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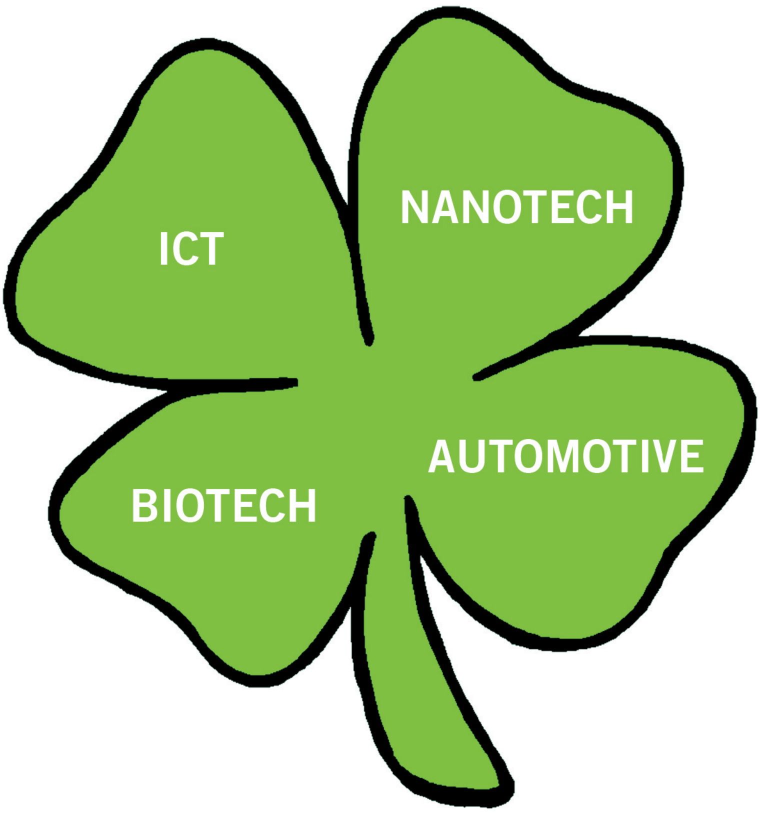
VA 2007:15

NEEDS-DRIVEN R&D PROGRAMMES IN SECTORIAL INNOVATION SYSTEMS



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VINNOVA´s mission is to *promote sustainable growth*
by funding *needs-driven research*
and developing *effective innovation systems*.

Through its activities in this field, VINNOVA aims to make a significant contribution to Sweden´s development into a leading centre of economic growth.

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Needs-driven R&D programmes in sectorial innovation systems

by

Lennart Norgren, Rolf Nilsson, Eugenia Perez, Hans Pohl,
Anna Sandström and Patrik Sandgren

Foreword

VINNOVA’s field of responsibility is innovation allied to research. In other words, groundbreaking, successful products, services or processes with a basis in science. Its task is to fund the research needed by competitive industry and a prosperous society; so-called needs-driven research. This report describes the roles of needs-driven R&D funding from an innovation system perspective. It provides a picture of industrial activity and innovativity as well as research and needs-driven state R&D programmes in the sectorial innovation systems for biotechnology, nanotechnology, information and communication technology and the automotive industry in Sweden. The analyses of innovation systems upon which the descriptions in this report are based comprise one of several contributions in VINNOVA’s work of identifying the needs of R&D programmes within each sectorial innovation system.

The report was written by Lennart Norgren, Rolf Nilsson, Eugenia Perez, Hans Pohl, Anna Sandström and Patrik Sandgren.

