Science and Technology Indicators

Summary

2005

Netherlands Observatory of Science and Technology

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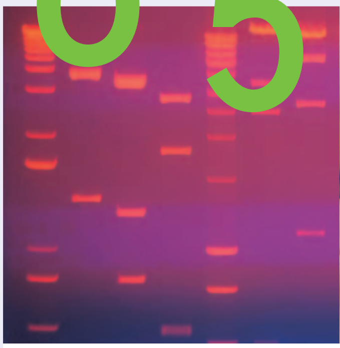

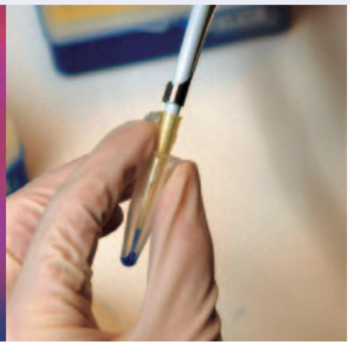

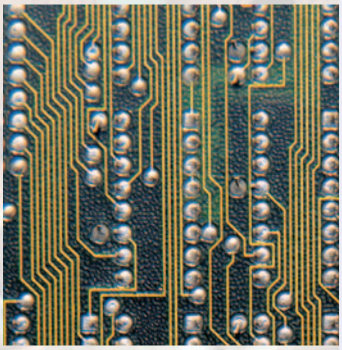

Netherlands Observatory of Science and Technology (NOWT)

NOWT is a formal collaboration of

Centre for Science and Technology Studies (CWTS)

Maastricht Economic Research Institute on Innovation and Technology (MERIT)

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Part 1 Introduction

1 Moving towards a knowledge-based economy

The Netherlands is a relatively small country located in North-Western Europe, in one of the wealthiest and most densely populated areas on our globe. With a population of more than 16 million, it is among OECD's leading countries in terms of economic performance. Being a well-developed and dynamic economy, with a large services sector accounting for more than 50% of the GDP, the Netherlands can boast on a relatively high labour productivity based on a high-tech infrastructure and modern facilities. Among the most important contributing factors of the open Dutch economy are its export position and its innovative capacity, the latter being a vital element for raising productivity levels, achieving sustainable economic growth, as well as securing our future competitive advantage. Both the industrial firms and the services-oriented business enterprises are increasingly internationally oriented; they are competing on the European or global markets, often with innovative products, services and processes.

Scientific research and technological development (R&D) are recognized as important strategic factors that will shape and drive our socio-economic future. The knowledge and skills of the Dutch, and the fruits of their creative efforts and know-how, are considered to be a powerful driving force of the Dutch economy. The Netherlands is not only the home base of several of the world's largest companies, but also of many innovative small and medium sized firms employing highly creative and well-educated workers, researchers, engineers and technicians. Our country has an excellent higher education system with numerous internationally recognized universities, as well as a wide variety of high-quality research institutes, which make the Netherlands one of Europe's hot spots of creativity and R&D activity. A significant share of the advanced, new knowledge that is being applied in innovative products and services originated from Dutch R&D, either scientific discoveries, the development of novel technologies, or from other knowledge intensive activities such as design, marketing concepts or organizational innovations.

Within the increasingly knowledge-oriented Dutch economy, our society is faced with many challenges of making efficient and responsible use of limited space, human and natural resources, and the environment.

Science and technology are key contributors to the creation of new knowledge, as well as improving and applying existing knowledge, for social and economic returns in general, and organizational and technological innovations in particular. The profound influence of R&D can be found across the entire societal spectrum in the Netherlands, ranging from industry, transportation and logistics, health care, educational services, sports and entertainment, to the arts.

Not surprisingly, science, technology and innovation have become one of the top government policy priorities in recent years. A strong science base and more effective utilization of results generated by research are indispensable if the Netherlands is to help fulfil Europe's ambition of becoming the world's most competitive economy. The national priorities of the Dutch government focus on improving the efficiency and effectiveness of the national knowledge production system, particularly in the public sector, by increasing the level of private R&D spending, by investing in scientific excellence in key fields of research and technology areas, and by developing an adequate supply of highly skilled human capital, a greater concentration and focus in strategic research areas, and by fostering the production of knowledge that promotes economic activity. A wide range of actions and policies have been initiated, or are currently being planned by, among others, the *Ministry of Education, Culture and Sciences* (OCW, 2004a; 2004b; 2004c) and the *Ministry of Economic Affairs* (EZ, 2003).[1] The establishment of the *Innovation Platform* in 2003, presided by the Prime Minister, will aid in formulating an integrated strategy and exemplifies the high level of government commitment to furthering the role of science, technology and innovation in the Netherlands.

2 Measuring and monitoring of science and technology

The growing economic and societal importance of knowledge-intensive economies 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, government agencies like the Netherlands *Ministry of Education, Culture and Science* need to monitor, as accurately as possible, structural shifts and recent trends in scientific and technological performance - not only in their own country but also in comparison to developments occurring in other nations.

Science and technology policy-making by the Dutch government has a long tradition of using statistical data for assessing the state of the S&T system in the Netherlands. The *Netherlands Observatory of Science and Technology*[2] (denoted here by its Dutch acronym NOWT) is one of the main government sources of factual information.[3] The sixth bi-annual report in NOWT's series of *Science and Technology Indicators Reports* covers a wide range of features characterizing the "knowledge system" in the Netherlands, not only the R&D-specific parts, 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. We tap our quantitative information and international statistics from various sources, including the *Organisation for Economic Co-operation and Development* (OECD), *EUROSTAT*, *European Commission* (EC), *Statistics Netherlands*, as well as the extensive in-house databases at CWTS and MERIT. The statistics on research output and scientific impact are

1 OCW, Science Budget, Policy document by Ministry of Education, Culture and Science (Ministerie van Onderwijs, Cultuur en Wetenschap OCW), 2004a. OCW, Higher Education and Research Plan, Policy document by Ministry of Education, Culture and Science (Ministerie van Onderwijs, Cultuur en Wetenschap, OCW), 2004b. OCW, Delta Plan for Science and Technology, Policy Document on Knowledge Workers by Ministry of Education, Culture and Science (Ministerie van Onderwijs, Cultuur en Wetenschap, OCW), 2004c. EZ, Innovation Letter, Policy document by Ministry of Economic Affairs (Ministerie van Economische Zaken, EZ), 2003.

2 NOWT is a formal cooperation between researchers based at the Centre for Science and Technology Studies (CWTS) at 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.

3 Other government reports (in Dutch) with statistical data and quantitative information on the Dutch R&D and innovation system are Kennis en Economie 2004 (Statistics Netherlands, CBS, 2004), and Kerncijfers 2000-2004 OCW (Ministerie van Onderwijs, Cultuur en Wetenschap, OCW, 2005).

generated by CWTS's version of *Thomson Scientific's Citation Indexes/Web of Science*. The patent data were extracted from the *European Patent Office*.

Obtaining reliable facts and figures on science and technology in general, and on R&D in particular, requires a systemic view supported by reliable information sources and series of internationally recognized quantitative indicators. But 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 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 the science and technology system within an internationally comparative framework. We have assembled an array of empirical evidence from domestic sources and international statistical agencies that enable us to analyze and monitor national and international trends in R&D and innovation systems.

This report provides an indicator-based scan of the performance of the Netherlands within such an international comparative perspective. The frame of reference is a set of eight benchmark nations comprising of our neighbouring countries (Belgium, Germany and the United Kingdom), other similar Western European countries (Sweden, Finland and Switzerland), and two non-European countries with a very active policy on gearing R&D towards innovation and economic development (Canada and Australia). The overview we present in this summary report comprises of an illustrative series of tables and graphs that were carefully selected from NOWT's Dutch-language *Science and Technology Indicators Report 2005*,[4] with the primary aim of highlighting several of the current characteristics that define the international profile of the Netherlands in science and technology.

4 Both this English language summary report and the associated Dutch-language full version of the report are electronically available on the NOWT website www.nowt.nl.

Part 2 Trends and perfor

3 Highlights and main conclusions

The Netherlands is one of the world's leading R&D nations, and among the very best in terms of its research performance. Accounting for just 0.25% share of the world population, Dutch researchers produce some 2.5% of all scientific publications worldwide in the *Science Citation Index®* and associated citation indices, which in turn receive 3% of all citations from scientists and scholars worldwide. Dutch research universities and institutes are among the most highly cited in many of the major scientific disciplines, within Europe as well as at the global level.

Also with regard to technical progress and technological innovations the Netherlands is performing well; our country hosts several large R&D-intensive companies such as *Philips*, *Shell*, *Unilever*, and *Akzo Nobel*, but there are also countless innovative knowledge-intensive SMEs. The Dutch workforce is relatively highly educated, and a large part of the Dutch population not only shows a keen interest in new scientific developments and technical inventions, but also enthusiastically adopts the use of new technologies in their daily lives.

The competitive position of the Netherlands within the global knowledge economy is at a fairly high level. However, the current performance is largely due to investments and efforts in the past. Dutch society and its economic environment are continually changing and setting new demands. We must be forward-looking and prepare for the future challenges and uncertainties. So, there is ample reason to seek for improvements whenever and wherever possible.

Overall, we conclude that the Netherlands is performing (very) well on certain aspects of the R&D system but less well, or even weak, on others. However, the same applies for the benchmark countries, none of which systematically perform better or worse. Nonetheless, significant differences do exist between these countries. Some of the noticeable strengths and weaknesses of the Netherlands warrant closer attention and more extensive elaboration. These will be discussed and highlighted in the following sections.

