country's share of world production has increased over the last years and has

Bibliometric indicators**Data:**

This analysis is based on data from Thomson Reuters (formerly the Institute for Scientific Information (ISI). Thomson Reuters produces the most important database for bibliometric purposes. It indexes peer-reviewed journals, including all major international journals in science, medicine and technology, as well as journals from the social sciences and humanities. This report includes data from the National Science Indicators (NSI) database and National Citation Report (NCR) for Norway. The NSI contains aggregated publication and citation numbers for detailed sub-fields. The analysis includes only regular articles and 'review' articles, but not book reviews, abstracts etc.

Methods:

Bibliometric indicators have some important limitations that must be considered in interpreting results. Among other things, the coverage of journals varies between disciplines. The best coverage is achieved for physics, chemistry, biomedicine and clinical medicine. In biology and technology coverage is also relatively high. However, coverage in the social sciences and humanities is poor. This is partly because Thomson Reuters does not index all the relevant journals and partly because publication patterns differ between disciplines; in some disciplines, less centralised research communication outside of international journals, plays a more important role, via national magazines, books, etc.

climbed from 0.53 per cent 10 years ago; impressive for a period when most Western European countries experienced a decline in publication share.

When publishing is weighted by population size, to provide figures on articles per thousand inhabitants, the Nordic countries perform very well. Norway comes fifth out of the countries listed in Table 1.3. Iceland is second, Denmark third and Sweden fourth. However, differences in publishing weighted by overall population size do not necessarily reflect national research performance: a better indicator would calculate the relationship between publication outputs and inputs such as R&D funding. However, these kinds of productivity measures, comparing differences in the relationship between 'inputs' and 'outputs', do not only reflect productivity differences, but would also vary as a consequence of differences in countries' scientific specialisation profile.

Table 1.3
Scientific publishing. Selected countries, numbers and percentages, 2010.

Country	Number of articles	Percentage of world production ¹	Number of articles per 1 000 capita	Relative change in the number of articles 2002–2010
USA	338 784	22.17	1.10	27
China	135 375	8.86	0.10	243
United Kingdom	93 092	6.09	1.51	32
Germany	88 420	5.79	1.08	29
Japan	72 882	4.77	0.57	-1
France	63 601	4.16	0.99	31
Canada	54 756	3.58	1.62	56
Italy	51 453	3.37	0.85	51
Spain	44 688	2.92	0.97	78
India	40 905	2.68	0.03	114
South Korea	39 843	2.61	0.82	133
Australia	39 559	2.59	1.79	74
Brazil	31 639	2.07	0.17	145
The Netherlands	30 948	2.03	1.87	55
Russia	26 836	1.76	0.19	3
Taiwan	23 834	1.56	1.03	108
Switzerland	22 239	1.46	2.85	59
Turkey	22 163	1.45	0.31	160
Sweden	19 976	1.31	2.14	28
Polen	19 512	1.28	0.51	72
Belgium	17 019	1.11	1.58	58
Israel	11 850	0.78	1.59	19
Denmark	11 836	0.77	2.14	50
Austria	11 425	0.75	1.37	48
Greece	10 219	0.67	0.91	79
Finland	9 881	0.65	1.85	30
Norway	9 367	0.61	1.94	81
Mexico	9 274	0.61	0.09	66
Portugal	9 048	0.59	0.85	136
Czech Republic	8 862	0.58	0.84	83
New Zealand	7 321	0.48	1.71	63
Ireland	6 640	0.43	1.49	121
Hungary	5 151	0.34	0.51	22
Iceland	781	0.05	2.45	110
The World	1 180 761	100.00	0.17	48

¹ The national share of global production is calculated based on the sum of all countries' publishing output.

Sources: National Science Indicators/Thomson Reuters/NIFU

Table 1.3 also shows how article production changed between 2002 and 2010. The increase in China's article production is particularly remarkable, having more than tripled during this period (an increase of 243 per cent). This is due to an expansion of the country's research resources, incentives to publish in peer-reviewed journals as well as increased coverage of Asian scientific journals by publication databases. Turkey and Brazil also have high growth rates, as do several other Asian countries, including South Korea, India and Taiwan.