VINNOVA, September 2007

Göran Marklund
Director and Head of
Strategy Development Division

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1 Globalisation and innovations

"Research saves Sweden" was the headline of an article in Dagens Industri in February 2006 on the globalising effect of intensified competition from Asia and Eastern Europe. The article described a report by the international auditing and consultancy company, KPMG. This report maintained that Sweden is one of the few countries in the Western world that is investing sufficiently in research and development to survive the competition and keep production in the country. Succeeding as a country in the future requires major investments in research and development, as this is the only way Sweden will have an advantage over the Asian countries.[1]

The previous government also emphasised research and development as an important condition for the competitiveness of Swedish industry. In June 2004, it presented its innovation strategy: *Innovative Sweden – a strategy for growth through renewal* (Ds 2004:36) to strengthen Swedish competitiveness. Following his keynote speech in 2004, the Swedish Prime Minister convened strategic discussions with several industries aimed at working out strategy programmes with them. The industries invited were Aerospace, Automotive, IT/Telecom, Forestry/Timber, Metallurgy and Pharma/Biotech.

The strategy programme presented at the end of 2005 began with the following preamble: "The government's understanding of how we should meet the international competition is clear. Sweden should compete through knowledge, innovation and renewal. We should not compete on the basis of low wages and poorer working conditions. We should continue to be highly placed in the manufacturing value chain and evolve with high-technology and the international markets. The role of the state is to create the conditions for Sweden to have the world's best research and training, a stable national economy, a first-class business climate and a smooth-running innovation system. Developing the conditions for innovation, for production, and for business is crucial if Sweden is to go on succeeding in the face of increasingly tough international competition."[2]

Globalisation is a phenomenon described either as a threat to Swedish growth and welfare or as an opportunity for increased growth. The implication of the term "globalisation" is that competition is intensified as a

[1] Dagens Industri, 16/2/06
[2] See for example "The IT and telecom industry – a part of Innovative Sweden". Government Offices of Sweden, 2005.

result of goods and services being bought and sold on a global scale and that prices tend to fall over time. Some of the preconditions for globalisation are: increasing mobility of production factors as a result of international deregulation in fields like commerce, the rise of low-cost countries in Eastern Europe and Asia and pressure from financial capital for ever-increasing output. For Sweden, competition from "low-wage countries" in Eastern Europe and Asia has come to mean that companies in labour-intensive industries are increasingly relocating standardised production and routinised services. But there is also a loss of research and knowledge-intensive jobs. Companies are seeking access to a workforce with a high level of skills and to environments with advanced R&D in order to strengthen their competitiveness.[3]

The consequences of globalisation are numerous, but the core factor is that cost pressure resulting from intensified competition is making companies concentrate on activities of which they have real mastery. To achieve competitive advantages on the global market, companies are therefore tending to *specialise* in a small number of activities. They are concentrating on one or more product areas and phasing out others. Parts of operations in a product area which other companies carry out more efficiently are phased out and purchased instead from them (outsourcing). This can apply to both support functions in the operation and components in the products. Outsourcing to foreign suppliers may involve shrinkage of Swedish industry; however, this need not be the case. The automotive industry in Sweden is an example of specialisation not needing to mean shrinkage in the sector. It has come to specialise in assembly and some components as well as intelligent control systems and vehicle and road safety, whilst other components are purchased from both Swedish and foreign suppliers. Despite this, the automotive industry currently employs more people than it did 10 years ago.[4]

The pressure of costs resulting from international competition also means companies are continuously compelled to rationalise their operation in order to reduce their costs. This means production is made more efficient in Swedish plants and/or that production moves overseas, chiefly to low-cost countries (offshoring). The hunt for cost reductions also adds pressure for quicker and more efficient transportation, reduced/eliminated warehousing, development of new production technology and more efficient product development plus leaning on suppliers for cheaper production. Globalisation also demands continuous *rationalisation* in the specialised company and its suppliers.

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[3] Isaksson, P, 2006.
[4] VINNOVA, VP 2006:01

Companies can also meet cost pressure with *product innovations*. They develop and launch new goods and services with improved properties. In order to meet the global competition, companies must continuously renew goods and services. Those companies which are unable to bring out internationally competitive new products will, in the long-run, be forced into price competition with low-wage countries.

