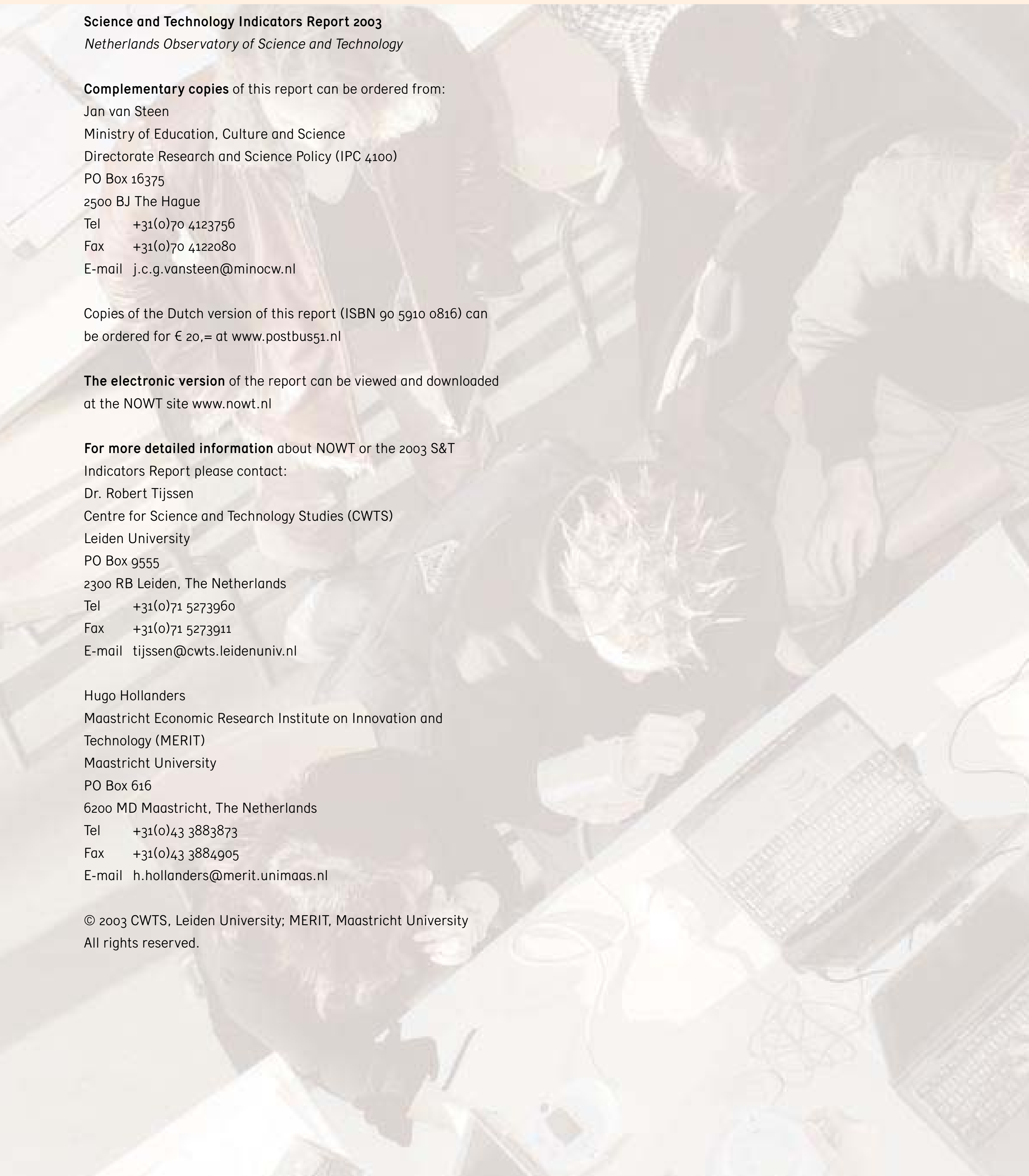
Science and Technology Indicators 2003
Summary

Netherlands Observatory of Science and Technology



Science and Technology Indicators Report 2003
Netherlands Observatory of Science and Technology

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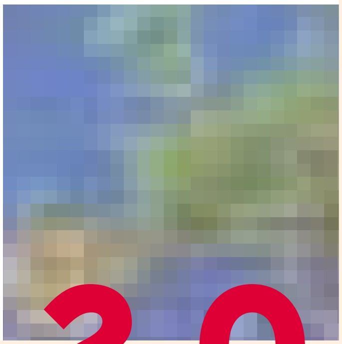

Science and Technology Indicators Summary

2003

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Foreword: the rela science policy

This indicator report is a special one: the fifth report by the Netherlands Observatory of Science and Technology (NOWT) containing quantitative information on developments in science and technology. Over the years, these reports have gained the status of a document of record on how the research and science system is performing. The full Dutch version of this report was published around the same time as the 2004 Science Budget, which makes it the definitive source on the state of affairs in the science and research system.

I will deal with the current and future role of the report in spreading information on science and innovation.

Function of the NOWT report

The NOWT report presents an overview of the Dutch knowledge infrastructure: its national and international status, its products, its impact and productivity, the cooperation it entails, and the use and usability of its knowledge. The report selects and analyses information on science and technology from various sources. And it is very selective. In this respect, it is complemented by the “Knowledge and economy” (“Kennis en economie” in Dutch) report, published by Statistics Netherlands. While the NOWT report focuses primarily on the science and research system, Statistics Netherlands focuses on innovation.

The NOWT report is intended for various audiences. It enables readers to analyse information from their own perspective. It is assisted by the NOWT website (www.nowt.nl), which provides large amounts of background information.

The strength of the NOWT report is that it sets a standard for spreading information about science and technology. What it lacks is depth. In its current form, the report presents an overview of the science and technology system, explains trends, and describes the management – the input and output – of scientific organisations. It gives an overall picture of performance in the Netherlands, but not enough information on the work of individual organisations. In 2002 and 2003, therefore, the government agreed indicator protocols with the large Dutch scientific organisations – the NWO, KNAW, and TNO – to describe in more detail their contribution to the system. The first results of the protocols

tionship with government

will be available soon, bringing the state of affairs of these organisations and their performance out into the open.

To make decisions on science and research policy, whether in government or in scientific organisations, we need information that is qualitative as well as quantitative. Information, for instance, on the state of affairs in individual scientific disciplines and trends expected in them; or information about the potential of science to deal with particular problems. Foresight studies, conducted by many organisations, provide this kind of information. But what they lack is an authoritative overview, a systematic evaluation, a plan to improve the methods used, and a programme for improving the collection of data. In the 2004 Science Budget, therefore, I announced that the Rathenau Institute[1] will be charged with the broader task of science system assessment. The link to future NOWT reports will of course feature in the forthcoming discussions with the Rathenau Institute.

Science policy

The recently[2] published 2004 Science Budget contains links to various points in the NOWT report:

- *Output and quality:* although the quality of Dutch research is high, we cannot rest on our laurels. So in the Science Budget, I have announced measures for focusing on excellence with further support for the highest achieving researchers.
- *Investments in R&D:* the Netherlands is far from reaching the EU goal of investing 3% of GDP on R&D. The government therefore intends to stimulate public-sector research with financial incentives: the €800 million BSIK incentive, grants for structural improvements to R&D worth €100 million from 2007 onwards, investments in the scientific information infrastructure, grants for individual researchers, and €100 million extra for the fiscal incentive already in place.
- *Focus and concentration:* the NOWT report shows that the Netherlands has a strong base on which to continue pursuing our three national priorities: ICT, genomics, and nanotechnology. Generally speaking, the Science Budget encourages focus and concentration, as exemplified by the matching of structural expansion with money from the universities' regular funds.
- *Public-private interaction:* The Netherlands is performing well in various aspects of public-private interaction. In the Science Budget, I have announced steps for intensifying cooperation between universities and the private sector and, generally, for adding economic value to university research.
- *Knowledge workers:* although people play a crucial role in the knowledge economy and knowledge society, the Netherlands has a barely sufficient pool of knowledge workers, especially in the pure siences and technology. The government has therefore recently published a white paper on knowledge workers, focusing specifically on the pure sciences and technology. The government has reserved extra funds of up to €60 million per year from 2007 onwards for various measures aimed at ensuring a supply of knowledge workers. They include steps to make it easier for foreign knowledge workers to immigrate to the Netherlands and steps to encourage more women and members of ethnic minorities to become knowledge workers.

To conclude

The knowledge economy and knowledge society are already with us. And the Netherlands has a burning ambition to secure a leading place for itself in them. In the Innovation Platform, chaired by the Prime Minister, the government provides a significant incentive for developing the knowledge society. The government sets great store by strengthening knowledge society, and I trust that future NOWT reports will reflect real progress made in this regard.

Maria J.A. van der Hoeven
Minister of Education, Culture and Science

[1] The Rathenau Institute performs technology assessments.
[2] The 2004 Science Budget was published in November 2003.

1 Introduction

Although just a tiny spot on the globe, the Netherlands has a population of over 16 million, which makes it one of the most densely populated countries in the world with around 475 people per km^2. Small as it is (approx. 34,000 km^2), the Netherlands is one of the OECD's top countries in terms of Gross Domestic Product (GDP). Achieving sustainable welfare, competitiveness and economic growth is a major issue in the Netherlands. One of the most important contributing factors to the Dutch economy is its knowledge intensity: in people, in organizations, in production processes, and within innovative products and services. The Netherlands is a hive of creativity and R&D activity. The Netherlands is the home base of several of the world's largest companies (e.g. Philips, Shell and Unilever)[3] and has numerous internationally recognized universities, as well as a wide variety of research institutes.

Science and technology are generally recognized as important strategic factors that will shape and drive the socio-economic future of highly developed nations. The profound influence of scientific knowledge and technological development can be found across the entire societal spectrum, ranging from industry, transportation and logistics, health care, educational services, sports and entertainment, to the arts. New technologies and (science-based) technical innovations are now considered one of the major driving forces in modern market-oriented industrialized societies. Within the increasingly knowledge-oriented Dutch economy, society is faced with many challenges of making efficient and responsible use of limited space, human and natural resources and the environment. As a consequence, the effective use of science, technology and innovation to help achieve these goals has become one of the top policy priorities in recent years.

The growing economic and societal importance of science and technology has spurred the need for more and better information on inputs, processes, outputs and impacts related to research and development (R&D) activities. For purposes of public accountability, policy design and assessment, governments need to monitor, as accurately as possible, structural shifts and recent trends pertaining to R&D-investments and scientific and technological

[3] *Shell and Unilever are Anglo-Dutch companies.*

performance - not only in their own country but also in comparison to other nations. Obtaining reliable facts and figures on science and technology requires a systemic view based on reliable information and series of interrelated indicators to provide a composite picture.

Science and technology policy-making by the Dutch government has a long tradition of using quantitative data and statistics to assess and compare the state of the S&T system in the Netherlands. The *Netherlands Observatory of Science and Technology* (denoted by its Dutch acronym *NOWT*) is one of the main government sources of factual information.[4] In this fifth report in NOWT's series of *Science and Technology Indicators* reports[5] we pay special attention to the "knowledge system", covering not only the R&D-specific parts of this system, but also the human resources (students in the higher education system, research staff in the public sector and business sector) as well as the economic and societal impact of science. In accordance with quantitative analyses of R&D systems we use the internationally prevailing statistics and information sources on R&D expenditure and human resources. The main sources are: the Organisation for Economic Co-operation and Development (OECD), EUROSTAT, the European Commission (EC), and Statistics Netherlands (CBS). The output performance metrics are based on counts of research articles in international journals, indexed by *Thomson-ISI*, that constitute verifiable and quantifiable data on outputs and impacts of scientific and engineering research. The patent data, relating to the European Patent Office (EPO) and the US Patent and Trademark Office (USPTO), were used to analyse trends in technological performance. Patent citations to the research literature, are analysed to disclose science-technology linkages. The international benchmarking comparison focuses on a small set of countries that resemble the Netherlands in terms of size, economic development, and the level of advancement of their S&T systems. These eight benchmark or 'focus' countries are: Belgium, Sweden, Finland, Switzerland, United Kingdom, Germany, Australia and Canada.