In Europe, Portugal and Ireland's publication volume grew most in the period, by 136 and 121 per cent respectively. There was also relatively strong growth in Iceland, the Czech Republic and Norway (growing by between 110 and 81 per cent). The major scientific nations of Britain, Germany and France saw growth of around 30 per cent, marginally above the USA's increase. In general, many of the smaller and newer EU countries experienced great growth in scientific publications in recent years. This is likely due in part to participation in EU Framework Programmes and other European research programs, as well as increases in these countries' own R&D initiatives.

Norway had the second strongest growth in publishing output of the Nordic countries (after Iceland) with an 81 per cent increase since 2002. Sweden's output grew the least, by just 28 per cent. In the last five years Norway's development has been more positive than the other Nordic countries, a turnaround from the period 1981 to 1999, when Norway had the second lowest growth among the Nordic countries. Areas that have grown particularly strongly in the more recent years (in terms of relative volume) include the social sciences and technology.

These positive developments in Norway are partly explained by the increased resources channelled into research as well as increased numbers of researchers. R&D expenditure in the higher education sector in Norway, where the bulk of journal publishing takes place, grew by 62 per cent in fixed prices, from 2001 to 2009. In addition, this increased productivity is associated with changes which have increased the focus on the production of publications. Since 2004, Norway has had a performance-based funding model for higher education institutions, and rates of academic publishing are one of the performance indicators. The institute sector and health trusts have also adopted publishing as performance indicators linked to funding. In this way, Norwegian research institutions have incentivised publishing (Sivertsen 2008). There is reason to believe that this system has contributed to the recent increases in scientific publication in Norway, although the overall significance of these incentive effects, relative to other factors, is difficult to determine.

Norwegian researchers published round 140 000 articles in the period 1981–2009 and together these have been cited more than 2 million times. It is of course the case that those countries producing the highest numbers of articles also tend to receive the most citations. However it is common to use measures that are independent of overall publishing volume, to assess whether a country's articles are having a high or low impact. One such indicator is the rela-

Bibliometric indicators

Using citations as an indicator

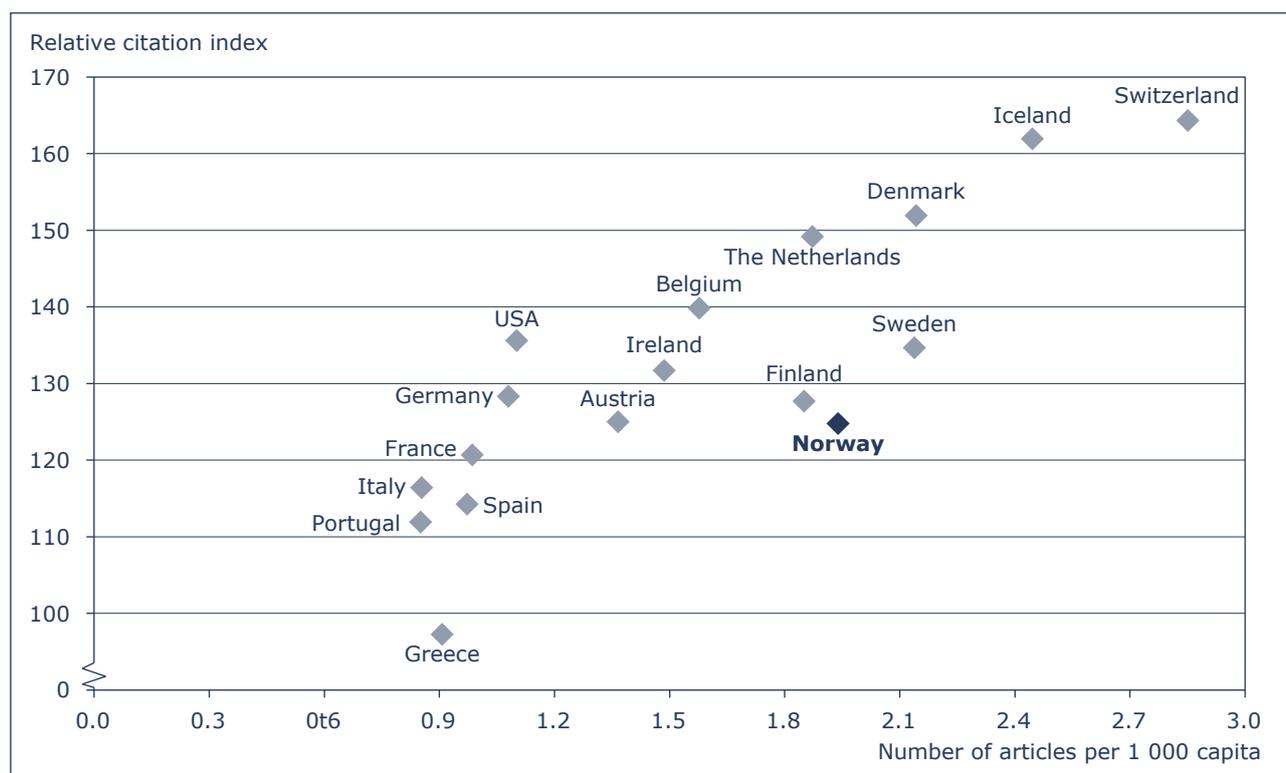
Scientific publications typically refer in some detail to previous literature. These references might be relevant to the concepts, methods, theories, empirical findings or other aspects of the publication. Thomson Reuters systematically record all the references in their indexed literature, making it possible to calculate how many times any given publication has been cited in the subsequent literature. Based on these statistics, citation analysis can be conducted on aggregated and national levels.