Those products which Swedish industry is currently selling in order to survive are the result of yesterday's investment. Tomorrow, somebody else will have learned to make cheaper or better products – often both. Companies' ability to create innovations – new or better products and processes – are crucial to their international competitiveness. An important pre-requisite for this capacity is that companies invest in research and development (R&D). A forthcoming study from Jönköping International Business School shows that on an industry level, there is a positive correlation between the intensity of R&D in an industry and export growth: the higher the R&D intensity, the higher the export growth. The explanation presented for the correlation is that R&D generates internationally competitive innovations which can be exported.[5]

The majority of innovations arise from the combination of need and knowledge of what is technically achievable. Innovations also combine knowledge from a range of sources; market, technology, design etc. Companies put the majority of their "innovation resources" into improving existing goods, services and processes based on knowledge of customer demand. To some extent, resources are being directed into new products which satisfy as yet unarticulated demand.

Companies are not self-sufficient in the knowledge and expertise necessary to develop innovations. They use other companies, customers and suppliers as well as universities and research institutes. Research from these can contribute to corporate innovations in a number of ways. It can bring new technical opportunities and knowledge to solve technical problems. The research also fosters a base of knowledge and expertise which companies can exploit through recruitment. The majority of the research at universities and research institutes is publicly funded, but companies also fund such research in order to support their own R&D.

This report deals with innovations, research and development and state-funded R&D programmes. It provides a picture of innovativity, R&D investment and state R&D funding on both the national level and in four

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[5] Andersson, M. & Johansson, S. 2006.

sectorial innovation systems. It also describes the roles played by state-funded R&D programmes in various types of sectorial innovation systems.

1.1 Innovative performance in Swedish industry

International competition is increasing demand for companies to be innovative and renew their operations in terms of both product portfolio and production processes. How do Sweden and Swedish industry perform in an international perspective with regard to such renewal? There are a large number of international studies which rank countries on the basis of competitiveness or innovative capability. Sweden appears amongst the leaders in several of them.

One of the most widespread measurements is carried out by the European Commission. Its comparison, entitled "European Innovation Scoreboard" is based on a harmonised measurement of 26 indicators, grouped into five connected blocks jointly reflecting different aspects of relevance for a country's long-term economic competitiveness.[6] The block of indicators is also merged into an overall summary called the European Innovation Index. According to the 2005 ranking, Sweden was placed at the top; Sweden has occupied a leading position with Switzerland, Finland and Denmark for a number of years.[7]

Since 2005, under the framework of the European Innovation Scoreboard, measurements have also been taken of the total of 25 industries.[8] Sweden ranked high in eight of them, with particularly strong results for certain sectors in traditional manufacturing.[9]

Another widespread measurement is the Growth Competitiveness Index, which is the World Economic Forum's annual ranking list of countries'

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[6] http://trendchart.cordis.lu/tc_innovation_scoreboard.cfm

[7] The results for Sweden are particularly impressive where it concerns lifelong learning, research and development in industry and patenting. However, it should be noted at the same time that advancement compared with other countries is shrinking and that Sweden has a negative trend compared with previous years. Levels below the EU average have also recorded for two indicators. Industrial funding of research carried out at Swedish universities and a low proportion of high-tech exports.

[8] The purpose of the measurement is to gain a clearer sense of innovation capacity on a sector level; the measurement is based on a total of 12 indicators. Since the results are, to some extent, based on estimates and compiled from a harmonised mean value for the EU, they should be interpreted with caution. Indicators in the survey have been merged into an "Innovation Sector Index" (ISI). The overall result shows that Sweden, with Finland and Germany, has the highest ISI when all sectors are compared.

[9] However, it is worth noting that if only the Swedish sectors are compared, the teleproduct industry, computer services sector and chemical industry (including the pharmaceutical industry) attain the highest ISI value whilst the automotive and pulp and paper industries are below the EU average.

growth capacity.[10] Sweden, plus the US and Finland are positioned amongst the most competitive countries in the world. Prior to the 2006 ranking, the index was reworked in order to better capture more factors of significance to international competitiveness. The 2006 year's index is therefore not entirely comparable with ranking lists from previous years. So as to be able to assess change over time, the 2005 index has been reworked taking into account the new indicators. These are grouped into nine categories, including: institutions, infrastructure, macroeconomics, inclination to change, higher education, market efficiency and innovativeness.