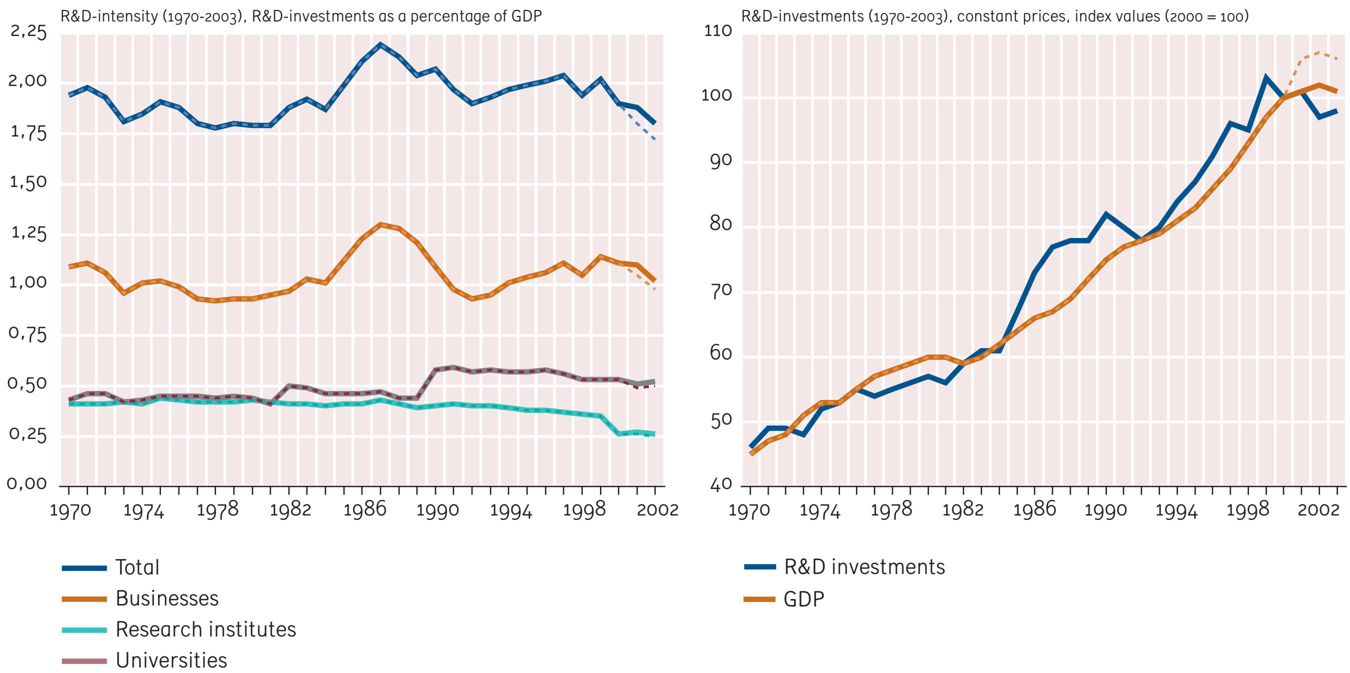
mance

4 Spending: R&D investments and funding

Although just one of many investments in the knowledge economy, R&D expenditures are considered to be among the most important indicators for benchmarking a country's performance within an international comparative context. Dutch R&D investments amounted to about 8.3 billion euro in 2003. The business sector accounts for almost half of the R&D spending, approximately 2 billion is spent at the universities, and the remaining quarter of the money can be divided up into three different categories (a) funding used to finance the Dutch Research Council (*Nederlandse Organisatie voor Wetenschappelijk Onderzoek* NWO), and the *Royal Academy of Arts and Sciences* (KNAW), and a number of international organizations for basic research (CERN, ESA, ESO, EMBL); (b) financing provided for a range of technology institutions such as the *Netherlands Organization for Applied Scientific Research* (TNO), the *Large Technological Institutes* (GTIs)[5], the *Agricultural Research Department* (DLO)[6], and other ministerial research services; (c) programmes and projects to promote interaction between the demand for knowledge and its supply, for example the open technology programme run by NWO's *Technology Foundation* (STW), the *Innovation-driven Research Programmes* (IOPs), the programmes of the *Leading Technology Institutes* (TTIs), and the BSIK program which consists of R&D projects in areas of strategic interest for Dutch industry and society at large (BSIK funding is partly government subsidy, partly private funding from participants). Funding is complemented by the fiscal facility

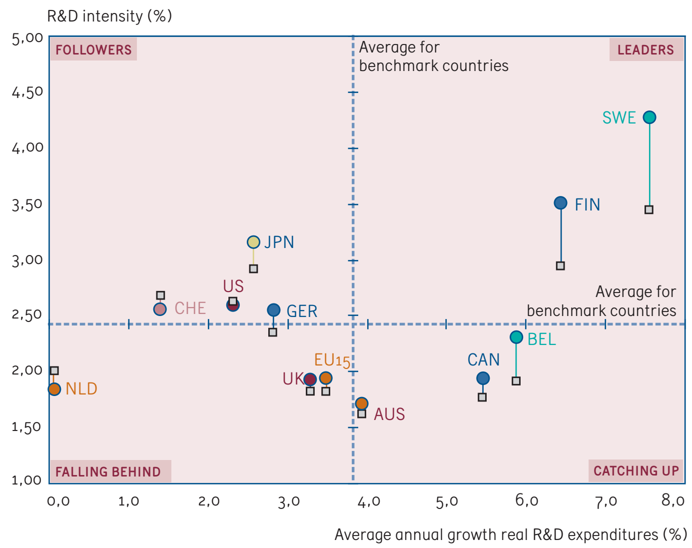
5 These are the National Aerospace Laboratory (NLR), the Maritime Research Institute Netherlands (MARIN), GeoDelft, WL | Delft Hydraulics, and the Energy Research Centre of the Netherlands (ECN).
6 DLO and Wageningen University are the two legal entities of the Wageningen University and Research Centre (WUR).

Figure 1 Long-term trends in total Dutch R&D intensity and R&D investments*



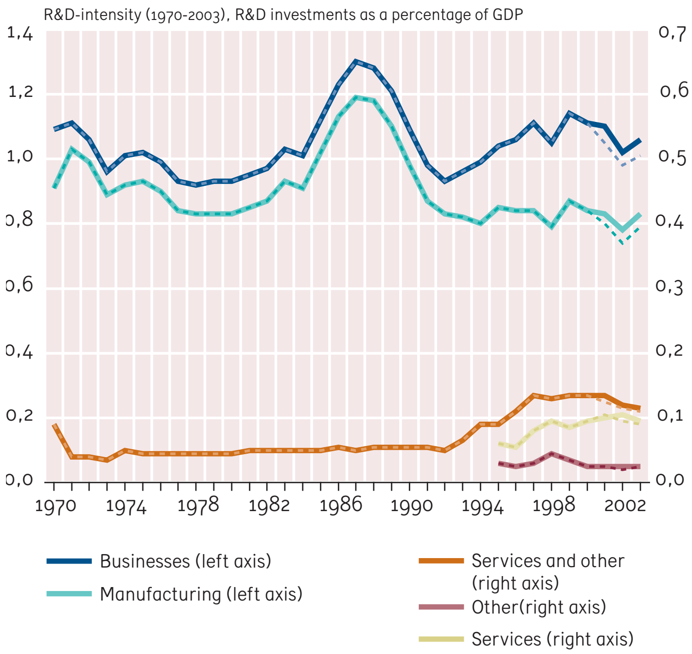
* Intensities and indices for 2001-2003 (after revision national accounts) shown by thin lines.
Data sources: OECD, Statistics Netherlands. Data treatments: MERIT.

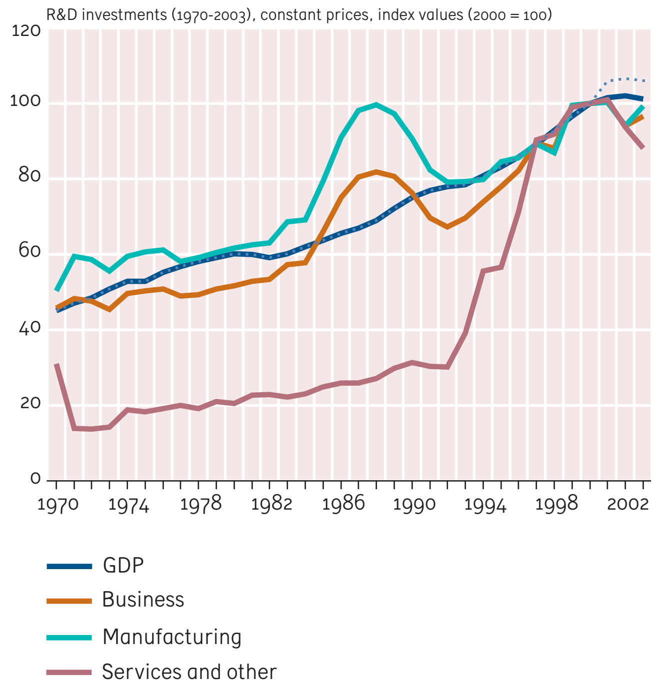
*Figure 2 Trends in total R&D intensity and R&D expenditures**



* R&D intensities are for 2003 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditures over a 5-year period. The dotted lines give the means for the benchmark countries. The R&D intensity of each country/region in 1998 is represented by a light grey square. GDP data are from before the 2001-2005 national accounts revision.
Data sources: OECD, Statistics Netherlands. Data treatments: MERIT.