Because of the intangible nature of knowledge, and its time-delayed effects and benefits, many R&D-related activities are difficult to identify and measure. Given the complexity and dynamics of science and technology systems one can only partly describe their performance in terms of these selected characteristics. As a consequence, the data and statistical material described in this report are at best partial indicators of R&D inputs, capacity and outcomes. Given these inevitable limitations, the tables, graphical representations and indicators in this report are primarily designed to provide a general overview of a number of important quantifiable aspects of that system within an internationally comparative framework. The findings and associated conclusions drawn on the basis of this material concerning the comparative strengths and weaknesses of the Dutch R&D system should therefore be viewed in this context.

4 *NOWT is a cooperation comprising of researchers based at two Dutch universities: the Centre for Science and Technology Studies (CWTS), at the Leiden University, and the Maastricht Economic Research Institute on Innovation and Technology (MERIT) of Maastricht University. NOWT was founded in 1992 and is funded by the Ministry of Education, Culture and Science (OCW). The Observatory's main objective is to provide a bi-annual report containing an overall assessment of the performance of the Dutch S&T system based on statistics, empirical data and quantitative analyses, within an international comparative framework. NOWT publishes an electronic newsletter, NOWT Update, with background information and news about the Dutch S&T system and R&D-indicators. This newsletter is posted on NOWT's website www.nowt.nl.*

5 *Both this English language summary report and the full Dutch version of the report are electronically available on www.nowt.nl.*

2 Performance on

2.1 Introducing the Scoreboard

The scoreboard presented in **Figure 1** introduces a set of key indicators by which the S&T performance of the Netherlands is compared to the average scores of the eight selected benchmark countries. The performance profile consists of four categories: (1) R&D investments and expenditure, (2) human resources, (3) interaction and cooperation, and (4) outputs and outcomes. The scores on each indicator refer to the current situation (2nd column) and trends in the preceding 5 years (3rd column). The traffic light colours (red/orange/green) indicate the relative position of the Netherlands compared to the average performance level of the benchmark countries, the figures within the cells indicate the score for the Netherlands.

key indicators

Figure 1. Science and Technology Performance Scoreboard 2003

The performance of the Netherlands compared to the average score of Belgium, Sweden, Finland, Switzerland, United Kingdom, Germany, Australia and Canada

	Current level *	Trends **
R&D investments and expenditure		
R&D intensity business sector (spending as % GDP)	1.08	↓↓
R&D intensity government sector (spending as % GDP)	0.26	↓↓
R&D intensity higher education sector (spending as % GDP)	0.53	↓↓
Human resources		
Age group 25-64 with tertiary education (% total population 25-64 years)	24.9	=
Knowledge workers (% work force)	15.9	↓↓
Researchers (‰ work force)	5.2	=
Interaction and cooperation		
Funding of (semi-) public R&D (% expenditure financed by business sector)	11.0	↑↑
Public-private joint publications (% total domestic publication output)	2.9	↑↑
Domestic joint publications (% total domestic publication output)	27.8	↑
International joint publications (% total domestic publication output)	43.5	↑
Outputs and outcomes		
Average number of publications per researcher in the public sector	0.47	↑
Citation-impact of publications (worldwide average=1.00)	1.24	=
Publications cited by industry (% total domestic publication output)	4.0	n.a.
EPO patent applications per researcher in the private sector	0.40	=
USPTO patents granted per researcher in the private sector	0.16	=

* Situation in 2002 or most recent preceding year. The score of the Netherlands compared to the unweighted mean of the scores of all eight benchmark countries (or the largest possible subset of those countries).

- >20% above average of the benchmark countries
- 5-20% above average
- Around average
- 5-20% below average
- >20% below average

** The scores of the Netherlands across the 5 years preceding the most current year of measurement relative to the unweighted mean of the scores of all eight benchmark countries (difference in relative performance in %)

↑↑ >20% increase/improvement; ↑ 5-20% increase/improvement; = around average;
↓ 5-20% decrease/deterioration; ↓↓ >20% decrease/deterioration; n.a. – not available/unknown.

The next sections of this chapter provide a brief discussion of the scoreboard results. Chapters 3 to 6 offer a more detailed account of the relative performance of the Netherlands in science and technology.

2.2 R&D investments and expenditure

As for the spending on research and development in the Netherlands, the R&D intensity (defined as a country's R&D expenditure relative to its GDP) is at an international comparative level. However, the growth of the expenditure in real terms is lagging behind the average of the benchmark countries. Broken down by institutional sectors in the Netherlands, we observe a relatively low R&D intensity in the business sector (1.08% of GDP) and a lagging growth of R&D spending. The composition of the business sector is characterised by a relatively small manufacturing industry, of which a relatively small number of firms are active in the R&D intensive high-tech and medium high-tech industrial sectors. The services sector in the Netherlands is relatively large compared to the other countries, but again is marked by a relatively low level of R&D intensity.

R&D expenditure by the public sector is comparatively high, especially within the government sector (0.26% of GDP) comprising of a wide spectrum of research institutes. The lead of the Netherlands in public R&D spending has diminished quite significantly in the recent past.

2.3 Human resources

Almost 1.3 million inhabitants of the Netherlands in 2001 can be classified as 'knowledge workers with a tertiary level education degree'. This figure corresponds with a 15.9% share of the work force, which ranks the Netherlands behind Finland, Sweden and Belgium. The share of people with a tertiary degree is slightly less than the average of the benchmark countries. The same applies to the share of R&D personnel in the total work force of the Netherlands.

The business sector accounts for an increasing fraction of the R&D personnel at the detriment of the share of the higher education sector. As for the 'leading-edge' core of the knowledge workers – the researchers, the Netherlands is significantly behind the other selected countries: a mere 5.2‰ of the work force is classified as researcher. The good news is that the number of researchers is increasing, especially within the business sector - in fact, in terms of growth rates the Netherlands is amongst the leading countries within Europe, surpassed only by Finland. Both the manufacturing and the services sector within the Netherlands contribute to this growth.

With regard to developments in the public sector, we observe a slight increase of research staff since 1997, which is predominantly driven by the significant growth of research staff funded by the Netherlands Organisation for Scientific Research (NWO). Despite this influx, the Dutch universities show one of the lowest growth rates within the group of benchmark countries. The number of first-year (bachelor) students enrolled in the Dutch universities has increased after several years of decline. The largest increases occur in the social and behavioural sciences, economics, and medicine. Even though the share of females in the university research staff has grown in recent years, the fraction still remains small compared to the benchmark countries.

2.4 Interaction and cooperation

Befitting a small and densely populated country, the Netherlands can boost on a tightly knit network of cooperative R&D programmes – both formal and informal - in which the public sector and business sector participate. The major formal cooperative arrangements and public-private partnerships are the Leading Technological Institutes (Technologische Top Instituten – TTIs), the innovation-driven research programme (IOPs), the joint R&D programmes and research networks funded by the government's recently launched "Knowledge and Research Capacity" programme (BSIK), as well as the large numbers of applied research projects funded by the Technology Foundation (STW). The four Leading Technology Institutes in the Netherlands were evaluated in a recent OECD report and promoted as an organizational model for other countries.[6]

The business sector in the Netherlands spends an 11% share of its R&D expenditure in the public sector, a relatively large fraction compared to the benchmark nations. Not only is the share higher, the growth of this funding source for the public sector R&D in the Netherlands also exceeds the increases of business funding of public sector R&D in those other countries.

Given this positive development, one would expect a certain degree of 'customer satisfaction' – that is, a fairly large share of companies that perceive the public R&D sector as an important source of input for business R&D. The results

[6] *OECD, Public-private partnerships for Research and Innovation: An evaluation of the Dutch experience, Paris: Organisation for Economic Cooperation and Development, 2003.*

of the Community Innovation Survey (CIS) indicate that some 22% of the "innovating companies"[7] in the Netherlands – a subset of all Dutch companies – use the services of universities as a source of R&D-related information.[8] About a third of those innovating companies (8% of all innovating companies) consider universities to be a 'very important' source. As for the non-university public research institutes, here we find a 30% share of innovating companies that declare to have used input from those research institutes. The level of appreciation within the business community, in terms of being an 'important' or 'very important' source, is comparable to the figures for the university sector.

Another indicator of public-private interaction and linkage within the realm of R&D are the quantities of jointly authored research publications published in international scientific and technical journals. The share of these co-publications amounts to 2.9% of the total domestic publication output of the Netherlands, which places us among the leading nations within the group of benchmark countries as well as at worldwide level. This score is partially due to the presence of some R&D-intensive and science-oriented companies in the Netherlands, first and foremost Philips, but also DSM shows an increase in the number of research publications in recent years. Although the quantities of public-private research publications are in decline in the Netherlands, the same applies even more for the benchmark countries, hence we observe a relative trend for the Netherlands in upward direction.

Nowadays, scientific research in general is characterised more and more by cooperation – both within and between institutions, as well as across national borders. Almost 28% of the research publications are extra-mural domestic co-publications, they list authors based in the Netherlands originating from two or more different organisations within the Netherlands. On top of which we find that almost half of the Dutch research papers are internationally co-authored publications - no less than 43% of the Dutch research publications, listing an author based in another country. Such a high share is not uncommon for a relatively small country like the Netherlands that can boast on an accessible ('open') and high-quality domestic research system. We observe a steadily growing focus on partnering with other European countries, which is no doubt partly a result of the cooperation-promoting Framework Programmes of the European Commission. Germany is the most prominent research partner of the Netherlands, accounting for the second largest share of the international co-publication (following the US). The international co-publications are better cited in the global research literature compared to domestic co-publications or those originating from a single institute in the Netherlands.

2.5 Outputs, outcomes and benefits

The Netherlands is amongst the leading countries in terms of its focus on "basic" longer-term research. This applies to the public sector R&D efforts as well as the R&D activities within the business sector. The excellent research performance is also manifest in the relatively high level of "research productivity"; the average number of research publications in international journals produced by public sector researchers compares favourably to the benchmark countries. Moreover, Dutch productivity has increased in recent years. Given the international orientation, and the high performance level, of the science base, it does not come as a surprise that our country is also amongst the very best in terms of the international visibility and relevance of Dutch science as measured by the citation impact of "Dutch" research papers (of which almost half are actually international collaborative papers). Dutch papers as a whole are cited 24% above worldwide average, ranking the Netherlands in third position (following the US and Switzerland). The scientific excellence is spread widely throughout the Dutch science system: the highly cited papers are not only being produced by our universities, but also by government research institutes, hospitals, as well as companies. It goes without saying that the impact of Dutch research capacity and scientific performance extends beyond its influence within international scientific communities: research activities also have a direct "societal" impact in terms of the research staff involved in teaching and training transferring part of their knowledge and skills to their students, thus educating them with high-quality and up-to-date information in order to extend their knowledge base and develop their analytical powers.

Owing to the presence of the research laboratories of the "Big 7" R&D intensive companies located within the Netherlands (Philips, Unilever, DSM, Akzo Nobel, Shell, ASML and Océ), and the above-mentioned focus on basic research activities, our country is amongst the leading nations in terms of research publications produced by industrial researchers. The share of industry within Dutch publication output amounts to 4.2%, a third of which are

7 Companies that declared to have performed innovation-related activities.

8 Note that this outcome relates to universities in general, i.e. in the Netherlands and abroad.

100% private sector produced solely by industrial researchers. The prominent place of industrial research within the Dutch science base is likely to have noticeable local effects within the public research sector. More specifically, in both the influence of private sector R&D on public-private cooperation (mentioned above), but also the magnitude and scientific quality of research activities in industrial-relevant fields, the Netherlands is one of the leading countries. One revealing sign of these close connections is the fact that publications produced by the public research sector are cited relatively often by industrial research publications (either from Dutch companies, or foreign companies): the Netherlands accounts for 2.6% of the publications cited by worldwide industry, which is slightly above the share of the Netherlands in the worldwide research literature. The interest from industry for Dutch research output spans a wide range of fields with a focus on agricultural and food science, and the biomedical sciences. Not surprisingly, we find both the general ('comprehensive') universities as well as our four specialized universities (three technical universities and the agricultural university) well presented within the publications cited by industry. The prominence of the Netherlands in these life-sciences fields is also manifest in Dutch research publications cited by patents, where the bulk of the citations come from patents produced by biotechnology companies and the pharmaceutical industry. The suppliers of Dutch scientific knowledge relevant for patented inventions and technologies are not only found within the university sector (and its academic hospitals), but also within the general hospitals, and amongst the institutes focusing on strategic research and applied research – especially TNO (Netherlands Organization for Applied Scientific Research), which is by far the largest research institute in the Netherlands.