In 2006, Sweden came in third place after Switzerland and Finland. Compared with the reworked 2005 index, Sweden has advanced from 7th place. Swedish areas of strength include technological readiness and higher education, where Sweden takes first and third place respectively. Sweden is less well-placed in market efficiency and macroeconomic foundations, where it comes in at 19th and 15th places respectively.[11] In an underlying index (Business Competitiveness Index) measuring the conditions for industry to increase its efficiency and productivity, Sweden advanced from 11th place to 7th place.[12] The US, Germany and Finland come top.

The UN also carries out measurements of countries' capacity for renewal. The Innovation Capability Index was presented in 2005 by the UN body, UNCTAD in its "World investment Report 2005"[13]. The Innovation Capability Index consists of indicators reflecting the country's technological activity (based on R&D investment, patent activity and scientific publication) plus the skill of the population (based on the educational level of the population). Sweden takes first place in this index in front of Finland, the US, Denmark and Norway. There was no update of the index in the 2006 edition of the World Investment Report.

IMD (the Institute for Management Development) publishes an annual ranking list of countries' international competitiveness. This ranking is based on some 300 criteria and is a combination of quantitative data and interviews with executives, broadly arranged into four groups; economic results, public sector efficiency, industrial efficiency and infrastructure. In the 2006 IMD list, Sweden came in 14th place, which means that Sweden occupies the same position as in 2005. In 2004, Sweden took 11th place and

[10] http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm
[11] http://www.weforum.org/pdf/Global_Competitiveness_Reports/Reports/gcr_2006/sweden.pdf
[12] http://www.weforum.org/pdf/Global_Competitiveness_Reports/Reports/gcr_2006/BCI.pdf
[13] UNCTAD World Investment Report, 2005

in 2003, 12th place. The US has placed first in recent years and in 2006 was followed by Hong Kong, Singapore and Iceland.[14]

Caution should be exercised in drawing far-reaching conclusions from these indices but as the review shows, Sweden is amongst the most prominent in several of the ranking lists and has been so for a succession of years. One explanation for this is partly that the studies utilise the same indicators. In the IMD study however, Sweden has a somewhat poorer position than in other studies. This is largely based on subjective survey responses but partially on other indicators. It should also be kept in mind that all indices are primarily based on indicators describing innovation inputs such as investment in research and development (R&D). This means the indices are more a reflection of conditions for renewal than of actual renewal.

Innovative performance of Swedish companies in a European perspective

Data on innovations and innovation activity in Swedish companies is collected by Statistics Sweden under the framework of the EU's Community Innovation Survey (CIS).[15] The most recent is related to the period 2002-2004.[16] During the period studied, a company with innovation activity was defined as:

- had introduced product or process innovation in 2002-2004 which was new, at least for the company
- had ongoing (not concluded) or discontinued activity during 2002-2004 to develop or introduce product or process innovations.

For a company to be classed as innovative it is sufficient for the new product or process to be new to the company; in other words, the product in question need not be new on the market. Also, the second criterion means companies can be considered innovative even if they had not launched a new product or process during the period.[17]

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[14] The challenges which have been identified for Sweden are: to get more people to do more work and to train, to strengthen the industrial sector, to support newly established enterprise, to encourage research in small and medium-sized companies and to foster business opportunities in the Baltic. IMD also confirms that there is no clear-cut correlation between total tax burden and growth. On the other hand, it is important to have a simple taxation system and for the money to be used efficiently.

[15] The purpose is to provide a picture of corporate innovation activity in member countries. The questionnaire was devised by Eurostat, the EU's statistical body in collaboration with the member countries. The survey covers manufacturing and service companies (SNI 10-74.3) with at least 10 employees.