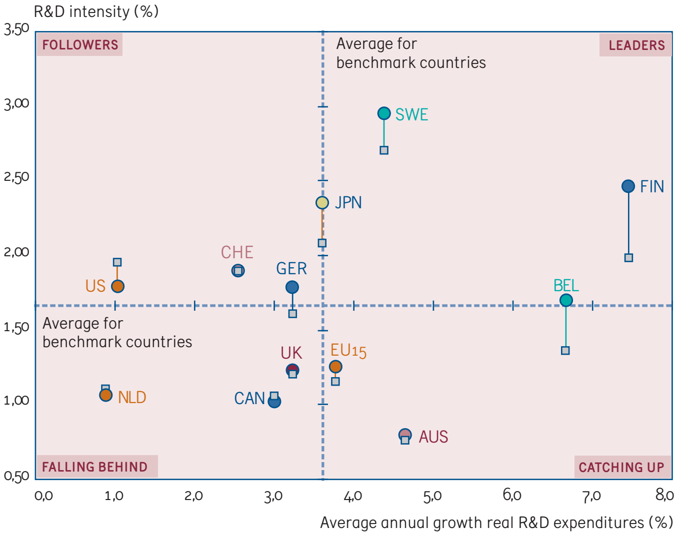
*Figure 3 Long-term trends in business sector R&D**





* Intensities and indices for 2001-2003 (after revision national accounts) shown by thin lines.
Data sources: OECD, Statistics Netherlands. Data treatments: MERIT.

*Figure 4 Trends in business sector R&D intensity and R&D expenditures**



* R&D intensities are for 2003 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditures over a 5-year period. The dotted lines give the means for the benchmark countries. The R&D intensity of each country/region in 1998 is represented by a light grey square. GDP data are from before the 2001-2005 national accounts revision.
Data sources: OECD, Statistics Netherlands. Data treatments: MERIT.

to promote research and development within business enterprises, named the *Research and Development Promotion Act* (WBSO).

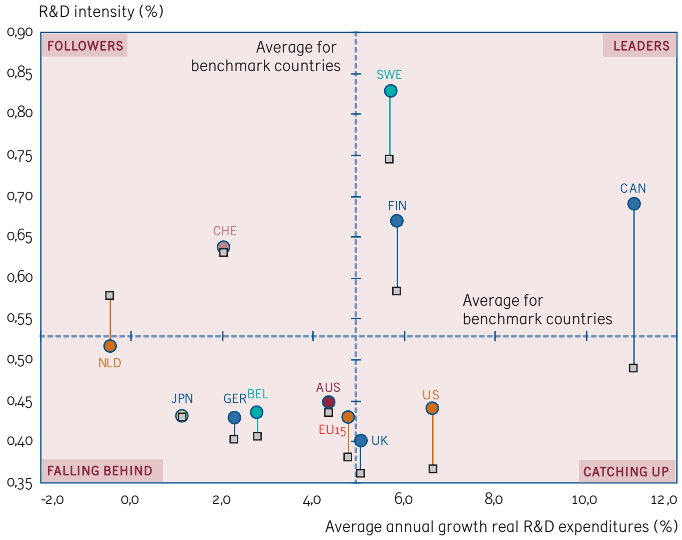
The 8.3 billion euro of expenditure translates to 1.76% of the Dutch Gross Domestic Product (GDP). This fraction is also referred to as the R&D intensity, which has witnessed a significant fall over the last five years (**Figure 1**). R&D investments in the Netherlands exhibit the lowest growth rate over the past five years (**Figure 2**). As a result, the Dutch R&D intensity is currently among the lowest within a selected group of benchmark countries, i.e. OECD countries with medium-sized economies and characterized by comparable R&D performance. The Netherlands would seem at risk of falling behind many of our main competitors within the global knowledge economy. Current R&D investments are also insufficient to reach the 2010 Barcelona aim, where the EU aims to achieve an R&D intensity of 3%, on top of which the Netherlands aspires to be among the top R&D performers in Europe.

A relative drop in R&D investment is largely due to the declining R&D intensity within the business sector (**Figure 3**). There are two explanations for this decline: (a) the diminishing share of the business sector in the Dutch economy, and (b) a decline in this sector's own R&D intensity (**Figure 4**). The latter decline is explained by two developments within the business sector: a drift from R&D intensive manufacturing towards R&D extensive services, and a shift within manufacturing sector from R&D intensive high-tech manufacturing towards low-tech manufacturing. As yet it is unclear whether or not these trends will have a negative impact on the innovation capacity and on productivity levels within the Dutch economy.

R&D activities are globalizing. This is also the case in the Netherlands. About 15% of the R&D investments in the business sector is now financed from abroad. 90% of these financial flows come from only six countries: United States, Belgium, France, Japan, Germany, and the United Kingdom. Overall, foreign countries are still net investors in the Dutch business sector. As for individual business enterprises, there is no conclusive empirical evidence that decreasing R&D investments by Dutch knowledge-intensive multinationals can be attributed to relocating and off-shoring of R&D activities.

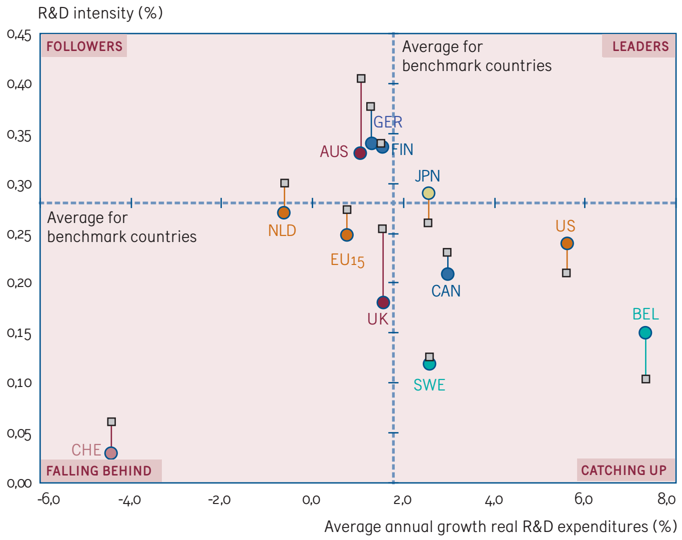
Dutch companies in particular tend to outsource R&D activities and contract their research to technology institutes and other non-university R&D institutes in the Netherlands, rather than to Dutch universities. The main task of these institutes, such as TNO, GTIs, DLO and other government research centres, is to carry out applied research on behalf of business enterprises and the public

*Figure 5 Trends in university R&D intensity and R&D expenditures**



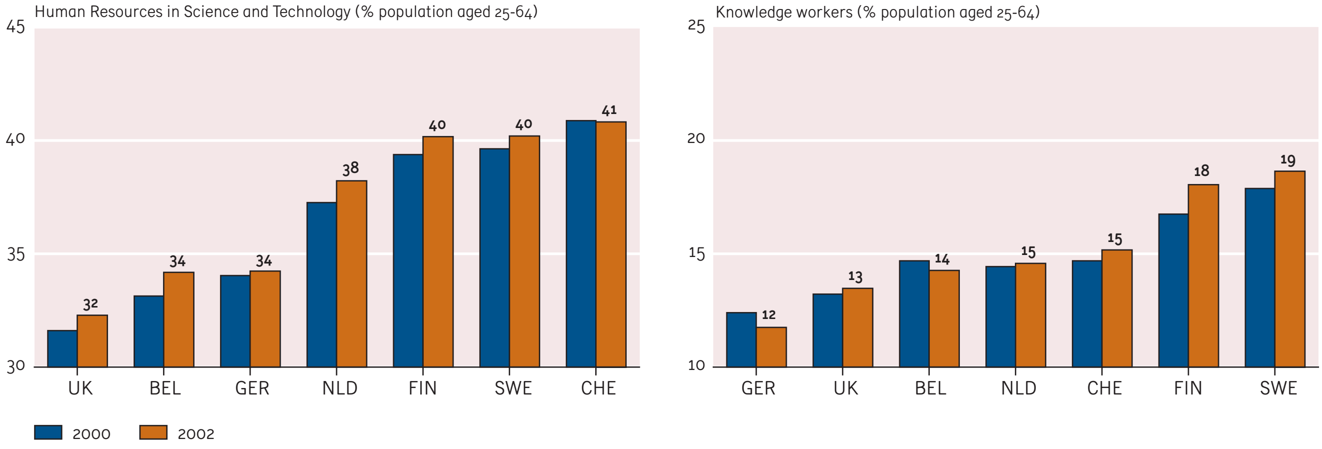
* R&D intensities are for 2003 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditures over a 5-year period. The dotted lines give the means for the benchmark countries. The R&D intensity of each country/region in 1998 is represented by a light grey square. GDP data are from before the 2001-2005 national accounts revision.
Data sources: OECD, Statistics Netherlands. Data treatments: MERIT.

*Figure 6 Trends in R&D intensity and R&D expenditures of non-university research institutes**



* R&D intensities are for 2003 or most recent year. Trends are calculated as the average yearly growth of real R&D expenditures over a 5-year period. The dotted lines give the means for the benchmark countries. The R&D intensity of each country/region in 1998 is represented by a light grey square. GDP data are from before the 2001-2005 national accounts revision.
Data sources: OECD, Statistics Netherlands. Data treatments: MERIT.

Figure 7 Human resources in science and technology



Data source: EUROSTAT. Data treatments: MERIT.

sector and to contribute to the application of scientific and technical knowledge. They thus have their own intermediate role in ensuring that the universities respond to the R&D demands of the business sector, and needs of society at large. With regard to those non-university research institutes, about 17% of public R&D investments were funded by the private sector in 2003, where the share of foreign funding has experienced a rapid increase since the early 1990s. As for the R&D performed by universities, the share of business expenditure in this sector has seen a strong increase since the early 1990s, levelling off at about 7% in recent years.