On the subject of patents, the Netherlands tops all benchmark countries in terms of patent productivity, that is the average number of patents produced per private sector researcher. This applies to patent applications at the EPO as well as issued patents at the USPTO. Calculations of productivity according to total population, rather than researchers, also indicate a strong position of the Netherlands within the EU-15, especially with regard to growth rates in productivity. These excellent performances can be attributed in large part to the patent output of Philips, the large electronics company with a business policy and IPR strategy that hinges on developing and maintaining extensive patent portfolios. The situation is less bright with respect to patenting in the 'high tech' areas: although the Netherlands is still among the best at EPO, we are lagging behind in terms of growth of high tech patents at USPTO.

Dutch universities and public sector research institutions are gradually embracing patents as a means to protect their discoveries and inventions, and exploit their IPR for commercialisation. The numbers of academic patents has increased steadily during the past decade, both for domestic patents as well as patents at EPO and USPTO. The commercial value of the university-owned patents has been limited so far. The Netherlands performs at an average level within Europe in terms of external commercialisation by means of launching R&D-based start-up companies.

According to European surveys Dutch people show an above-average interest in scientific and technological developments, especially by television broadcasts, but also on the Internet and other (printed) communication modes. Relatively few Dutch scholars and researchers communicate their findings, or disseminate their views and opinions, to the general public in the Netherlands. Science centres offer a vehicle to reach out to the population. Although the Netherlands can boast on several famous museums and excellent science centres, in terms of relative numbers of museums and centres the Netherlands are within the middelslice of the European countries. Although the Dutch men show a keener interest in science and technology in general, women are particularly interested in news items related to health and environment. These gender-based differences also affect preferences in educational programmes at universities: females are more likely to opt for degrees in the social and behavioural studies or medicine, rather than degrees in the natural sciences or engineering sciences.

3 R&D infrastructur

3.1 An international benchmark

R&D intensities, defined as the percentage of R&D expenditure of GDP, are of one the most common indicators to benchmark the R&D performance of countries. **Figure 3.1** shows the overall R&D intensity on the vertical axis for a selection of OECD countries. The R&D intensity of the Netherlands is just above the average of the EU-15, but it is outperformed by most of the richer OECD countries. Of the focus countries, only Australia, the UK and Canada score below the Dutch R&D intensity. Most EU-15 countries lag behind Japan and the US. Only Sweden and Finland outperform Europe's two main competitors.

However, countries should not only be benchmarked using current performance, as this could hide possible changes in performance over time. The horizontal axis in Figure 3.1 shows the average yearly growth of *real* R&D expenditure over the previous five years. Countries with low R&D intensities are among the strongest growing countries: Portugal, Greece, Ireland and Spain. It thus seems easier to grow strongly from a backward position then from a leading position. But Finland demonstrates that also a leading country can show a strong growth performance. The strong growth in Finnish R&D expenditure is a direct result of their deliberate efforts over the past years to increase their R&D efforts. The Netherlands is not doing that well. Real growth of Dutch R&D expenditure is smaller than that in most countries and is below the EU-15 mean. The relative poor EU-15 growth performance seems a direct result of the disappointing growth performance of three of its larger countries - France, the UK and Italy.

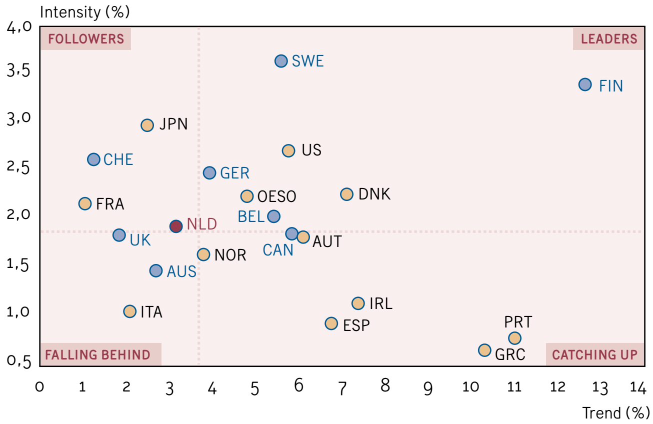
Based on their respective relative performance in both current R&D intensity and growth of real R&D expenditure, countries can be classified into four groups:

- *Leaders* or countries with an above average R&D intensity and growth;
- *Followers* or countries with an above average R&D intensity but a below average growth;
- *Catching up* countries, i.e. countries having an above average growth but a below average R&D intensity;
- *Falling behind* countries, i.e. countries with both a below average R&D intensity and growth.

e and expenditure

Figure 3.1 The Netherlands is almost falling behind in R&D performance

R&D expenditure (GERD): intensity (% of GDP) and trend

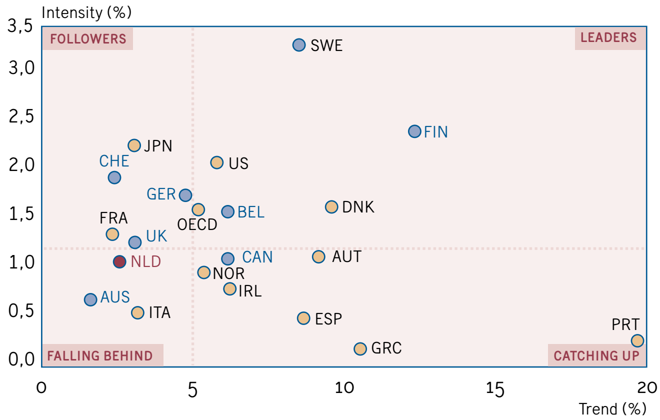


R&D intensities for 2000 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditure over a 5 year period. The dotted lines give the EU-15 means, focus countries are in blue and the Netherlands in red.

Source: OECD, EUROSTAT, Statistics Netherlands. Data treatments: MERIT.

Figure 3.2 The Netherlands is falling behind in business R&D performance

Business R&D expenditure (BERD): intensity (% of GDP) and trend



R&D intensities for 2001 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditure over a 5 year period. The dotted lines give the EU-15 means, focus countries are in blue and the Netherlands in red.

Source: OECD, EUROSTAT. Data treatments: MERIT.

Sweden, Finland, the US and Denmark clearly belong to the group of leaders. Japan. Switzerland and France are the followers. Ireland, Spain, Portugal and Greece show strong signs of catching up. Italy and Australia are falling behind. For the UK, the Netherlands[9], Norway, Belgium, Canada, Austria and Germany either their current or their trend performance is too close to the EU-15 mean to clearly classify them in one of these groups.

For the EU-15 the lagging growth performance of its largest countries is clearly holding back its average growth performance. Even the strong growth performance of some of its smaller countries cannot compensate for this. The gap between the EU-15 and the US has thus not only increased over the last 5 years but is expected to increase even further in the next 5 years.

9 More recent data even suggest that the Netherlands is falling behind in 2001 as its R&D intensity has fallen to 1.89 and that of the EU-15 has increased to 1.93.

Business R&D performance

In most countries, between 50% and 75% of total R&D expenditure is spent by the business enterprise sector. Countries with a high share of business R&D expenditures are also those with high overall R&D intensities. **Figure 3.2** depicts current and trend performance for R&D for the business enterprise sector. Sweden has by far the highest R&D intensity, followed by Finland, Japan, the US and Switzerland. The Netherlands is performing below the EU-15 mean, and is outperformed by most countries. Only Australia, Ireland, Norway and the Southern European countries show an intensity rate below the Dutch one. Portugal, Finland and Greece show the strongest growth in real business R&D expenditure over the past 5 years. Also here the Netherlands is lagging behind the EU-15 mean. The Netherlands, Australia and Italy are clearly falling behind.

The weak performance of the Dutch business enterprise sector explains why the Netherlands is in danger of falling behind in its overall performance (as shown in Figure 3.1).

There are three explanations why the Dutch business enterprise sector is performing below average:

- The relatively small size of the manufacturing sector within total industry;
- The relatively small size of high-tech and medium-high-tech manufacturing sectors within total manufacturing;
- The relatively small R&D intensity in the services sector.

Within industry, manufacturing has the highest R&D intensity compared with services and other industry. Countries with a large manufacturing sector are thus expected to have a higher R&D intensity in their enterprise sector. The 22% share of the Dutch manufacturing sector within industry is far below that of the average 27% share for the focus countries.

Manufacturing sectors can be classified according to their average R&D intensity in high-tech sectors, medium-high-tech sectors, medium-low-tech sectors and low-tech sectors. The sectoral distribution in the Netherlands is skewed towards medium-low and low-tech sectors, those sectors with, on average, low R&D intensities. Whereas medium-high and high-tech sectors make up more than half of the manufacturing sector in the US and Germany, its relative size is only about one-third in the Netherlands.

The share of services within industry in the Netherlands is only just above the average share for the focus countries. But the R&D intensity of 0.40 for Dutch services is almost 25% smaller than the average R&D intensity of services in the focus countries.

Two effects can thus explain the gap between the R&D intensities in the Netherlands and the focus countries:

- A *structural effect*, measuring the impact of a sectoral distribution which is skewed towards sectors with low R&D intensities;
- An *intensity effect*, measuring the impact of simply having lower R&D intensities within individual sectors.

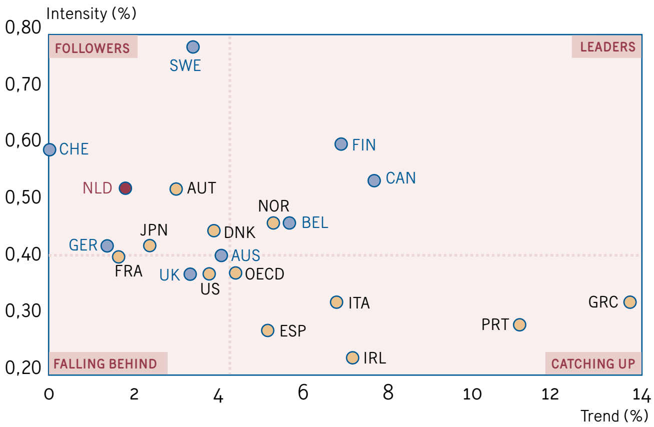
The structural and intensity effect both explain about half of the gap between the industrial R&D intensity in the Netherlands and the focus countries. Two-thirds of the gap in the R&D intensity for manufacturing is explained by the structural effect, one-third by the intensity effect.

Higher education sector

Dutch universities spend about 2.1 billion euro on R&D in 2000. The Netherlands is among the countries with high R&D intensities in the higher education sector (**Figure 3.3**). Only

Figure 3.3 R&D spending in Dutch universities above average but lagging growth

R&D expenditure in the higher education sector (HERD): intensity (% of GDP) and trend

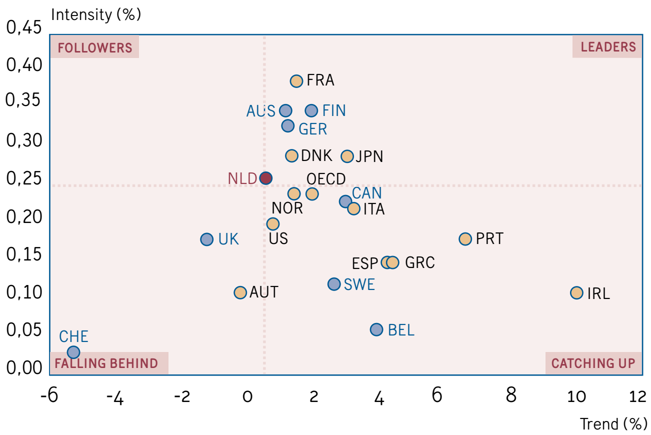


R&D intensities for 2000 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditure over a 5 year period. The dotted lines give the EU-15 means, focus countries are in blue and the Netherlands in red.

Source: OECD, Statistics Netherlands. Data treatment: MERIT.

Figure 3.4 Dutch research institutes: average R&D intensity and growth performance

R&D expenditure in the higher education sector (HERD): intensity (% of GDP) and trend



R&D intensities for 2001 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditure over a 5 year period. The dotted lines give the EU-15 means, focus countries are in blue and the Netherlands in red.

Source: OECD, Statistics Netherlands. Data treatment: MERIT.

universities in Sweden, Finland, Switzerland and Canada spend relatively more on R&D. Dutch growth performance is not only below the EU-15 average, but also below that of most countries. The high ranking of the Netherlands is thus endangered. As Belgium in 1999 and Canada in 2000, other countries might surpass the Netherlands in the near future.