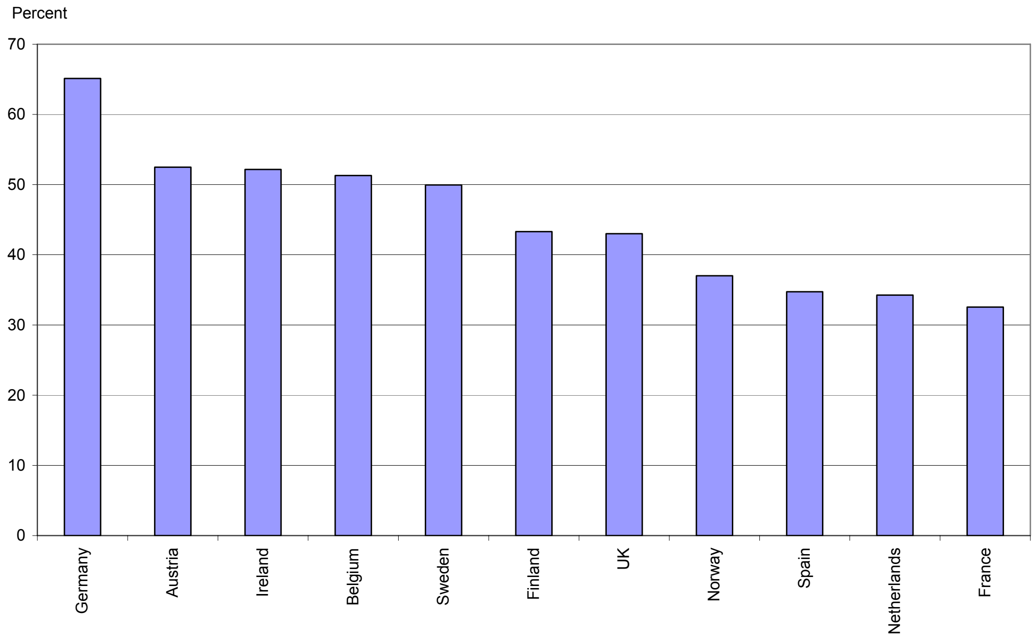
[16] Statistics Sweden, 2006. "Innovation activity in Swedish companies, 2002-2004".

[17] Companies which state that they had not introduced a new product or production process, or have discontinued such processes are defined in the study as non-innovative. But they may only be regarded as non-innovative during the three-year period being studied. They

For the period 2002 to 2004, 49% or just under 9,000 out of just over 18,000 Swedish companies with at least 10 employees were "innovative" according to the two criteria.[18] Of the innovative companies, 95% had either introduced a product innovation (32%) or process innovation (21%) or both (42%). Thus, only 5% had discontinued or not concluded their innovation activity during the period (criterion 2).

In a European comparison, Sweden thereby occupies a relatively advanced position (figure 1.1.1). In Germany however, the proportion of innovative companies is significantly higher (65%). Austria, Belgium and Ireland show around the same proportion as Sweden. Finland and Great Britain show a somewhat lower proportion, whilst the proportion for Norway, Spain, the Netherlands and France is considerably lower.

Figure 1.1.1 Proportion of innovative companies in some European countries, 2002-2004



Source: http://ec.europa.eu/eurostat/

A common European pattern is that the proportion of innovative companies is greater amongst large rather than small companies. In Sweden, the proportion of innovative small companies (10-49 employees) was just under 45%, whilst that for large companies (250 or more employees) was just over 75%. The corresponding figures for Germany were 60% and 90%.