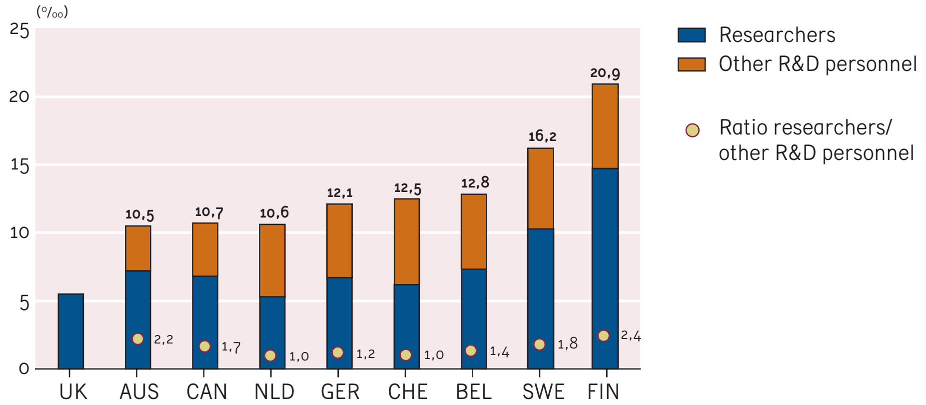
Both universities and non-university research institutes exhibit R&D intensities comparable to the average of the benchmark countries, yet the growth of real investment lags far behind those countries in both sectors (**Figure 5** and **Figure 6**). When corrected for inflation, the level of university R&D has actually declined in the previous five years by nearly 0.5% annually, a marked contrast with the almost 5% annual growth in other countries. The public sector research system is clearly falling behind in terms of R&D funding growth rates. The question remains to what extent this development reflects a catching up process of other benchmark countries in terms of building efficient and effective R&D systems, comparable to that of the Netherlands, or whether our country is actually being surpassed also in that respect.

The public support for government-funded scientific research among Dutch people is comparable to that in the other countries. A recent *Eurobarometer* survey has shown that about 75% of all Dutch respondents favour government-funded scientific research (see Figure 17). However, Dutch people are reluctant to the idea of the government funding additional investments in scientific research; a minority of only 25% of the Dutch respondents agrees with the survey statement that the Dutch government should increase their funding of scientific research at the expense of other government expenditures.

5 People: human resources and human capital

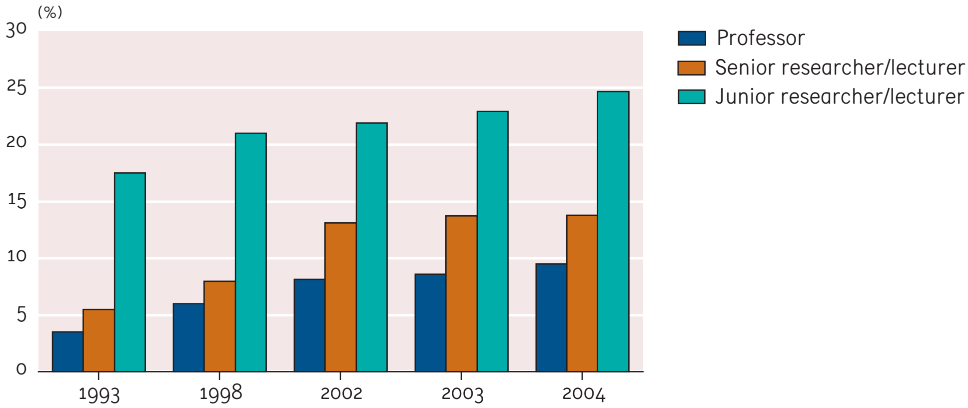
An advanced knowledge-based economy is critically dependent on a sufficient supply of highly educated workers, employees who can exploit their advanced knowledge, skills and know-how in their daily line of work. The Netherlands has an ample supply of these skilled workers: some 38% are classified as ‘human resources in science and technology’ (**Figure 7**). Almost 15% of the working-age population, some 1.3 million inhabitants of the Netherlands, belongs to the subgroup of knowledge workers, those professionals that enjoy both a tertiary education degree and work in R&D-related jobs. These people can be found both within the manufacturing sector as well as the services sector. Only a minor fraction of them, those designated as R&D personnel, are actually involved with the development, storage, diffusion and immediate applications of new scientific and technological knowledge.

Figure 8 Researchers and other R&D personnel in 2001/2002 (‰ of labour force)



Data source: OECD (MSTI 2005-1). Data treatments: MERIT.

*Figure 9 Trends in shares of female staff at Dutch universities**



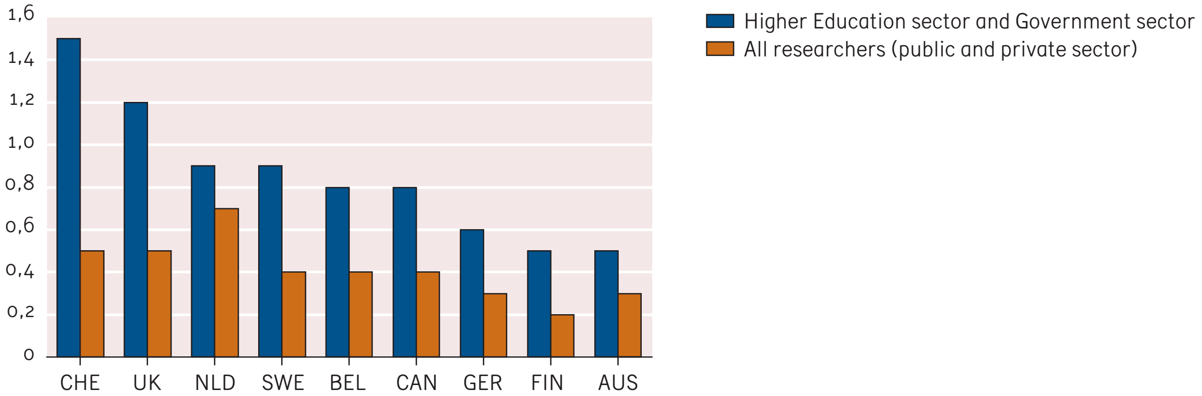
* Percentage of all staff employed in those positions (either temporary or permanently) at all universities in the Netherlands.
Data source: VSNU. Data treatments: CWTS.

At the forefront of these knowledge-generating efforts are the university graduates, academic researchers and scholars, and the corporate researchers and engineers. The Netherlands has a relatively small R&D working force, some 11% of the working population (**Figure 8**). The share of researchers (5%) is the smallest of all benchmark countries. The quantities of R&D staff and the number of researchers have hardly increased in recent years, particularly within the business sector. This relatively small R&D force can boast on competitive levels of effectiveness in terms of R&D-outputs (see Figure 10 and Figure 15).

Nonetheless, several structural problems exist with respect to R&D-relevant human resources in the Netherlands. One of them is the labour market perspective for university graduates and researchers, which is currently characterized by a shortage of attractive job opportunities and a declining interest among Dutch youth to pursue a scientific career. The Dutch government launched a concerted effort which has led to an increase in the supply of new Science and Engineering graduates from 6 per thousand in 1998 to 7.3 per thousand in 2003. One of the greatest challenges is to retain talented young researchers after they have completed their training. Currently, the immigration of highly-skilled individuals alleviates some of the shortages as indicated by the high shares of foreign researchers employed at Dutch universities, especially the technical universities. The shares of female researchers are still relatively low (**Figure 9**). The fraction of female researchers is growing gradually, but they are still significantly underrepresented within the university research staff, especially within the higher ranks. Recently the number of university researchers has started to increase again, albeit with an average annual increase of just 1%. Almost 20% of

Figure 10 Research productivity

Average annual number of research articles published in the period 2000-2003 per researcher employed in 1997-2000 (full time equivalents)



Data sources: CWTS/Thomson Scientific; OESO/MSTI 2003/2. Data treatments: CWTS.

the university researchers now originate from abroad; this share exceeds 30% at the technical universities.

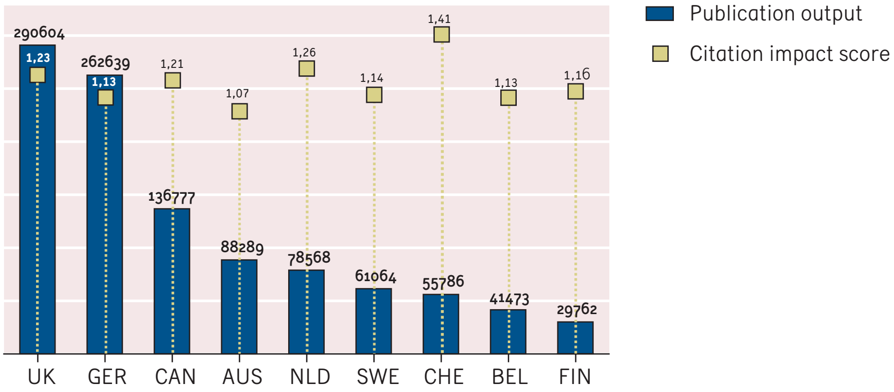
In view of the current problems to recruit sufficiently large quantities of R&D-staff from the higher educated Dutch population, especially females, it would seem that a significant segment of the "human capital" in the Netherlands is under-utilized in terms of offering them attractive working conditions and career prospects as researchers. Such a working environment might prove to be a liability given the internationalization of the labour market for highly qualified knowledge workers in general and the aging of university scientific personnel in particular. As in several other countries, these global developments may also threaten the adequate supply of the required human resources in the Dutch R&D system.