Research institutes (government sector)

R&D performance by Dutch research institutes is close to both the EU-15 R&D intensity and the EU-15 average growth performance (**Figure 3.4**). This sector covering the non-business research institutes has been one of the strongest chains in the Dutch R&D system for many years. Among the larger research institutes is TNO, which spend 370 million euro on R&D in 2001, making it the third biggest R&D spender in the Netherlands (only Philips and Akzo Nobel spent more on R&D).

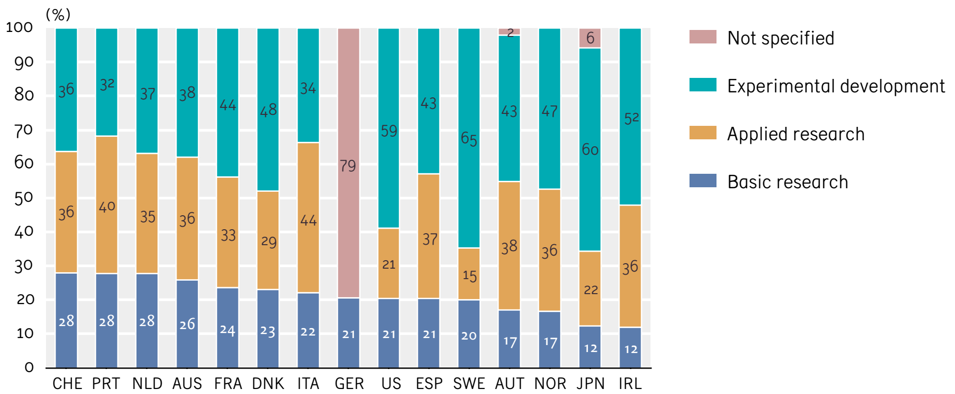
Basic research and the knowledge economy

R&D activities cover three different but related activities:

- *Basic research*, which is oriented towards increasing the public knowledge pool. Universities but also research institutes in the non-business sector are the main performers of basic research.
- *Applied research* is also oriented towards increasing knowledge, but is directed primarily towards solving a specific problem or objective. Both research institutes and business enterprises are the main performers of applied research;
- *Experimental development* uses existing knowledge to create new products or processes or to improve existing products or processes.

The development of the knowledge economy in the long run depends in particular on current expenditure for basic research. Separate data on these three R&D activities are not available for all countries or not as recent as data on total R&D expenditure. In Europe, about 20% of total R&D is spend on basic research, 30% on applied research and 50% on experimental development. The Netherlands is spending a large share of its resources on basic research (**Figure 3.5**) and as such contributes to the long run development of the Dutch knowledge economy and that of other countries. On the other hand, Dutch business enterprises are spending relatively less on experimental development, hampering the translation of existing knowledge into new or improved products and processes and thus endangering Dutch competitiveness in the near future. Also Dutch research institutes spend relatively less on experimental development than those in other countries.

Figure 3.5 The Netherlands is spending a large share of its R&D on basic research



Data are for 2000 or most recent year. Shares for the Netherlands are approximations based on 1999 data for basic research from Statistics Netherlands (share of man-years) and extrapolations of 1993 data for applied research and experimental development from the OECD (expenditure shares).

Source: OECD, Statistics Netherlands. Data treatment: MERIT.

Sources of funding: differences between countries

Figure 3.6 gives the sources of funding for both total R&D spending and R&D spending in the non-business sector, covering both research institutes and the higher education sector. In most countries the main sector of funding is the business sector. In about half of all countries the business sector finances more than half of total R&D. Between 1990-1995 and 1995-2000 the share of funding has increased in 16 countries. The share of government funding has decreased in 18 countries and in only 3 countries the government finances more than half of total R&D. The business sector finances an even larger share of about 67% of total R&D in the top-6 countries with highest R&D intensities. The business sector finances only 48% of R&D in the Netherlands. The Dutch funding structure corresponds closest to that of Denmark and Spain.

Public-private co-operation as measured by the percentage of industry-financed expenditures in the non-business sector, is particularly high in Belgium, the Netherlands, Ireland, the UK and Finland. The Dutch enterprise sector traditionally subcontracts a large share of its R&D to (semi-) public research institutes as TNO and the five Large Technological Institutes (GTIs).[10] Between 1990-1995 and 1995-2000 this share of industry-financed expenditures has also increased strongest in the Netherlands from 7% to 10%.

[10] *These are NLR (National Aerospace Laboratory), ECN (Netherlands Energy Research Foundation), WL/Delft Hydraulics, GD (GeoDelft) and MARIN (Maritime Research Institute Netherlands).*

Figure 3.6 R&D: Sources of funding

The shares of funding and intensities are calculated as average 1995-2000 shares and intensities. Non-business R&D covers spending in by research institutes (GOVERD) and higher education (HERD).

Source: OECD. Data treatment: MERIT.

3.2 The Dutch R&D infrastructure

Funding structure of Dutch R&D

In 2000, the Netherlands spent 7.7 billion euro on R&D.[11] The funding structure of Dutch R&D is shown in **Figure 3.7**. Overall we see a decreasing share of government funding since 1995. The Ministries of Education, Culture and Science (OCW), Economic Affairs (EZ), Agriculture, Nature and Food Quality (LNV) and Transport, Public Works and Water Management (V&W) are the biggest financers. Direct government funding has been steadily decreasing since 1995. Only in the business sector direct government funding has grown in importance. General university funds have been decreasing from 1995 to 1999. The increase from 1999 to 2000 is due to a change in accounting by Statistics Netherlands. As of 2000, the financial flows attributed to university researchers financed by NWO are no longer accounted for in the sector covering the research institutes but directly in the higher education sector. Without this change in accounting, the relative share of general university funds would not have changed. The growing shares of industry-financed R&D in the higher education sector and research institutes and that of government funding in the business enterprise sector are evidence of a more intense public-private co-operation in the Netherlands.

Manufacturing spends most on R&D

The business sector not only finances most of Dutch R&D, it is also the biggest R&D spender. In 2001 business enterprises spend about 58% of Dutch R&D. Within the business sector, the manufacturing accounts for more than 75% of business R&D spending (**Figure 3.8**). But the importance of manufacturing has been declining due to a relatively stronger increase in services R&D spending. Between 1995 and 2001, R&D expenditures in manufacturing have grown with 6% per year, in services they have grown with 15% per year. Large companies spend about 80% of total business R&D. Several large multinationals (Philips, Akzo Nobel, Unilever, ASML, DSM and Shell) account for almost half of total business R&D, but their importance has been declining as these have multinationals have increased their R&D spending in the Netherlands less than that in other countries.

Increased share of business financed R&D in government sector

The government sector includes a wide range of diverse research institutes, including among others TNO, the five GTIs, NWO and KNAW (Royal Netherlands Academy of Arts and Sciences), and spent about 13% of total Dutch R&D in 2000.[12] An increasing share of the R&D expenditures in this sector is financed by the private sector. For TNO, direct government funding has decreased from 40% early 1990s to 35% in 2002. Funding out of private contracts has increased from 40% early 1990s to almost 50% in 2002. Similar trends can be observed for most of the research institutes making up the GTIs.

Decreased share of direct government financed university research

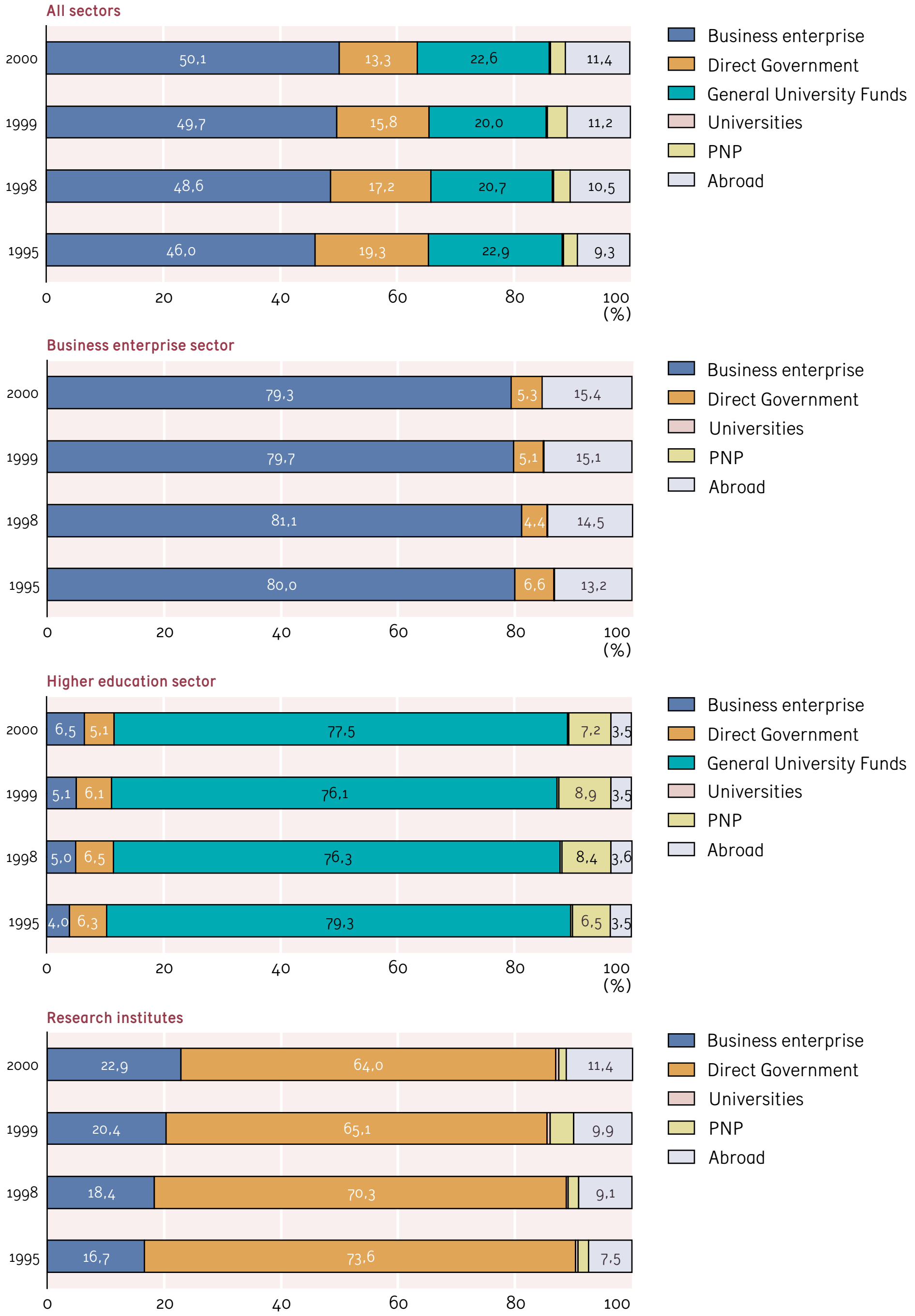
With a spending share of about 27%, the relative importance of the Dutch university sector is higher than that in most benchmark countries. Only in the Southern European countries, which have low overall R&D intensities, universities are responsible for an even larger share of total R&D spending. The 14 Dutch universities have seen a modest increase in their funds in real terms as compared to most other countries (cf. Figure 3.3). **Figure 3.9** uses data on university R&D personnel funded out of direct and indirect government funding and external funding to show the decreasing share of direct government funding. An increasing share of R&D performed by universities is funded either indirectly by NWO and KNAW or externally by commissioned work either for the Dutch government, the European Commission or the private sector. The share of funding from the private sector in total external funding has increased significantly from a 20% share in the early 1990s to 27% in 2000.

Among the fastest growing Dutch universities are Maastricht University (UM), Vrije Universiteit (VU, located in Amsterdam) and the University of Nijmegen (KUN). The University of Groningen (RUG) and Tilburg University (UvT) have shown the largest decrease in absolute size.

[11] More recent data show that in 2001 R&D spending has increased to 8.1 billion euro. The expenditure data for 2000 are different from those reported by the OECD as the 2000 data were corrected by Statistics Netherlands late 2003.