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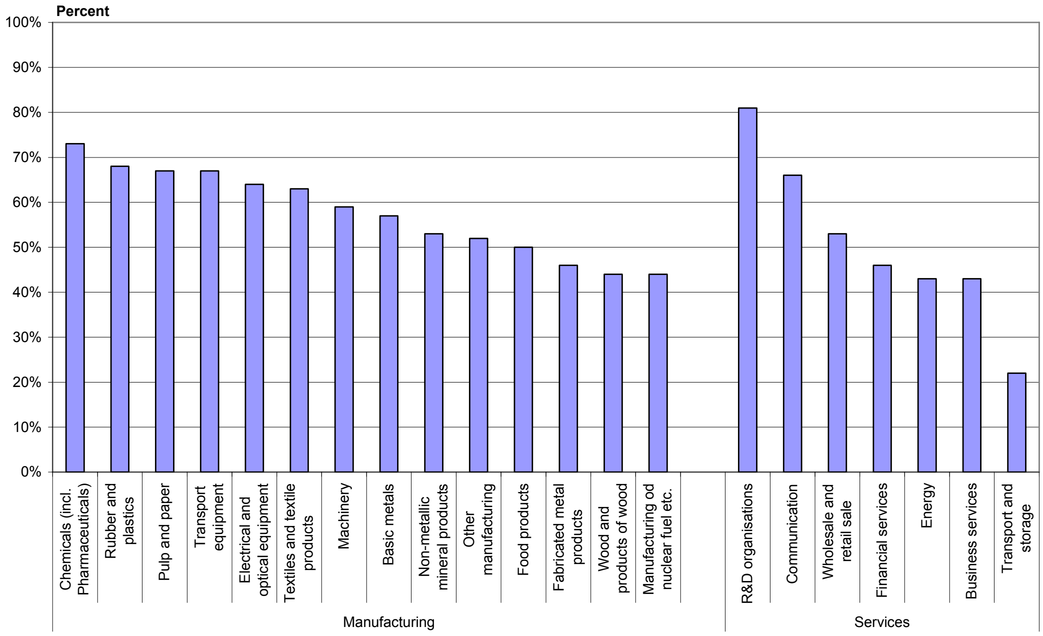
may have introduced products and run innovation activity prior to 2002. Almost 50% of these "non-innovative" companies were also identified as innovative in the study for the period 2000-2002.

[18] An increase of two percentage points since earlier measurement for the years 1998-2000.

In Sweden, the industry showing the highest proportion of innovative companies is R&D organisations, an industry in the service sector (figure 1.1.2). Clearly the lowest proportion shown is transport and storage. Within the manufacturing sector, the chemical industry which includes the pharmaceutical industry shows the highest proportion of innovative companies. Although there are exceptions, such as the rubber and plastic industry, industries which invest a great deal in research and development show a higher proportion of innovative companies than industries where not much is invested in research and development.

Figure 1.1.2 Proportion of innovative companies in Swedish industries, 2002-2004.