It is common to assume that articles are cited more or less depending on their influence on further research. Citations are therefore used as indicators of scientific 'impact'. The average number of citations for a country's publications is a widely used indicator, and is seen as offering an indirect gauge of the attention a country's publications achieve among the international scientific community. Citation indicators have increasingly been used in the evaluation of research. However, it is important to recognise that there are limitations and weaknesses to such indicators, and that they therefore cannot replace peer evaluation (see Aksnes 2005).

tive citation index, which provides the average number of citations per publication for each country. It shows how often each country's publications are cited, relative to the global average (which is normalised to 100). However, there are large differences in average citation frequency between different disciplines: a molecular biology article is cited, on average, about ten times as often as an article in mathematics. A country's citation rates will therefore depend on the distribution of articles across various disciplines, and the concentration of publications in highly cited fields could increase a country's citation rate significantly. To correct for these differences, we have weighted each country's citation indicators in the analysis that follows, meaning that the national index is weighted according to the relative distribution of articles across different fields. The Citation Index used here therefore allows more direct international comparisons.

Norway performs fairly well on the relative citation index, with an index of 125. This result means that the Norwegian articles were cited 25 per cent more often than the world average. In the 1980s, Norwegian research was less cited than the international average, but a significant increase in citation fre-

Figure 1.9
The number of publications per capita, 2010 and the relative citation index for selected countries: 2007–2009.¹



¹ The relative citation index for articles published in 2007, 2008 and 2009 and the accumulated citations for these publications up to 2010. The index for each country has been weighted to reflect each country's relative distribution of articles across subject areas.