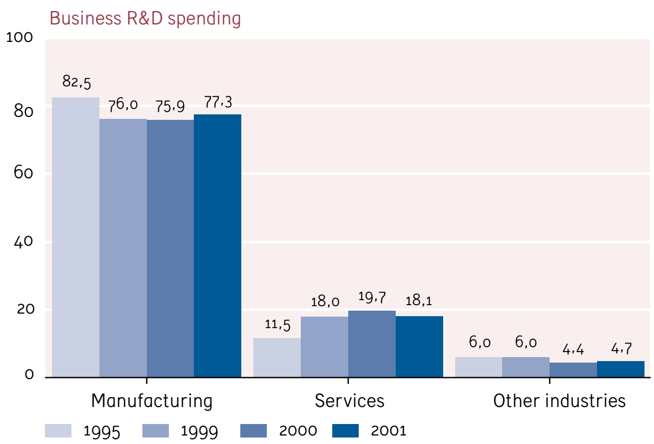
[12] NOWT 2000 reported a spending share of 18% in 1998. The sharp decline is the direct result of the fact that as of 2000, due to a change in accounting by Statistics Netherlands, the financial flows attributed to university researchers financed by NWO are no longer accounted for in the government sector but directly in the higher education sector.

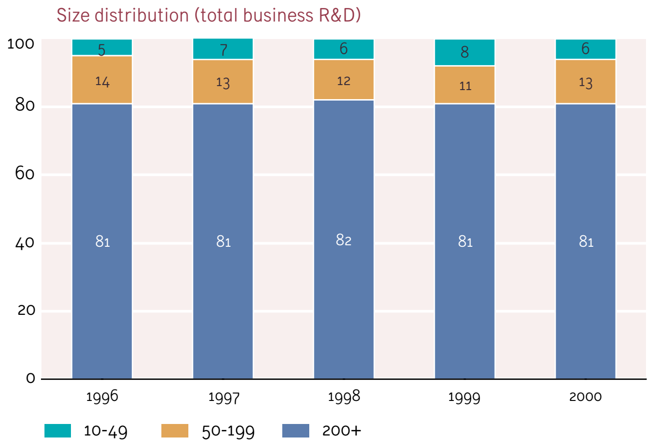
Figure 3.7 Financial flows in the Dutch R&D infrastructure



Source: OECD, Statistics Netherlands. Data treatment: MERIT.

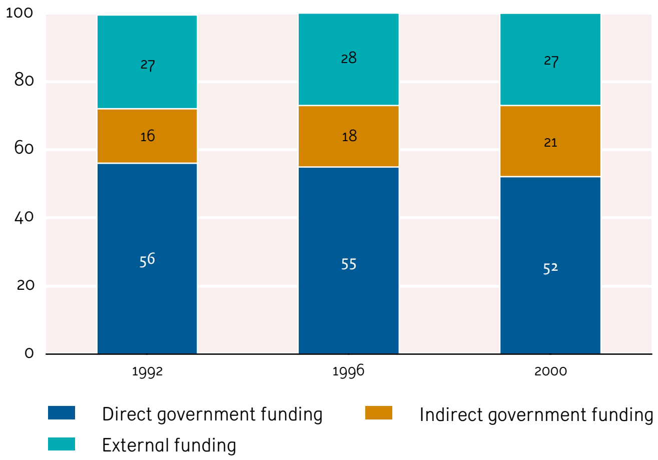
Figure 3.8 Business R&D: manufacturing and services and size classes





Source: Statistics Netherlands. Data treatment: MERIT.

Figure 3.9 R&D spending by Dutch universities: increasing importance of indirect government funding



Source: VSNU. Data treatment: MERIT.

4 Human resources

Human resources are one of the key components of a knowledge economy. An adequate supply of highly skilled knowledge workers, R&D personnel, researchers, university graduates and new students are of the utmost importance for the development and diffusion of new knowledge – developed domestically or abroad –, products and processes. The Science and Technology Performance Scoreboard 2003 shows that the Netherlands is not only performing worse than the eight benchmark countries but that the gap to these countries has been increasing over time.

4.1 From knowledge workers to researchers

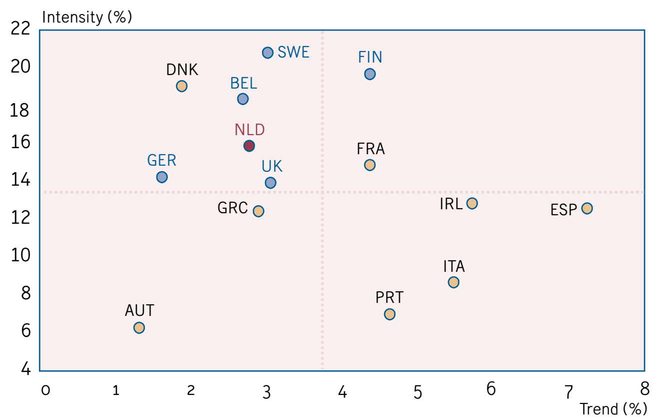
Knowledge workers are defined as all workers who both have a higher education degree and who work in a S&T-occupation. **Figure 4.1** shows that the Netherlands compares well to most of the other (benchmark) countries. Although the growth of knowledge workers is below that of the EU-15, the Netherlands has consolidated its position as one of the leading countries.

Only a small share of all knowledge workers is actually involved in R&D. The share of R&D workers (or R&D personnel) varies between 9 and 20 per mille of the labour force in the focus countries and is equal to 11 per mille in the Netherlands. R&D workers comprise both researchers and technical assistants, the latter assisting the former in doing their research. Researchers can be seen as the core of the R&D workers. **Figure 4.2** presents a benchmark of the relative size of the number of researchers and the growth in this number over the past 5 years.

The intensity of researchers in the labour force varies from 3 per mille in Italy to 13 per mille in Finland. The Dutch intensity is below that of the EU-15 and those of all focus countries. Finland also shows one of the highest growth rates, together with Greece, Spain, Ireland, Austria and Portugal. Dutch growth performance is above average EU-15 growth and is in between the growth performance of the focus countries.

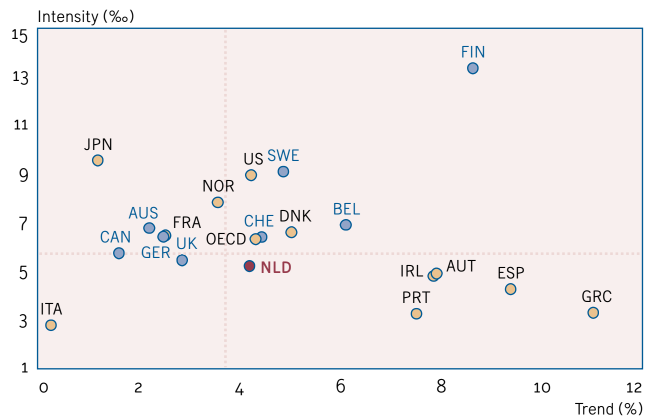
One explanation for the fact that the Dutch intensity is below that of most countries is that the Netherlands has the lowest ratio of researchers per 100 R&D workers of all countries. A similar graph as Figure 4.2 for total R&D personnel (cf.

Figure 4.1: Knowledge workers (% of labour force and trend)



Intensities for 2001 or most recent year. Trends are calculated as the average yearly growth of the number of knowledge workers over a 5 year period. The dotted lines give the EU-15 means, focus countries are in blue and the Netherlands in red.
Source: EUROSTAT. Data treatment: MERIT.

Figure 4.2: Researchers (‰ of labour force and trend)



Intensities for 2000 or most recent year. Trends are calculated as the average yearly growth of the number of researchers over a 5 year period. The dotted lines give the EU-15 means, focus countries are in blue and the Netherlands in red.
Source: OECD. Data treatment: MERIT.

Figure 3.3 in the main report) would show that the Dutch intensity of R&D workers in the labour force is just above the EU-15 mean and also above that of Canada and Australia.

In particular in the business and higher education sector the Netherlands experiences a relatively low ratio of researchers per 100 R&D workers. In the higher education sector this can partly be explained by the financing scheme in which up until 2000 university researchers who are financed by NWO or KNAW were not included in the higher education sector but in the government sector.

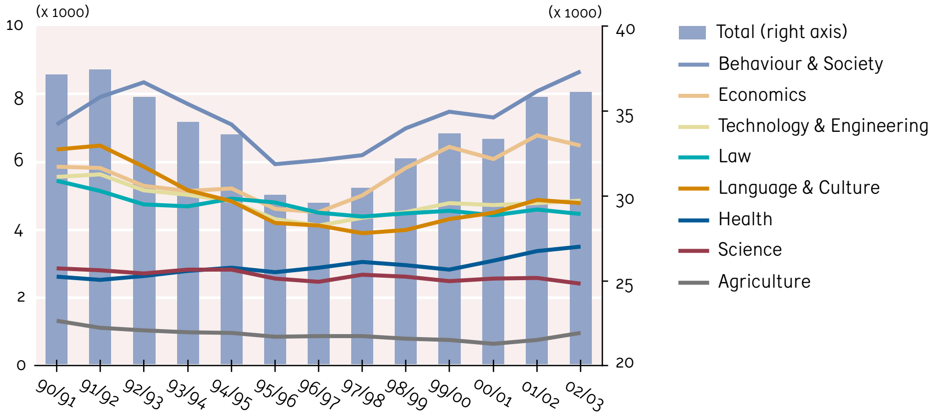
4.2 Human resources in the Netherlands

About 25% of the Dutch labour force has some form of higher education. The share and growth of the number of people with a higher education degree are well above the EU-15 mean. University graduates are not only better equipped to adopt and use new technologies, university graduates also contribute positively to the participation rate of a country's labour force. In 2002 the participation rate in the Netherlands for all workers was 66%, for workers with a university degree it was 87%. An increase in the number of university graduates is thus expected to raise the relative number of knowledge workers and to raise the number of people actually at work.

After a decrease in the number of new entrants in Dutch universities up until mid-1990s, the number of first-year students has increased by more than 20% to 36,000 in 2002/03. In particular in the sectors Behaviour & Society, Economics and Health. The number of new students has increased in Technology & Engineering but has decreased in Science. Both sectors are seen as the core of the higher education system in educating and delivering new researchers and technicians for the innovative activities of the business sector. One of the main weaknesses in Dutch innovation performance is the low rate in S&E graduates. The share of S&E graduates in the population aged 20-29 is only half of the average share in the EU-15.[13]

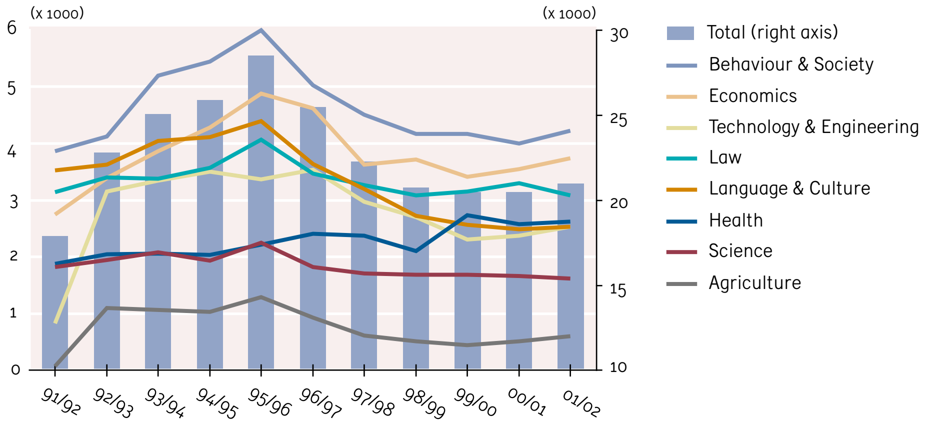
[13] *European Commission, 2003 European Innovation Scoreboard, SEC(2003) 1255, Brussels.*

Figure 4.3 Increase in number of first-year university students



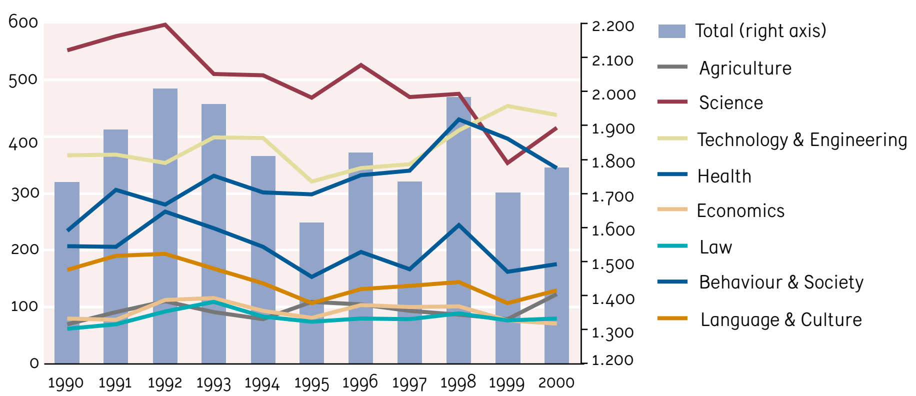
Source: CRIHO, OCW. Data treatment: MERIT.