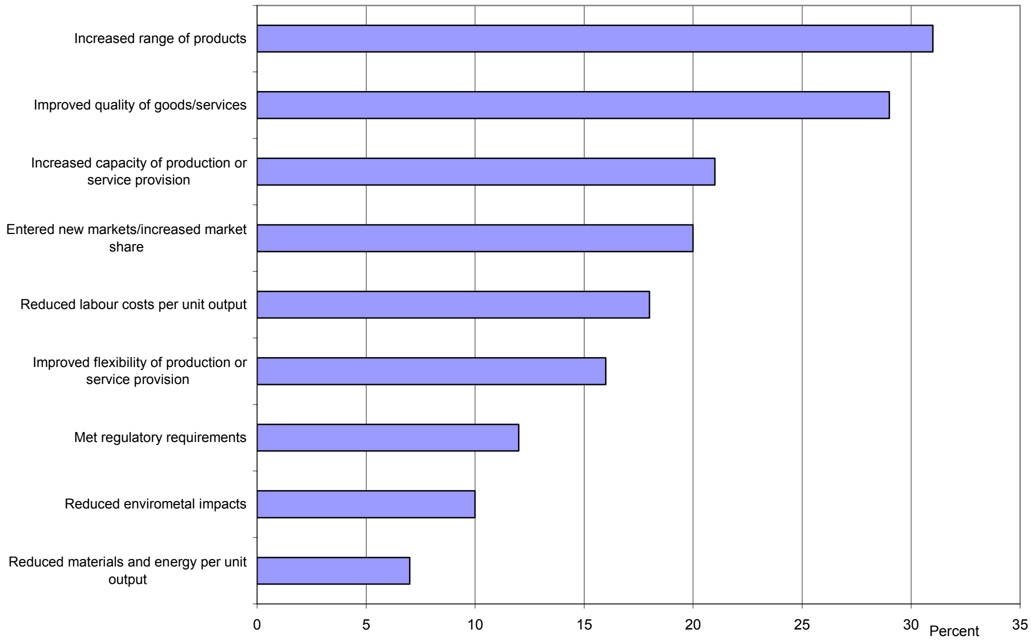


Source: SCB 2006, Innovationsverksamhet i svenska företag 2002-2004

Just as with Sweden, the proportion of innovative companies also varies between industries in other countries. The common denominator is that the proportions are uniformly higher in the manufacturing sector than in the service sector. Some industries have a high proportion of innovative companies in all countries. This applies to the chemical industry (including the pharmaceutical industry), the electrical and optical industry and the transport equipment industry. Within the service sector, R&D organisations generally show a high proportion of innovative companies.

In Sweden, the two most common impacts of the innovations were an expansion in the product range and/or an improvement in the quality of goods/services. For one in five companies, the innovations gave access to new markets (figure 1.1.3).

Figure 1.1.3 Proportion of innovative companies in Sweden that stated each of the impacts of innovations launched 2002-2004.



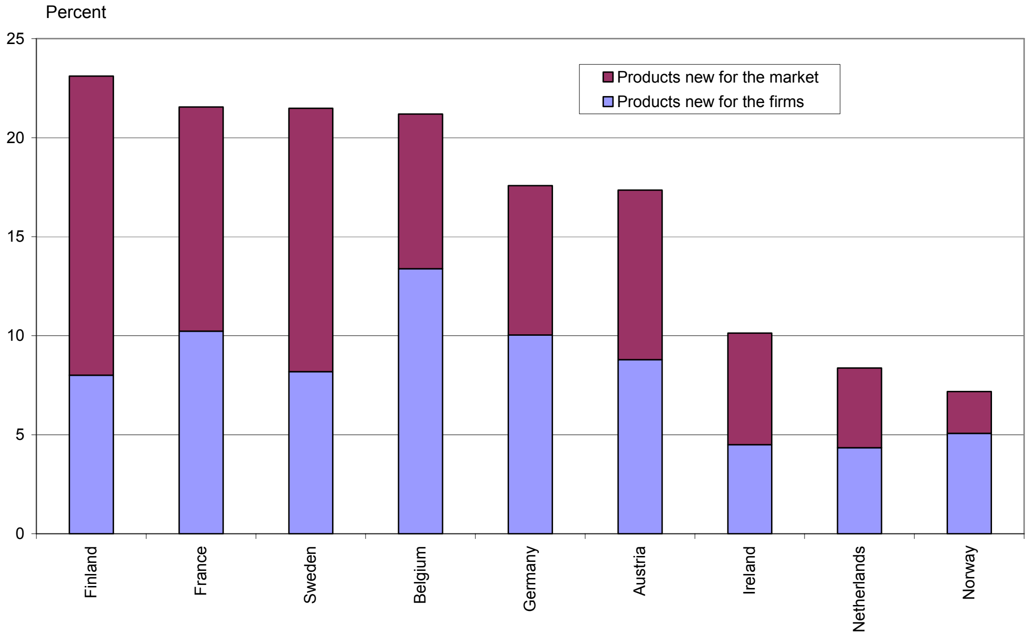
Source: SCB 2006, Innovationsverksamhet i svenska företag 2002-2004

Note: Companies could state several impacts

There are industry-based differences in regard to the impact of innovations. In the chemical industry, which includes the pharmaceutical industry, just under 40% of companies stated that the innovations involved access to new markets/increased market shares. Amongst R&D organisations, the corresponding proportion was 45%. This can be compared to companies operating in the textile and textile products industry as well as the wood and products of wood industry where 4% and 10% respectively of the innovative companies stated that a significant impact was access to new markets/increased market shares. For these industries, a clearer impact was increased capacity for production of goods or service provision.