The availability of highly skilled human capital is generally considered to be an important factor, if not the prime reason, to sustain the local knowledge-based economy, and for multinational enterprises to (re)locate R&D activities in foreign countries like the Netherlands. University graduates and PhD graduates constitute a pool of human resources out of which companies and research institutes can select their future researchers and technical personnel, in particular those who graduated in natural sciences and engineering. The number of first-year students in these fields has increased significantly in recent years; as has the number of PhD graduates, but at a slower pace. During the next few years, significant shortages are expected on the Dutch labour market for knowledge workers, particularly in the educational, medical and paramedical occupations as well as for ICT/computer sciences staff.

6 Creating knowledge: production of scientific and technical information

The Netherlands is among the leading countries in terms of its focus on basic ("exploratory") longer-term research. This applies both to the public research sector and to many of the R&D-intensive business enterprises. The excellent research performance is also reflected in the relatively high level of research output. Dutch researchers are major contributors at the international frontiers of basic science; collectively they produce a daily average of some 80 research publications that are published in international peer-refereed scientific and technical journals, often in co-operation with Dutch co-workers and/or foreign colleagues. Contributing some 2.5% of all scientific publications worldwide, the publication output rate of Dutch researchers puts the Netherlands among the most productive countries of the world. The largest share of those research articles, review articles and research letters (69%) are being produced by scientists and scholars employed at the 13 universities in the Netherlands. Researchers at non-university research institutes (either publicly funded or semi-public) account for the second largest share of the publication output (17%). In terms of annual per capita production within the public research systems, the Netherlands ranks number 3 within the set of benchmark countries, with an average output of almost one publication per researcher per year (see **Figure 10**). We even take pole position when the production of the private sector researchers is included, owing in large part to the substantive publication output of some corporate R&D laboratories of the Dutch multinational enterprises, notably *Philips*, the large electronics company with its central research labs located in Eindhoven.

Figure 11 Scientific publication output and citation impact of the Netherlands and benchmark countries, ***



* Number of research publications published in 2000-2003 within international peer-reviewed journals indexed by Thomson ISI databases;
** Field-normalized citation impact score based on publications in 2000-2003 and citations received during the same time-interval. This normalized citation impact score indicates the extend to which a country's citation impact differs from the average impact score of all countries within the same field of science. The average score is fixed at 1.0 per field of science.
Data source: CWTS/Thomson Scientific. Data treatments: CWTS.

The Netherlands produced almost 80,000 research articles in the international scientific and technical literature during the 4-year interval 2000-2003 (**Figure 11**). However, research quantity does not necessarily equate to research quality. But in the case of the Netherlands, the empirical evidence strongly suggests that quantity and quality do go hand in hand. Measured in terms of citation impact scores of Dutch research articles in the international scientific and technical literature, the Netherlands is among the best performing countries with a score that is 26% above the worldwide citation average within the respective fields of science. Dutch science is among the best within the reference group, second only to Switzerland.

The citation impact performance of the Dutch science base varies significantly across fields of science. **Table 12** displays an overview of that variety in relation to the relative size of those fields. Some fields have a much larger publication output, when compared to their relative output levels in the benchmark countries. This research specialisation index highlights 11 fields with a significant 'over-representation' in the Netherlands, including *Information and communication sciences*, *Agricultural and food science*, *Astronomy and astrophysics*, but also *Language and Linguistics*. Some of these fields enjoy high citation impact rates more than 40% above world average (*Information and communication sciences*), while others are at world average (such as *Language and Linguistics)*. Conversely, some fields produce comparatively low quantities of articles also manage to achieve (very) high levels of citation impact within the international research literature; fields such as *Chemistry and chemical engineering*, *Physics and materials science*, and *Electrical engineering and telecommunication* are among the most highly cited in the Netherlands. Only very few fields of Dutch science are cited below worldwide average.

Not surprisingly, the citation impact scores of all Dutch universities and many of the research institutes are (far) above the worldwide average, and often are among the highest in Europe. Many of our research universities feature among the best within international rankings.[7] In fact, each Dutch university has at least one field of science in which it excels in terms of producing a relatively large number of papers belonging to the top 10% most highly cited research publications worldwide. This includes fields within the natural sciences, medical and life sciences, technical sciences, but also the social sciences (including economics). Some of the non-university research institutes, KNAW-funded and NWO-funded research institutes in particular, also belong to the European top performers: research publications from this institutional sector as a whole reach a citation impact level that is 38% above the worldwide average.

7 The rankings published by Times Higher Education Supplement (www.thes.co.uk/worldrankings/) and by the Shanghai Jiao Tong University (ed.sjtu.edu.cn/ranking.htm).

Table 12 Typology of fields within the Dutch research system by research specialisation and international citation impact

Research Specialisation Index (RSI)*

Relative Citation Impact (RCI)**	Under-representation (RSI ≤ -.10)	Average (-.10 <RSI < +.10)	Over-representation (RSI ≥ +.10)
Very high (RCI ≥1.40)	Chemistry and chemical engineering	Computer science	Information and communication science
High (1.20<RCI< 1.40)	Physics and materials science Electrical engineering and telecommunication		Clinical medicine Agriculture and food sciences Astronomy and astrophysics
Above average (1.10<RCI≤ 1.20)	Mathematics Biology Environmental science and technology Creative arts, culture and music	Basic life sciences	Management science Educational science
Average (.90<RCI≤1.10)	Earth science and technology Instruments and instrumentation Civil engineering and construction Law and criminology	Basic and experimental medicine Health science Medical engineering and other medical sciences Mechanical engineering and aerospace General and industrial engineering Political science and public administration	Psychology Economics and business Statistical sciences Other social and behavioral sciences Language and linguistics
Below average (RCI≤0.90)	Energy and fuels Literature	Sociology and antropology History, philosophy and religion	

* Research Specialisation Index (RSI): Share of field's output of research articles within the total publication output of the Netherlands during the years 2000-2003, compared to the corresponding average share of the field within the selected benchmark countries (unweighted by total publication output of each country).

** Relative Citation Impact (RCI): quantity of citations received during the years 2000-2003 by research articles with at least one author affiliate address in the Netherlands, as compared to the worldwide quantities of citations received within the same field of science and the same time-interval (fields of science corresponding with Thomson Scientific's Journal Categories)

Data source: CWTS/Thomson Scientific. Data treatments: CWTS.

The Netherlands cannot only boast of a high-performance science system, but also a very diverse one with a wide range of research-performing universities, institutes, medical centres, and business enterprises. **Table 13** presents an overview of this variety at the level of the main institutional sectors. This profile of the Dutch science depicts the distribution of research outputs broken down by institutional sector and by broad field of science. For example, the university sector (including the academic hospitals and medical centres) account for 71% of all Dutch research articles in the medical and life sciences, whereas the private sector contributes a mere 3%. All eight sectors have noticeable levels of research activity in these fields of science. Also listed are the citation impact statistics for each sector. Here we find a score of 1.18 for the Dutch university sector in medical and life sciences, 18% higher than the worldwide average score. Interestingly, the private sector reaches a citation impact of 30% above average in

Table 13 Research performance profiles of institutional sectors in the Netherlands

Share of institutional sectors of the total publication output per broad field of science (% P); citation impact score of sectors within broad fields of science (C) *,**

Broad field	Universities acad. hospitals		Non-univ. research inst.		Hospitals, med. centres		Government institutes		Other public institutes		Private sector	
	%P	C	%P	C	%P	C	%P	C	%P	C	%P	C
Medical and life sciences	71	1.18	13	1.34	11	1.11	1	1.06	1	1.07	3	1.30
Natural sciences	67	1.26	20	1.26	1	0.90	1	1.02	1	0.72	8	1.24
Engineering sciences	64	1.10	14	0.99	—	—	1	0.61	—	—	15	0.98
Agriculture and food sci.	37	1.15	51	1.35	1	N/A	1	N/A	—	—	10	1.50
Social sciences	84	0.98	9	1.20	3	0.82	1	N/A	1	N/A	2	1.16
Economics	82	0.94	10	0.94	—	—	4	N/A	—	—	2	N/A
Law	69	1.24	11	N/A	2	N/A	11	N/A	—	—	2	N/A
Arts and humanities	83	0.76	11	1.15	2	N/A	1	N/A	2	N/A	1	N/A

* Field-normalized citation impact score based on publications in 2000-2003 and citations received during the same time-interval. This normalized citation impact score indicates the extend to which a country's citation impact differs from the average impact score of all countries within the same field of science. The average score is fixed at 1.0 per field of science.

** Thresholds for inclusion:

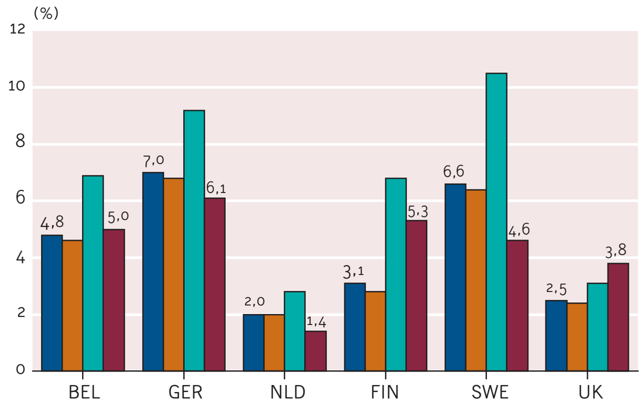
— Institutional sectors accounting for less than 1% of the total output of the Netherlands in a broad field in 2000-2003;

N/A Citation score is not available due to lack of publication output (i.e. based on less than 100 publications per institutional sector in 2000-2003).

Data sources: CWTS/Thomson Scientific. Data treatments: CWTS.