Figure 4.4 Decrease in number of university graduates



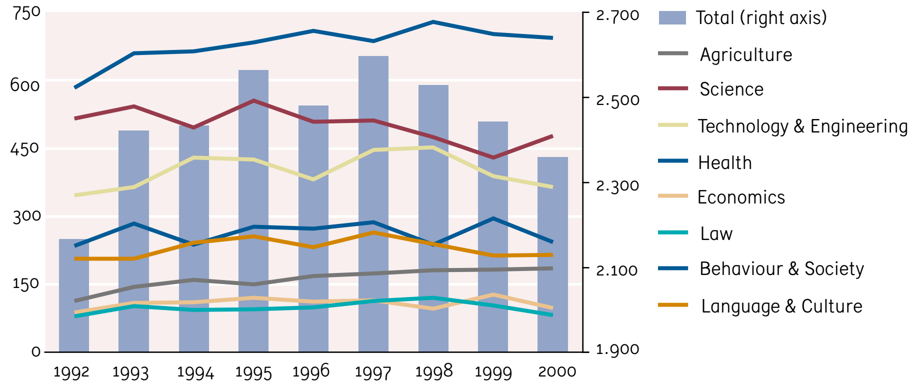
Source: CRIHO, OCW. Data treatment: MERIT.

Figure 4.5 Fluctuations in number of PhD candidates



Source: VSNU, OCW. Data treatment: MERIT.

Figure 4.6 Decrease in number of PhD's



Source: VSNU, OCW. Data treatment: MERIT.

The number of university graduates has been decreasing since mid-1990s, only for Health we see a positive trend in the second half of the 1990s. However, on average it takes about 4.4 years for a student to graduate. The uptake in the number of first-year students is thus expected to lead to an increase in the number of graduates as of 2001/02. Figure 4.4 indeed shows a modest increase in that year.

Most university graduates do not pursue an academic career but enter the labour force after their graduation. Most of those who do pursue an academic career will enter the AIO-scheme[14] to attain a PhD. The number of PhD candidates is at a lower level than early 1990s but after the sharp decline in 1995 (**Figure 4.5**), the number of PhD candidates has been increasing again, most notably in Technology & Engineering, Language & Culture and Behaviour & Society.

The sharp decline in the number of PhD candidates between 1993 and 1995 partly explains the drop in the number of PhD's since 1997 (**Figure 4.6**). Only in Agriculture the number of PhD's has increased since 1996. The sharpest declines are seen in Law, Economics and Behaviour & Society; the number of S&E PhD's has decreased by 5%.

Universities play a crucial role in the knowledge economy. But growing problems of ageing, a shortage of job opportunities for young researchers, and a declining interest of Dutch youth in a scientific career endanger an adequate supply of university researchers in the near future. For 2008 shortages are expected in all scientific disciplines, in particular for positions as lecturer and senior lecturer.[15] Shortages for positions as full professor are also expected in Science and Technology & Engineering.

One option to deal with these shortages is to increase the number of female researchers. The share of female researchers in the Netherlands is small compared to those in the benchmark countries. Most female researchers are found in Health and Behaviour & Society, whereas in Science and Technology & Engineering, the two disciplines most important for the knowledge economy, female researcher are very scarce. This is partly explained by the fact that females, on average, have a more profound interest in the softer sciences.

14 AIO is the Dutch acronym for PhD candidate or doctoral student.
15 Cf. Table 3.28 in the Dutch report.

5 Interaction and co

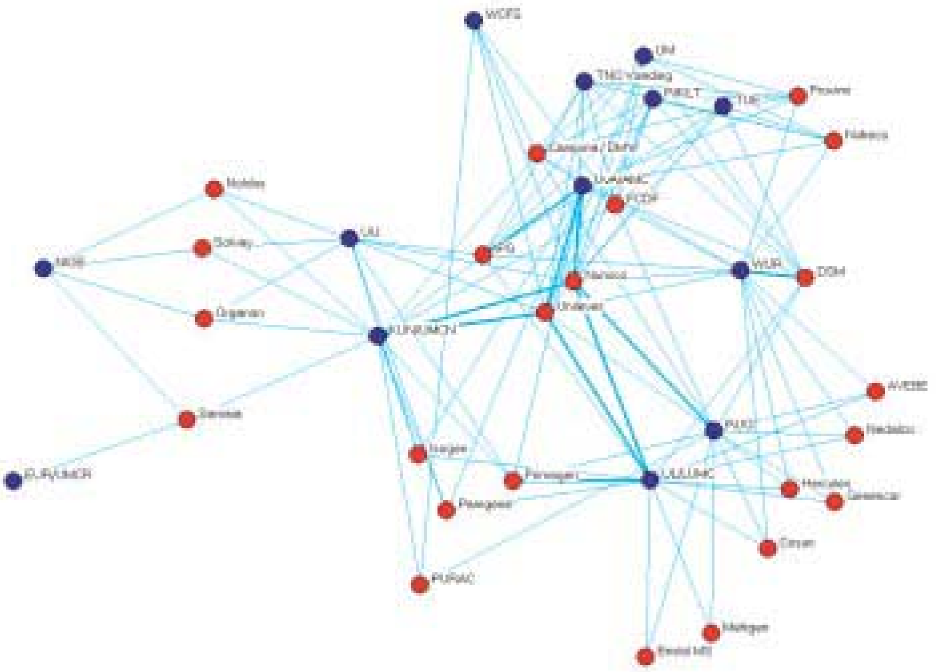
5.1 R&D networks

Dutch public and private organisations work often together in joint R&D projects, programmes and networks. In doing so universities and public research organisations contribute – albeit often indirectly – to innovation processes. The public sector supplies human resources (e.g. recently graduated engineers or PhD graduates), offers access to technical facilities, and provides knowledge and know-how though contract research or consultancy arrangements. According to the Dutch CIS presenting data for 1998-2000, one of the key results is that some 22% of the "innovating companies" in the Netherlands use the services of universities as a source of R&D-related information. About a third of those innovating companies (8% of all innovating companies) consider the universities to be a 'very important' information source, an additional 29% value their contribution as being 'important'. As for the non-university public research institutes, here we find a 30% share of innovating companies that declare to have used input from those research institutes. The level of appreciation within the business community is comparable to the figures for the university sector: 9% consider it 'very important', 33% rate it as 'important'.

Figure 5.1 provides an illustrative example of a public-private R&D programme: the innovation-driven research programme (IOPs) in the field of Genomics. The Ministry of Economic Affairs funds the IOPs. The red dots present companies based in the Netherlands, the blue dots refer to public sector institutions. The linkages between refer to the presence of company representatives in the advisory boards of research projects or research programmes of universities or other public research organisations. Overall, we observe a wide variety of public and private organisations. Many of the large R&D-based Dutch companies participate in this network (e.g. Unilever, DSM, and Numico). We also find a range of medium-sized or small biotechnology companies, such as Genencor, Pamgene and Isogen. The network contains a blend of research activities, in part focusing on biomedical research which is marked by the presence of many university hospitals (e.g. KUN/UMCN and LEI/LUMC), as well as activities and organisations oriented towards the food sciences such as TNO Voeding and WCFS (Wageningen Centre for Food Sciences, one of the four Leading Technology Institutes).

operation

Figure 5.1 Public-private R&D network of IOP Genomics



Blue – Dutch universities and public research institutes; red – companies and private R&D institutes en private institutes. The size of the connecting line indicates the quantity of pairwise relationships (thin line = 1 relationship).

Source: Senter (Annual Report 2002). Data treatment: CWTS.

5.2 Joint research publications

One of the few internationally comparable indicators of public-private R&D interaction are the occurrences of public-private co-publications, that is, research publications published in international scientific and technical journals that are co-authored by researchers in the public and private sector. The share of these co-publications amounts to 2.9% of the total domestic publication output of the Netherlands, which places us among the leading nations within the group of benchmark countries as well as at worldwide level. This score is partially due to the presence of some R&D intensive and science-oriented companies in the Netherlands, first and foremost Philips, but also DSM shows an increase in the number of research publications in recent years. Although the quantities of public-private research publications are slightly in decline in the Netherlands, we observe an even stronger downward trend in many of the benchmark countries. It goes without saying that these joint publications are but a 'tip of the iceberg' in terms of reflecting the magnitude and intensity of interactions, cooperation and knowledge flows between the public research sector and the business sector, especially with regard to the R&D intensive industries and large science-based companies.

Besides collaborating with one another, Dutch researchers are increasingly likely to work with foreign scientists on research publications. Befitting a small and highly networked nation, Dutch research is increasingly characterized by a wide variety of collaborative arrangements, both within institutions, between institutions, and with partners working abroad. Some 28% of the scientific publication output produced by the Netherlands can be classified as 'domestic co-publications' carrying the addresses of two or more Dutch research institutions. Overall, 43% of all Dutch research publications are internationally co-authored publications – that is, they list at least one foreign institution. The share of internationally co-authored publications is still in a slow but steady upward trend – a general phenomenon that occurs in most countries, reflecting the internationalisation and globalisation of basic research. With more financing now coming from the EC, specifically targeted to promote intra-EU cooperation, Dutch researchers are also co-publishing more with their European counterparts than in the past (**Table 5.2**). Our largest neighbour country, Germany, is our most prominent European research partner in terms of international co-publications.

Table 5.2 Scientific partnership countries of the Netherlands

Share of foreign countries in the co-authored publications listing at least one Dutch author address (in %) *

	1994-1995	1996-1997	1998-1999	2000-2001
1 United States	18.2	17.3	16.8	16.8
2 Germany	10.5	10.8	10.8	11.3
3 United Kingdom	11.3	11.0	11.2	11.3
4 France	7.4	7.0	6.6	6.6
5 Italy	4.8	5.2	5.9	5.5
6 Belgium	6.0	6.0	5.7	5.5
7 Spain	3.1	3.3	3.4	3.3
8 Sweden	2.9	3.0	3.1	3.1
9 Switzerland	3.5	3.6	3.4	2.9
10 Russia	2.7	2.9	2.8	2.9
11 Canada	3.0	3.0	2.6	2.7
12 Denmark	2.4	2.2	2.5	2.2
13 Japan	2.4	2.3	2.5	2.2
14 Finland	1.5	1.7	1.6	1.9
15 Australia	1.5	1.7	1.8	1.8
16 Austria	1.3	1.4	1.5	1.5
17 Poland	1.7	1.6	1.3	1.5
18 Norway	1.3	1.4	1.3	1.3
19 China	0.8	0.9	1.0	1.2
20 Czech Republic	1.0	1.0	0.9	1.0
21 Portugal	0.8	1.0	1.0	0.9
22 Hungary	0.9	0.8	0.9	0.9
23 Greece	0.8	0.8	0.9	0.9
24 Israel	0.9	1.1	1.0	0.9
25 Brazil	0.7	0.6	0.7	0.8
26 India	0.5	0.6	0.5	0.7
27 Ireland	0.5	0.7	0.5	0.6

* Percentage of the country in all author addresses listed in (partially) Dutch research publications that refer to organisations or people based in countries other than the Netherlands.

Source: CWTS/ISI. Data treatment: CWTS.

6 Outputs and outco

6.1 The Dutch research base in world class

Advanced industrialized countries like the Netherlands need to maintain a lead in the scientific fields where they are strongest, while maintaining the capacity to do science that is recognisably world class, across the board. Only in this way small nations can also gain full access, through collaboration and the international exchange of new knowledge and ideas, to all relevant science that is done abroad. Participating in research frontiers and 'hot topics' also entails publishing in high-quality (peer reviewed) international scientific and technical journals. This kind of publication output in the open scientific literature, focussing on the global research community, enables international comparisons between countries in terms of their research activity, productivity and scientific impact. Using publication output as a yardstick the Netherlands is shown to be amongst the leading countries worldwide both in terms of output and citation-impact (**Table 6.1**).