Source: National Science Indicators/Thomson Reuters/NIFU

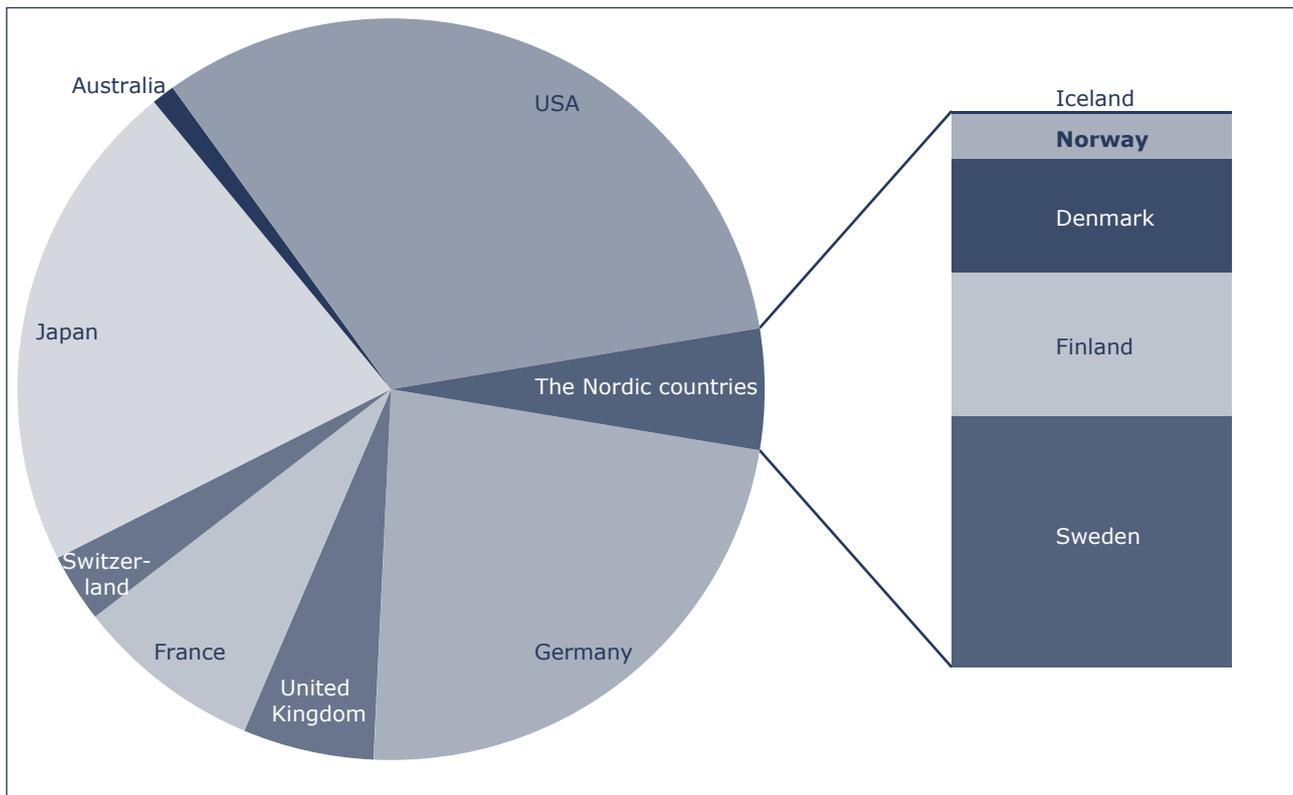
quency was achieved during the 1990s. While these results are positive for Norway, almost all western and northern European countries had index values well above 100 in this period (the OECD countries average was 110) and Switzerland (index of 164) and Iceland (162) achieved the greatest impact according to the citation index (Figure 1.9).

Compared to the previous period for the Citation Index (2004–2006) Norway's performance stood out as it was one of only five of the OECD countries that did not increase its results on the index. The average for EU 15 countries improved from 109 to 115 in this period. Increases were particularly strong for many of the northern European countries. These changes cannot simply be attributed to increased citation rates, but also to methodological issues such as the expansion of the range of journals covered in the database (see above). Many of the new journals that have been added are cited much less often. Therefore, if researchers in certain countries publish more in these lower-cited journals, the average citation rate will drop. Norway saw a decline in the citation index of 1.8 points from 2004–2006, breaking a long running trend of in-

creases in its citation index. The reason for this development for Norway has not been fully analysed or explained, as yet. When it comes to the number of publications, one sees that this normally corresponds relatively strongly with resource availability: increased research resources leads to increases in the number of researchers, which in turn increases the number of articles. There is no such direct correlation in terms of citation frequency and resource supply – although there may be a connection. Norway's position in terms of these results has worsened compared to many other countries, over the last three years. However, weakened citation results must be viewed in the context of the major growth in scientific production in Norway: in such a situation it is perhaps unsurprising that improved scientific impact, as measured by the average citation rate per article, has been difficult to maintain or improve.

Norway's level of publication activity and citation rate varies greatly between disciplines. If we focus instead on different fields of science, technology, medicine and social sciences, two types of indicators can be calculated. First, the activity index, which is an in-

Figure 1.10
EPO¹ patents originating in OECD countries: 1999–2008.