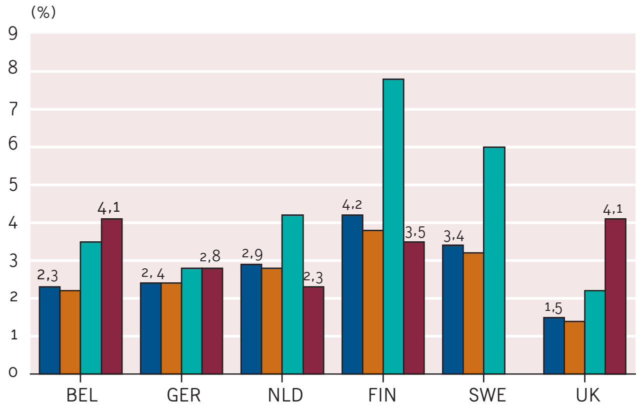
this field; although fairly small in terms of publication output, corporate science in the Netherlands appears to generate significant international scientific impact.
Generally speaking, scientific excellence is spread widely throughout the Dutch science system: the highly cited papers are not only being produced by universities, but also by government research institutes, hospitals, as well as companies. It goes without saying that the impact of Dutch research capacity, and its scientific performance, extends beyond its influence within international scientific communities; the research activities of academics also have a direct "societal" impact in terms of the research staff involved in teaching and training activities in which their knowledge and skills are transferred to their students and co-workers.
Overall, we observe that the Dutch research system offers a broad and high-quality organizational base in many fields of science. We owe this structure and its scientific achievements partly to R&D investments and policies in the past, often as early as in the 1970s and 1980s. Although the level of investment in the public sector has declined since the early 1990s, the indicators reveal a fairly efficient research system with relatively modest expenditure levels and comparatively high levels of productivity and international scientific impact. This state of affairs offers the kind of knowledge base that can make effective use of current increases in targeted investments by the Dutch government, aiming at achieving both research excellence and improved R&D infrastructure in the strategically important 'key areas' within our science, technology and innovation system.
Given the small size of the Netherlands, and the tightly knit research community, scientific co-operation has always been one of the pillars of Dutch science and a key driving force for future developments. The Netherlands can only perform at the highest level if its national science infrastructure remains of outstanding quality, both in terms of human resources and of technical facilities. Both the creation of favourable labour market conditions in order to facilitate top research, and an increasing concentration of resources, may facilitate an increase in the quality and efficiency of the research infrastructure. University research schools and *Leading Technological Institutes* (TTIs) are two of many examples. These government co-funded initiatives are specifically meant to enhance both economies of scale and focus within the Dutch science system. They serve to achieve critical mass within science fields by means of promoting more collaboration between the various relatively small

*Figure 14a Relevance of universities as information sources for innovation**



* % innovative companies that consider universities to be a 'very important' source of information
Data source: Eurostat (Community Innovation Survey 3). Data treatments: MERIT.

*Figure 14b Relevance of non-university research institutes as information sources for innovation**



* % innovative companies that consider non-university institutes to be a 'very important' source of information
Data source: Eurostat (Community Innovation Survey 3). Data treatments: MERIT.

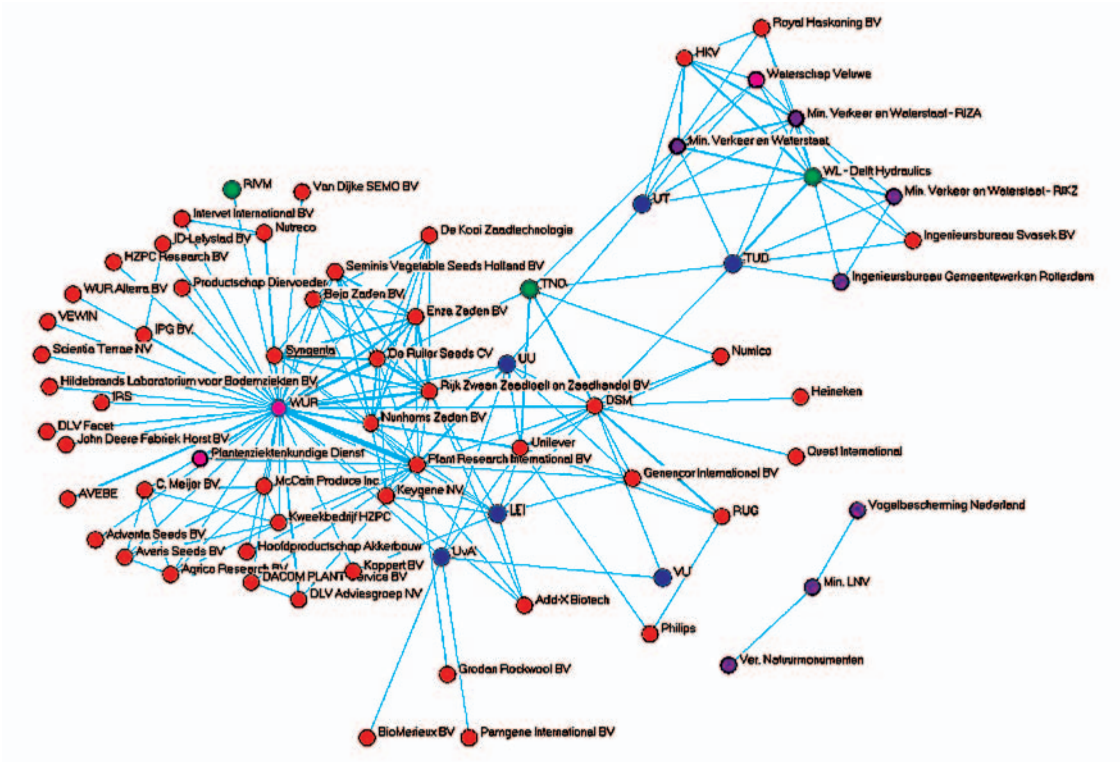
populations of Dutch researchers, leading to a more attractive infrastructure for foreign companies and external financers who are considering new R&D investments in the Netherlands.

7 Crossing the divide: public-private research linkages and networks

Public-private R&D co-operation is another major driving force, and binding factor, of the Dutch knowledge system. These networks of linkages between the public sector and the private sector, and the intermediate organizations supporting those linkages, encourage the utilization of scientific and technical knowledge produced by universities and other publicly funded research institutes. Befitting a small and densely populated country, the Netherlands benefits from a tightly knit network of R&D programmes - both formal and informal - in which the public sector and business sector participate, and where colleagues (and competitors) meet and cooperate. Dutch public and private organizations collaborate often in joint R&D projects, programs and networks. In doing so, universities and public research organizations 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.

The latest of Europe's *Community Innovation Survey* held in the Netherlands, presenting data for the years 2000-2002, provides insight in how companies perceive universities. One of the key results is that only 2% of all innovating companies in the Netherlands consider universities (in the Netherlands or elsewhere) to be a 'very important' information source. Although we find an increase in appreciation compared to earlier years (1.4% in 1994-1996), this share is still considerably below that of the benchmark countries (see **Figure 14a**). The main reason for this is the presence of a wide range of "intermediate" non-university research institutes within the Netherlands whose mission is to conduct applied and strategic research, and related services, for R&D-based business sectors. The Dutch private sector appreciates the contributions of these research institutes significantly higher than those of the university sector: 2.9% consider it 'very important', a score above the average of the benchmark countries (see **Figure 14b**).

Figure 15a R&D network among research organizations and business enterprises within the Netherlands in the field of life sciences,**,****

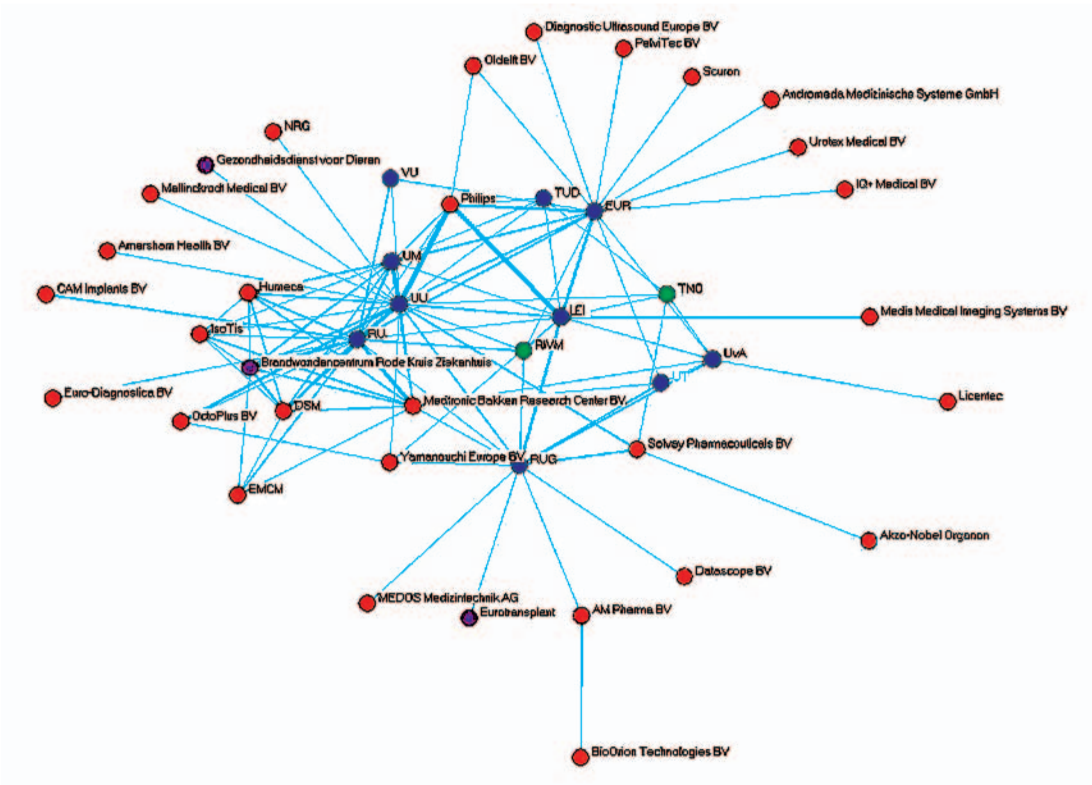


* Public sector organizations and enterprises active within the same research projects funded by the Dutch Technology Foundation (STW), either as research partners or through other modes of participation (co-funding, membership of advisory boards).
** The lines connecting different organizations and enterprises indicate two or more joint projects; the thick lines represent three of more joint projects.
*** Colour codes: blue - universities; green - public research institutes; red – business enterprises and private research institutes, purple – other public institutes.
Data sources: STW. Data treatments: CWTS.