Dutch researchers produced a relatively large number of research papers in the international scientific and technical journals, some 19,000 in 2001.[16] This volume of output corresponds with 2.1% of all scientific publications worldwide, which ranks the Netherlands twelfth. About 75% of Dutch research articles originate from the 13 research-performing universities (including academic hospitals), 20% from public or semi-public organisations and centres of expertise, and the remaining 5% from industry and international organisations based in the Netherlands. As for the scientific specialisation of the Netherlands, we resemble countries like Finland and the United Kingdom where the medical sciences are by far the biggest field of science.
The scientific productivity, in terms of the average number of papers produced by the researchers in the public sector is relatively high compared to the selected benchmark nations. The internationally visibility, relevance and "impact" of those publications on worldwide science can be estimated by looking at the (relative) quantity of citations these publications receive from other, later, publications in those

[16] The analyses are based on research papers in journals whose contents are indexed by the Philadelphia-based Institute for Scientific Information (ISI) for its series of Citation Indexes in CD-ROM-edition.

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Table 6.1 Netherlands is one of the leading scientific nations

Scientific publication output and international citation impact by country, 1997-2001

	Output of research publications*		Relative citation-impact**	
	Counts	Worldwide rank	Impact score	Worldwide rank
United States	1,269,036	1	1.42	2
United Kingdom	354,724	2	1.21	4
Japan	337,810	3	0.85	18
Germany	313,712	4	1.09	9
France	231,550	5	1.01	13
Canada	164,182	6	1.21	5
Italy	150,013	7	0.95	17
Russia	127,965	8	0.32	29
China	115,403	9	0.41	27
Spain	106,023	10	0.85	19
Australia	103,648	11	1.01	12
Netherlands	93,129	12	1.25	3
India	73,787	13	0.37	28
Sweden	72,469	14	1.13	8
Switzerland	65,878	15	1.44	1

* Publication counts based on 'whole counting' scheme where each publication is assigned in full to all countries listed in the author address. Counts refer to 'research articles', 'review articles', 'notes' and 'letters'.

** Citation impact normalized by worldwide citation counts within all ISI-covered journals attributed to fields of science (worldwide average citation average per field =1.0). Citation counts excluding author self-citations.

Source: CWTS/ISI. Data treatment: CWTS.

scientific and technical journals: the "citation impact".[17] The Netherlands ranks number 3 in terms of its impact. The impact of Dutch publications reaches a level of 1.25 - that is, 25% above the worldwide citation average of all publications in the corresponding fields of science.[18] The excellent performance not only reflects the quality of the Dutch academic sector, but also the quality of the non-university research institutes, as well as of other public sector organisations and companies producing highly cited research papers. The Netherlands can be referred to as a pre-eminent country in terms of the quality of the basic research performed in its science system.

Recent results published by the European Commission on the overall citation impact scores of EU-based universities reveal that no less than seven Dutch universities belong to the top 20 most highly cited universities in the EU-15 (EC, 2003).[19] The university sector comprises three groups of universities. The first group includes the larger general universities of Leiden (LEI), Utrecht (UU), Groningen (RUG), Amsterdam (UvA), Free University Amsterdam (VU) and Nijmegen (KUN). The second group includes the smaller

17 Research papers in international journals are often cited in the reference list of subsequent papers dealing with the same, or related, subject matter. Usually such 'citations' indicate the use of those papers and the research they represent. Highly cited papers are generally considered to be of above-average impact on scientific progress and of above-average scientific quality.

18 The citation impact of a paper is compared to the average impact of all papers in the same journal.

19 European Commission, Third European Report on Science and Technology Indicators, Brussels, 2003.

general universities of Rotterdam (EUR), Tilburg (UvT) and Maastricht (UM). The third group consists of more specialized universities including the three technical universities of Delft (TUD), Eindhoven (TUE) and Twente (UT) and the agricultural university in Wageningen (WUR). All universities can boast on high citation impact scores in several fields of science.

Not only Dutch universities are highly cited, also non-academic research institutes and private firms have high citation-impact scores (**Figure 6.2**). The Netherlands has numerous well-known (semi-)public research institutes such as TNO, active in fields ranging from nutrition to industrial technology, DLO (the governments Agricultural Research Department, now merged with the University of Wageningen into the Wageningen University and Research Centre), the GTIs and RIVM (the National Institute of Public Health and the Environment). In addition, both NWO and KNAW run a diverse set of research institutes. Many of these non-university institutes are involved in cutting-edge basic research, actively publishing in the international scientific literature, and achieving citation impact scores that range from average to excellent.

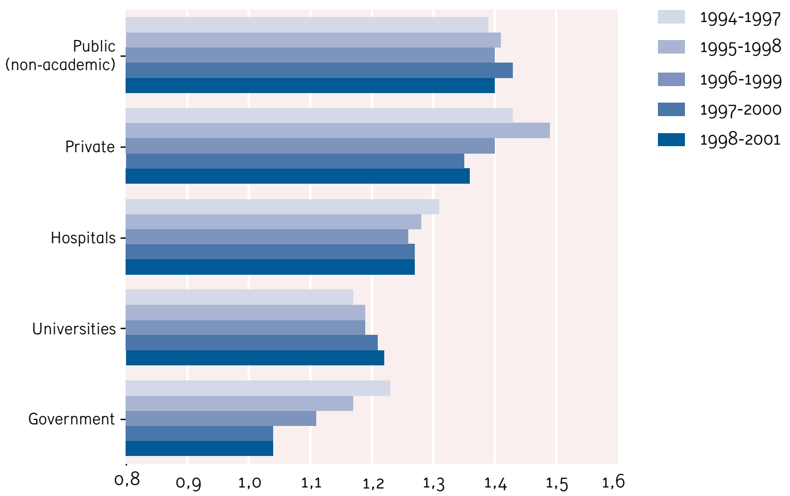
6.2 Research in the private sector

The Netherlands also has a prominent place on the world stage when it comes to industrial research. As mentioned above, several Dutch companies are quite active in R&D and conduct their share of longer-term ('basic') scientific and technical research. R&D-staff that are employed by firms also publish regularly in the international technical and scientific literature. This applies especially to the researchers and engineers working at the R&D laboratories of the largest industrial multinationals located in the Netherlands (Philips, Shell, Unilever, Akzo Nobel and DSM). The Dutch private sector - all companies based in the Netherlands - accounted for 4.2% of the Dutch research articles in international journals in 2001. Based on this share of publication output, the Netherlands is one of the leading countries worldwide in terms of private basic research (**Figure 6.3**). The majority of those articles are co-produced with researchers working in the public sector, either in the Netherlands or abroad. The number of these public-private co-publications has increased slightly during recent years, and now accounts for 68% of the total publication output of the Dutch business enterprise sector.

The publications originating from the companies define a scientific specialisation profile of Dutch corporate sector. This profile is dominated by polymer science, electronic en electrical engineering, and applied physics – a reflection of the research activities of the largest science-intensive companies: Philips, Unilever and DSM. Dutch universities and research institutes are also quite active in all these fields, often cooperating with partners both nationally and internationally.

The private sector is also a major user of research findings. But what is the impact of public science on basic research conducted by industrial researchers? The application of research findings is reflected in the list of references of

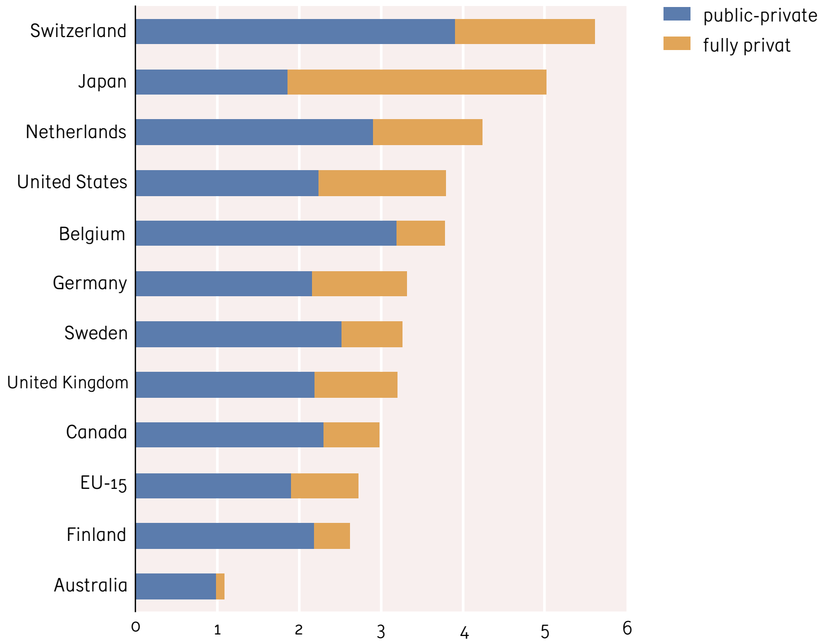
Figure 6.2 High citation-impact of Dutch research in non-academic research institutes and private enterprises



Source: CWTS/ISI. Data treatment: CWTS.

Figure 6.3 Share of business sector in the scientific output of nations

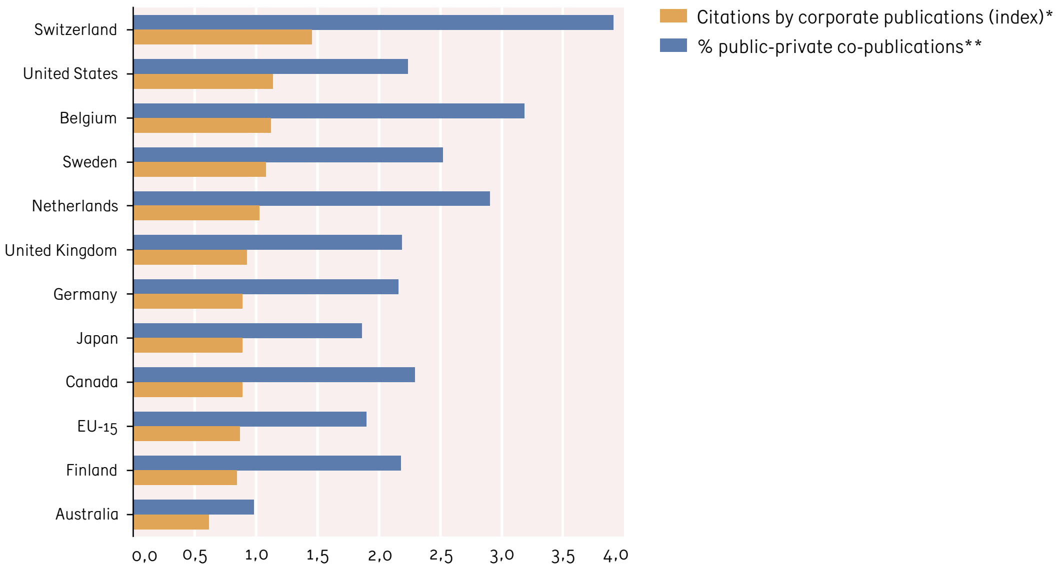
Fraction of companies in the output of research publications in scientific and technical journals broken down by public/private co-publications and fully private publications, 2001 (in % of the total publication output of countries).



Source: CWTS/ISI. Data treatment: CWTS.

Figure 6.4 Attractiveness of domestic science bases on corporate science

Share of public-private co-authored research publications (as % of domestic publication output); share of citations received from corporate research papers worldwide relative to the share of the domestic publication output in the worldwide publication output.*,**



* Publication and citation counts refer to the time-interval 1996-2001. Relative citation impact score: worldwide average = 1.0.

** Publication counts refer to the time-interval 1996-2001. Public-private co-publications include at least one author address referring to a company or a private sector R&D laboratory located in the country, and at least one address referring to an institution in the public sector in that same country.

Source: CWTS/ISI. Data treatment: CWTS.

corporate research publications. Examining the address information mentioned in the cited research literature within all corporate publications worldwide provides a rough estimate of the contribution of domestic science bases to corporate basic research. The result of these statistical analyses is depicted in **Figure 6.4**. It reveals that Dutch research papers account for 2.9% of the cited literature, which is well above the overall contribution of the Netherlands in the global research output (2.2%). Worldwide corporate science cites relatively often to Dutch research in the field of Agriculture and food science, and to research in the biomedical sciences. Both the general universities and specialised universities appear to be significant sources of information for scientific and technical research in the private sector. Not only does the Netherlands have a high output of scientific knowledge, but much of what it produces is also put to good use in technological development. This is evident from the sharp increase in references in patents to Dutch research publications in the late 1990s, particularly in the biomedical sciences.