¹ EPO-A-dokuments (applications). Origin is derived from the applicant's address (using fractional counting); the date of application determines the time period it is allocated to.

Source: NIFU on the basis of OECD data: http://stats.OECD.org/wbos/Index.aspx?DatasetCode=PATS_IPC.

indicator that shows whether a country has a higher or lower proportion of publications in a particular field than the average for all countries; it therefore expresses the internal balance between the fields in any given country, but says nothing about production in absolute terms. This kind of result is commonly referred to as the specialisation index. Second, it is possible to calculate the relative frequency of citations in different fields (a field-specific citation index). A country's publication performance within a particular field can then be compared with others, to see if it is cited more or less often than the global average for the field. If we look at the results of such indicators, it is clear that Norway's activity profile differs considerably from the average.¹¹ In general, Norwegian research involves a relatively strong focus on biology, earth sciences and social sciences. Conversely, there is relatively low activity in areas such as physics, chemistry and technology. This specialisation pattern has its roots in the country's history. Norway's tradi-

tional focus on marine and coastal industries and fishing, support specialisations linked to biology. This may also account for Norway's relatively high activity in ecology, environmental science and zoology. With the exception of botany and microbiology, Norwegian biological research is more cited than the international average.

Norway also shows a strong specialisation in earth science, but only received an average level of citations in this field. A sharp increase in geosciences publishing marks the most significant change in the national academic profile since the early 1970s, directly related to Norway's emergence as an oil nation.

1.5.3 Patents

Intellectual Property Rights, or IPR, have long been used as a measure of the results of research and innovation activities. This applies primarily to patents. Aggregate patent data systematise information about various aspects of knowledge, including what is being invented, by whom, when and where. Such analyses of patents can be compared with other indicators, such as

¹¹ Based on NIFU's analysis of data from the National Science Indicators/Thomson Reuters/NIFU.

trade statistics, to raise awareness about where this activity comes from and, importantly, where it is applied.¹²

This section is based on the Norwegian patent applications sought via the Norwegian Industrial Property Office¹³ and/or pending through Europe at the European Patent Office (EPO).¹⁴ Norwegian actors can use the EPO as a home office, on an equal footing with European countries, after Norway became a full member of the European Patent Convention (EPC) in 2008. This represents a step to a stronger international orientation of the patent system, and this is expected to affect patenting patterns of Norwegian players going forward. This section provides a brief status report on Norwegian patenting in Europe and in Norway during this transition, where particular efforts are made to distinguish between different types of applicants.

An overview of Norwegian patenting via the EPO, in the years prior to Norway's EPC membership, gives a sense of Norwegian patenting in an international context. Norway's European patent activity for the period 2000–2008 was modest compared to other OECD countries. Figure 1.10 presents EPO patents from a number of OECD countries for the nine-year period. It shows that 64 per cent came from just three

countries: the USA, Germany and Japan. The figure shows Norway's European patents compared with other countries in the period.

Norwegian actors accounted for 3 750, or 0.4 per cent of all European applications originating from OECD countries. The corresponding figures for Danish actors was 8 410. The number of Norwegian applications is lower than in the other Nordic countries, which in turn are overshadowed by the larger countries. OECD countries increased patenting activity in Europe by 14 per cent from the first three years of the period (1999–2001) to the last (2005–2007). The corresponding increase for Norwegian companies was 10 per cent, and this was also the period before the Norwegian membership in the EPC came into force.

In general, patent protection is mainly sought in the domestic market, e.g. mostly just in Norway for most Norwegian actors. This pattern in activity persisted during the first year of Norwegian membership of the EPC (2008) when Norwegian companies did not increase their demand for patent protection in Europe (in nominal terms) from the previous year. Norwegian EP applications were flat in 2008, at 460 applications (the same as the previous year), while the number declined for most OECD countries.

¹² See the OECD's Patent Manual (2009) for an up-to-date presentation of patents as indicators.

¹³ Extracted from the patent database at the Norwegian Industrial Property Office, February 2011.

¹⁴ Based on raw OECD data: http://stats.OECD.org/wbos/Index.aspx?DatasetCode=PATS_IPC.