Despite the fact that many of the knowledge intensive companies in the Netherlands often do not perceive research universities as prime sources of information for their innovation (in contrast to their views on intermediary R&D-organizations such as *TNO*), these companies do participate in several local and national R&D networks with both universities and other public research institutes. These public/private R&D alliances, networks and consortia are the backbone of the large BSIK program. They are primarily focused on knowledge and research capacities in applied areas of science, and many other applied research projects, such as those funded by the Dutch *Technology Foundation* (STW) and the Innovation-driven Research Programmes (IOPs). All Dutch universities, and many public research institutes, play a dominant role in STW-funded R&D projects and the BSIK program. These collaborative arrangements include all the large R&D companies located in the Netherlands, but also many of the innovative SMEs (small and medium sized enterprises).

The network graphs depicted in **Figure 15a** and **Figure 15b** are illustrative examples showing the network of linkages within STW-funded R&D projects dealing with the life sciences and the medical sciences. The linkages usually refer to the presence of company representatives in the STW advisory boards of research projects, while in other cases they reflect genuine R&D cooperation. Both graphs

Figure 15b R&D network among research organizations and business enterprises within the Netherlands in the field of medical sciences,**,****

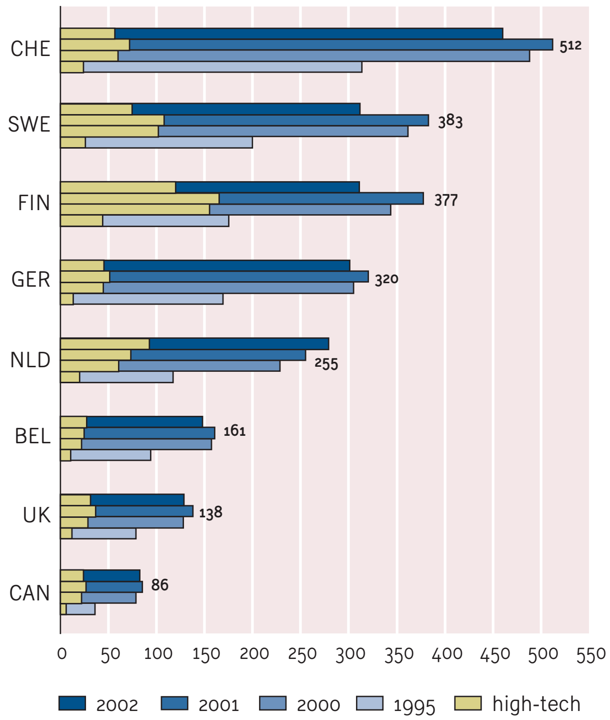


* Public sector organizations and enterprises active within the same research projects funded by the Dutch Technology Foundation (STW), either as research partners or through other modes of participation (co-funding, membership of advisory boards).
** The lines connecting different organizations and enterprises indicate two or more joint projects; the thick lines represent three of more joint projects.
*** Colour codes: blue - universities; green - public research institutes; red – business enterprises and private research institutes, purple – other public institutes.
Data sources: STW. Data treatments: CWTS.

depict a wide variety of public and private organizations, showing a few core organizations, usually universities that are centres of excellence in the field and major hubs of research activity. Many of the large R&D-based Dutch companies are active in these networks, especially the leading innovators and the R&D-intensive companies in the biopharmaceuticals industry, the food processing industry, and those developing advanced medical equipment. This includes a range of medium-sized or small biotechnology companies.

The volume of public-private co-publications in the research literature is a proxy measure of the nature and intensity of successful public-private research co-operation. About 70% of publications by Dutch corporate researchers are published jointly with researchers from the public sector, mostly university researchers. More than 50% of these corporate research publications originate from five companies: *Philips*, *DSM*, *Unilever*, *Akzo Nobel* and *Shell*. Many of these joint research publications represent cutting-edge basic science and are highly cited in the international research literature.

*Figure 16 Patent applications per million inhabitants**



* Patent applications at the European Patent Office (EPO). Patents as assigned to country of residence. Data for patent applications for 2002 are provisional and may differ from final data.
The ranking of countries is based on 2001 data.
Data source: EUROSTAT. Data treatments: MERIT.

Although patents that are filed at international patent offices are only the tip of the iceberg in terms of reflecting technical breakthroughs and innovations, these patent applications do offer a good first impression of the degree in which companies and economies are successful in the development and application of new technologies and techniques. Despite the very large patent production by *Philips*, the Dutch business sector shows an average patent performance compared to the group of benchmark countries (see **Figure 16** for the case of the patents at the *European Patent Office* - EPO). Dutch performance on high-tech patents is better, largely due to the large output of these specific patents by *Philips*.

The share of the (semi) public sector in Dutch patent production is comparatively minor. Both universities and non-university research institutes show a significant decline in the number of EPO patent applications in recent years. However, one must bear in mind that university inventions and technologies are usually transferred or sold to companies that file for patents, where university researchers are mentioned as co-inventors.

The comparatively limited amount of effort and funds devoted to further development of scientific discoveries into technologies and devices, and the commercialization of such science-based innovations by the business sector, is often seen as one of the major structural weaknesses of the European science system. This knowledge exploitation gap, often referred to as the "European Paradox", also features prominently as a focal point of attention within the Dutch science policy. The noticeable contrast between the good performance of the science system in terms of publication output and citation impact on the one hand, and the average performance in terms of patenting on the other hand, hints at a "Dutch Paradox". The Netherlands seems to be lagging behind the leading countries, such as the USA, that are better at successfully transferring scientific and technical knowledge into (patentable) technical inventions and other products with economic added value. Moreover, the rate of launching new knowledge intensive companies (including university spin-offs) also appears to be lagging behind the performance in other European countries. However, there are also positive developments; in 2004 and 2005 Dutch

Table 17 Impact of Dutch science on private sector research in the Netherlands and abroad

Share of Dutch business enterprises within private sector research articles with citations citing to other research articles produced by Dutch public sector organizations*; share of Dutch companies in the Dutch public-private co-authored research articles**

Field of science***	Citations from private sector research articles* % of field	% of Dutch companies	% Dutch companies in co-publications**
Medical and life sciences			
Clinical medicine	29.2	3.6	45.3
Basic and experimental medicine	19.2	4.5	53.0
Health sciences	1.4	5.1	74.0
Medical engineering and other medical sciences	1.1	7.8	70.1
Natural sciences			
Basic life sciences	16.6	6.6	66.5
Chemistry and chemical engineering	8.9	12.0	81.9
Physics and materials science	4.9	5.3	68.5
Biology	2.6	6.6	69.0
Environmental sciences and technology	1.7	7.6	78.0
Earth sciences and technology	1.3	2.1	57.9
Computer sciences	1.2	4.9	71.6
Engineering sciences			
Electrical engineering and telecommunication	1.1	11.1	76.5
Agriculture and food sciences	2.3	14.7	74.4

* Citing publications published in 2003; cited publication published in 2000-2003.

** Dutch public-private co-authored research articles published in 2003.

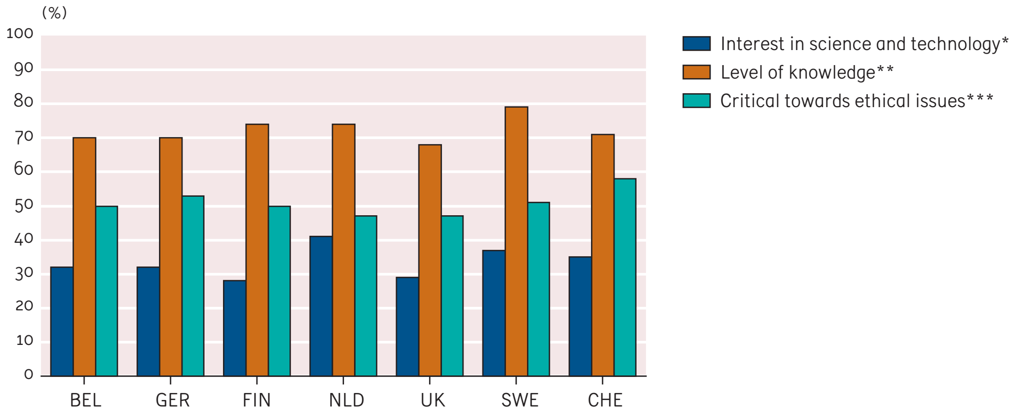
*** Criteria for selection of industrially relevant fields of science: (a) where the research articles are produced by Dutch public sector organizations and published in 2000-2003, (b) that received more than 100 citations from research articles produced by companies worldwide in 2003.

Data source: CWTS/Thomson Scientific. Data treatments: CWTS.

companies were very interested in so-called 'innovation vouchers', a new government initiative to promote knowledge transfer, that allow companies to buy R&D time, or specific knowledge or skills, from Dutch universities and research institutes.