6.3 Patent output and productivity

The Netherlands is also one of the key players on the world stage when it comes to technological development and patenting. It is generally accepted that patents taken out on technical inventions can be used as a proxy measure of technical advances and technological innovation, especially in technical areas and industrial sectors where patents are often used by companies to protect intellectual property. Hence, the innovative capacity of the business sector in the Netherlands can partly be derived from the (relative) number of patents acquired by Dutch inventors employed by firms and institutions. The international comparison of the Dutch patent output was based on data provided by the EPO and the USPTO. With the presence of several large multinationals in sectors where patenting is used quite often to protect intellectual property (e.g. Philips, the electronics company), it is to be expected that the Netherlands will perform above average both in the number of patent applications at the EPO and the number of patents granted by the USPTO. The Dutch share in the EPO patent applications was almost 5% in 2002. Less than 1% of all USPTO patents in 2001 were allocated to Dutch inventors. In both cases the Dutch share marks a relatively strong patent position considering the economic size of the Netherlands, and the major contribution of Philips accounting for some 35% of the Dutch-invented USPTO patents. A large proportion of the Dutch patents taken out in the private sector are in the fields of electronics and the food industry. Philips is the major contributor of Dutch patents and one of the most prolific companies worldwide in terms of patenting.

Figure 6.5 compares the number of EPO patent applications per 1000 researchers in the private sector. Dutch patent productivity is the highest of the countries shown, and is about 50% above the EU-15 average. Germany, Italy and Sweden show an above average patent productivity. The strongest increase in patent productivity is seen in Norway and the US. Of the leading countries the Netherlands has the lowest growth rate, and is only growing faster than Belgium, Greece and Finland. Finland even shows a negative growth, which is partly explained by the very strong growth of business researchers.

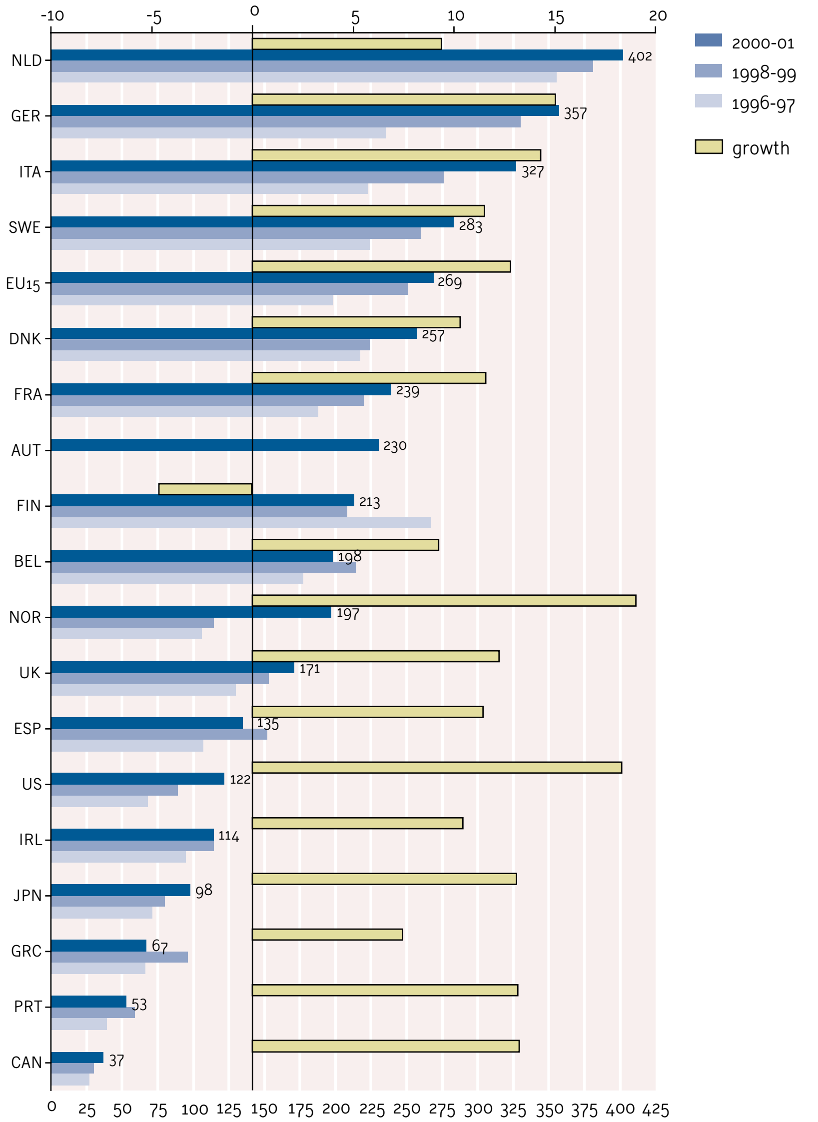
The Netherlands ranks 3rd in USPTO patent productivity, clearly behind Switzerland and the US and just before Germany and Sweden. Dutch growth performance in USPTO patent productivity is close to the mean value of the EU-15. The Dutch performance is less than excellent in the domain of the high-tech patents: although Netherlands is still among the leading contributors within the EPO patenting system, our share of high-tech patents within the US patent system lags behind

Patents contain references to source documents describing inputs and background material relevant to the development of the inventions and the claims made in the patent. A quantitative analysis of all technical inventions patented in the United States shows that the number of such "patent citations" to Dutch research publications contributes about 1 ½ % of all citations to the research literature, which is slightly less than the Dutch contribution to the worldwide scientific literature (2.2%). Some 40% of those citations refer to UPSTO patents attributed to the medical and pharmaceutical sector, 27% relate to patents in chemicals and materials sector. The universities in the Netherlands accounted for some 70% of the cited Dutch research articles. This includes a significant number of research publications originating from the university hospitals. TNO is also a noticeable contributor of Dutch research publications cited in the patent literature, especially with regard to research in the medical sciences and life sciences.

The Dutch universities and public sector research institutions are gradually embracing patents – both domestic patents, EPO patents or USPTO patents – as a means to protect their discoveries and inventions, and exploit their IPR for commercialisation. Numbers of academic patents has increased steadily during the past decade, both for domestic patents as well as patents at EPO and USPTO. The commercial value of the university-owned patents has been limited so far in the sense that for only 19% of these patents licences were given out to exploit the patent. The patents owned by the public research institutes score 17%.

The Netherlands performs at an average level within Europe in terms of external commercialisation by means of launching R&D-based companies – either university-based spin-off companies or start-up companies benefiting directly from the public sector R&D. As for spin-off activity within the Dutch public research sector, our country appears to be lagging behind several other Western European countries.

Figure 6.5 EPO patent applications per researcher



Patent productivities are calculated as the average number of patent applications per two years divided by the average number of researchers in the business enterprise sector of the previous two years. Growth rates are calculated as the average yearly growth between 2000-2001 and 1996-1997.

Source: OECD, EUROSTAT. Data treatment: MERIT.

6.4 Science in the public domain

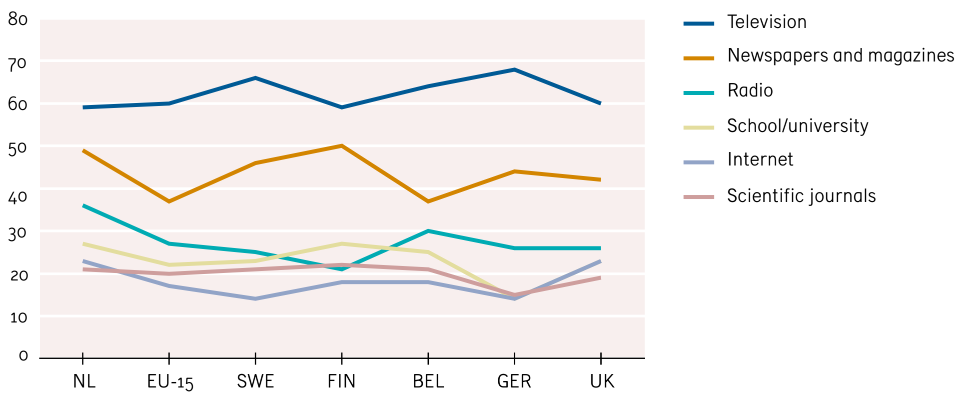
According to European surveys Dutch people show an above-average interest in scientific and technological developments, especially by television broadcasts. However, as compared to the other EU nations, the Dutch public is slightly more inclined to gather relevant information on science and technology from the radio and the Internet (**Figure 6.6**).

Dutch newspapers publish an average of six items per week referring to empirical research findings, half of which are related to items within the domain of the social and behavioural sciences. Relatively few Dutch scholars and researchers communicate their findings, or disseminate their views and opinions, to the general public in the Netherlands. A survey within the Netherlands indicates that researchers acknowledge the need for more "societal impact": two thirds of the respondents state that impacts and benefits of science on society should be made more visible to the public eye.

Science centres offer a vehicle to reach out to the population. Although the Netherlands can boast on several famous museums and excellent science centres, in terms of relative numbers of museums and centres, the Netherlands are within the middelslice of the European countries. Although the Dutch men show a keener interest in science and technology in general (a European wide phenomenon), women in the Netherlands are particularly interested in news items related to health and environment. The Swedes – a highly educated population like the Dutch - exhibit a pattern of differences between the sexes that is quite similar to the situation in the Netherlands. These gender-based differences also affect preferences in educational programmes at Dutch universities: females are more likely to opt for degrees in the social and behavioural studies or medicine, rather than degrees in the natural sciences or engineering sciences.

Figure 6.6 Important sources of information concerning scientific developments

Share of respondents in each country mentioning the two sources they perceive to be the most important



Source: EC Eurobarometer 55.2, 2001(Steinmetzarchief). Data treatment: CWTS.

List of abbreviations

AHCI	Arts & Humanities Citation Index
AUT	Austria
BEL	Belgium
BERD	Business Enterprise Expenditure on R&D
BSIK	Besluit Subsidies Investeringen in de Kennisinfrastructuur
CBS	Statistics Netherlands
CHE	Switzerland
CIS	Community Innovation Survey
CRIHO	Centraal Register Inschrijving Hoger Onderwijs
CWTS	Centre for Science and Technology Studies
DEU	Germany
DLO	Agricultural Research Department
DNK	Denmark
EC	European Commission
ECN	Netherlands Energy Research Centre
EPO	European Patent Office
ESP	Spain
EU	European Union
EUR	Erasmus University Rotterdam
FIN	Finland
FP	Framework Programme
FRA	France
EZ	Ministry of Economics Affairs
GD	GeoDelft
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GOVERD	Government Intramural Expenditure on R&D
GRC	Greece
GTIs	Large Technological Institutes
HERD	Higher Education Expenditure on R&D
ICT	Information and Communication Technologies
IOP	Innovation-driven research programme
IPR	Intellectual Property Rights
IRL	Ireland
ISI	Institute for Scientific Information
ITA	Italy
JPN	Japan
KNAW	Royal Netherlands Academy of Arts and Sciences
LEI	Leiden University
LNV	Ministry of Agriculture, Nature and Food Quality
MARIN	Maritime Research Institute Netherlands
MERIT	Maastricht Economic Research Institute on Innovation and Technology
NLD	The Netherlands
NLR	National Aerospace Laboratory
NOR	Norway
NOWT	Netherlands Observatory on Science and Technology
NSE	Natural Sciences and Engineering
NWO	Netherlands Organization for Scientific Research
OCW	Ministry of Education, Culture and Science
OECD	Organisation for Economic Co-operation and Development
PRT	Portugal
R&D	Research and Development
RIVM	National Institute of Public Health & Environmental Research
RUG	University of Groningen
S&E	Science and Engineering
S&T	Science and Technology
SCI	Science Citation Index
SME	Small or medium-sized enterprise
SSH	Social Sciences and Humanities
SSCI	Social Sciences Citation Index
STW	Technology Foundation
SWE	Sweden
TNO	Netherlands Organization for Applied Scientific Research
TTIs	Leading Technological Institutes
TUD	Delft University of Technology
TUE	Eindhoven University of Technology
V&W	Ministry of Transport, Public Works and Water Management
VSNU	Association of Universities in the Netherlands
UK	United Kingdom
UM	Maastricht University
US	United States
USPTO	United States Patent and Trademark Office
UT	University of Twente
UU	Utrecht University
UvA	Universiteit van Amsterdam
UvT	University of Nijmegen
VSNU	Association of Universities in the Netherlands
WCFS	Wageningen Centre for Food Sciences
VU	Vrije Universiteit Amsterdam
WL	Delft Hydraulics
WUR	Wageningen University and Research Centre