Over the previous decades Dutch industry has been a significant source of funding for and a close partner of many Dutch universities and research institutes. Consequently, Dutch science has focused on those industrially relevant research areas of significant interest to R&D-intensive companies operating within these sectors, especially the large multinationals such as *Philips*, *Akzo Nobel*, *DSM* and *Unilever*. One way of assessing and monitoring the relevance of Dutch science for industry in broader context – both the Netherlands and worldwide – is to identify which corporate R&D laboratories are producing research articles that refer to articles by Dutch universities and research institutes. A second source of information is the set of joint research articles that are produced by corporate researchers in cooperation with their colleagues in the public sector (usually academics). Results of the statistical analyses of these cross-sectoral citations and co-publications are presented in **Table 17**. These findings clearly indicate that public/private R&D linkages span a range of R&D-intensive industrial sectors, but tend to concentrate in a few "core" sectors where ties have traditionally been particularly strong: food and agro-industry, chemicals, and electronics. Given the relatively large share of Dutch companies in public/private co-publications, the Dutch public research system is particularly relevant to Dutch industry in five fields of science: Chemistry and chemical engineering, Environmental sciences and technology, Agriculture and food sciences, Electrical engineering and telecommunications, and Health sciences. Judging by the citation flows from corporate research worldwide, these strategic fields for Dutch research also seem to be of particular interest to science-dependent industry in other countries.

Figure 18 Science and technology and the general public: level of interest, level of knowledge, and public attitudes
Share of respondents per country (2004)



* Survey questions 1-5, 1-6 and 6-1; average share of respondents within a country that were 'very interested' in "New inventions and technologies" en "New scientific discoveries", and "Read articles on science in newspapers, magazines, or on the Internet ".
** Survey questions 12a-1 to 12a-4, 12b-6, 13a-6, 13b-2 to 13b5, 15a-5; average share of respondents within a country with a positive view concerning the relevance of science and technology ('fully agree', or 'partially agree').
*** Survey questions 12a-5, 12b-1, 13b-6, 15a-1 to 15a-4, 15a6, 15b-6, 17-10; average share of respondents within a country with a critical view concerning ethical issues related science and technology.
Data sources: European Commission (Eurobarometer 2005). Data treatments: CWTS.

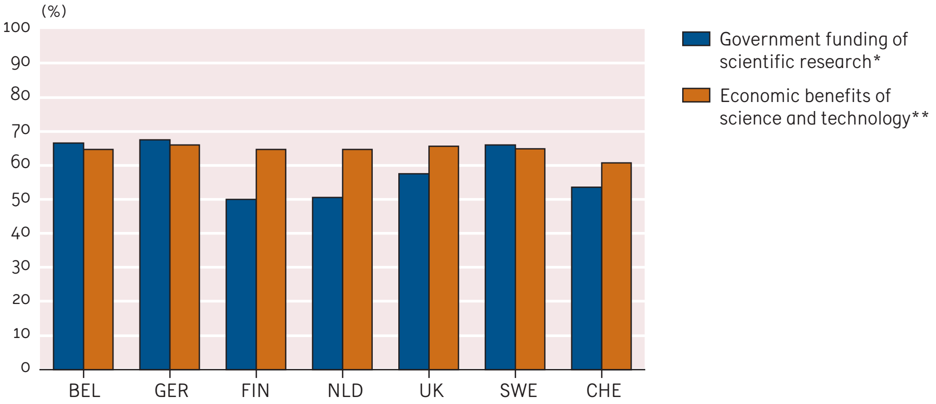
8 Science, technology and the public: views, opinions and attitudes

A recent survey conducted among the Dutch population revealed that only 25% of the Dutch feel that they are sufficiently informed about the knowledge economy, whereas more than 50% state that they are being insufficiently informed. Not surprisingly, these views are partially related to the socio-economic background and educational level of the survey respondents. For instance, the majority of the lower skilled population in the Netherlands indicates that they have insufficient schooling and skills in order to compete and fully participate in the knowledge economy; in particular they consider their know-how for handling high-tech equipment and tools to be inadequate.

Looking at knowledge transfer from the other end, another recent survey conducted in the Netherlands among university professors, showed that 13% of them spend a significant fraction of their time on transferring knowledge to society. About 60% of that time is spent on domestic transfer, 30% is internationally oriented, and 10% is focused on the local region. With regard to the target groups, 40% is spent on transfers to governments and public sector agencies, 30% to business sectors, and the remaining 30% relates to the general public. Almost two out of three professors agree that it is their responsibility to popularize science, the same fraction is not opposed to the view that scientists should interfere in the public debate on science.

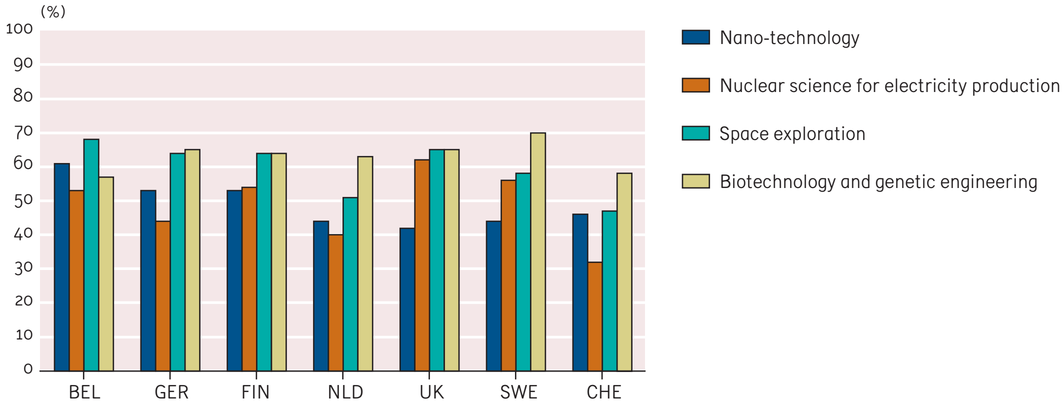
Data from a recent large-scale *Eurobarometer* survey conducted within the European Union indicate that the interest of Dutch people in scientific and technical subjects is among the highest within the group of benchmark countries: more than 40% of the Dutch are very interested in new scientific discoveries, inventions and technologies (see **Figure 18**). The general level of factual knowledge about science and technology within the general public is only slightly less than that of the benchmark countries. The survey results show that the Dutch are also fairly similar to other European countries with respect to their views on ethical issues related to the social responsibilities of researchers and applications of science and technology in general.

Figure 19 Science and technology and the general public: government funding and economic benefits
Share of respondents per country (2004)



* Survey questions 13a-1 and 17-1; average share of respondents within a country with a positive view ('fully agree', or 'partially agree').
** Survey questions 12b-2, 12b-4, 13a-2, 13a-3, 13a-5, 13b-1, 15b-1, 17-7, 17-9; average share of respondents within a country ('fully agree', or 'partially agree').
Data sources: European Commission (Eurobarometer 2005). Data treatments: CWTS.

Figure 20 Public views with respect to the positive impacts of new technologies
Share of respondents per country (2004) *



* Percentage of respondents (age 15 or older) expecting the technology to have a positive impact on 'our way of life during the next 20 years'.
Data sources: European Commission (Eurobarometer 2005). Data treatment: CWTS.

The Dutch are also relatively positive with regard to the economic significance of science and technology, in particular the role of scientific research and technological development within industry, although they are significantly less in favour of increasing government spending on scientific research compared to the other countries (see **Figure 19**).

Dutch people seem more sceptical with regard to the added value of more investments in science. This cautious attitude is also reflected in the views of the Dutch public about future benefits and positive impacts of space exploration, nuclear energy, and nano-technology (**Figure 20**).

List of abbreviations

BSIK	Decree regarding Subsidies for Investment in the Knowledge Infrastructure (Besluit Subsidies Investeringen Kennisinfrastructuur)
CERN	European Organization for Nuclear Research (Organisation Européenne pour la Recherche Nucléaire)
ESA	European Space Agency
ESO	European Southern Observatory
EMBL	European Molecular Biology Laboratory
GTIs	Large Technological Institutes (Grote Technologische Instituten)
HOOP	Higher Education and Research Plan (Hoger Onderwijs- en Onderzoeksplan)
IOP	Innovation-driven Research Programmes (Innovatie-gerichte Onderzoeksprogramma's)
KNAW	Royal Netherlands Academy of Arts and Sciences (Koninklijke Nederlandse Akademie van Wetenschappen)
NWO	Netherlands Organisation for Scientific Research (Nederlandse Organisatie voor Wetenschappelijk Onderzoek)
R&D	Research and Development
STW	Technology Foundation (Technologiestichting STW)
TNO	Netherlands Organisation for Applied Scientific Research (Nederlandse Organisatie voor Toegepast Wetenschappelijk Onderzoek)
TTI	Leading Technology Institutes (Technologische Topinstituten)

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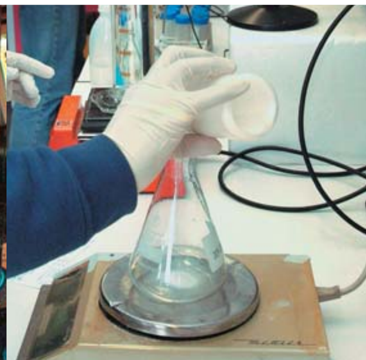

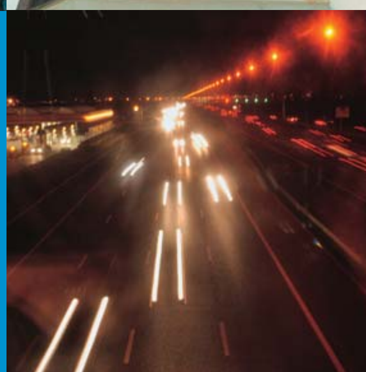

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