A measure of the degree of innovativity in the CIS study is new products (goods and services introduced 2002-2004) as a proportion of 2004 corporate and industrial turnover. The distinction here is between products which are new to the market and those which are new to the company but not to the market. In a European comparison, Sweden is placed somewhat after Finland, where the proportion of turnover from new products was just over 23% (figure 1.1.4). Looking just at the proportion of turnover from products which are new to the market, only Finland shows a higher proportion than Sweden.

Figure 1.1.4 Proportion of turn over in innovative companies in 2004 that came from new products launched 2002-2004

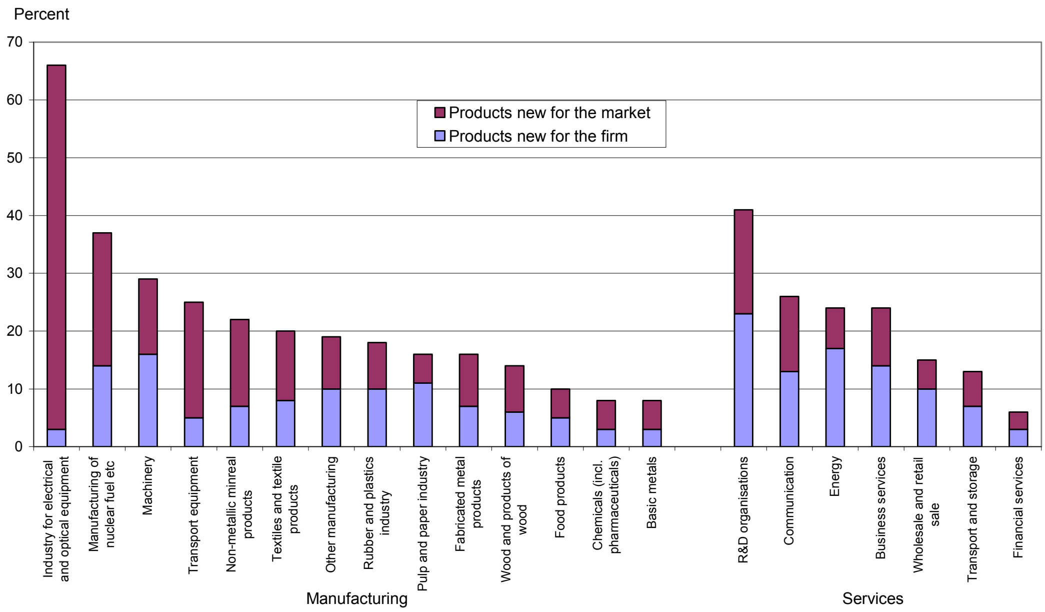


Source: http://ec.europa.eu/eurostat/

For all countries, the proportion of turnover from new products is greater within the manufacturing sector than it is in the service sector. For individual industries, there are some for which the majority of countries show a higher proportion compared with the average for the whole economy. This applies to the electrical and optical equipment industry, machinery and transport equipment industry. In the service sector, R&D organisations show a large proportion of turnover from new products in the majority of countries.

In Sweden, the differences amongst the industries are great (figure 1.1.5). In certain industries, the proportion of turnover from new products is very high. For example in the electrical and optical equipment industry this proportion reaches 66% of turnover and 63% of turnover comes from products new to the market. For the R&D organisations, 41% of the turnover came from new products and 18% came from products new to the market.

Figure 1.1.5 Proportion of turn over in Swedish innovative companies in 2004 that came from new products launched 2002-2004 distributed by industries



Source: SCB 2006, Innovationsverksamhet i svenska företag 2002-2004

With some exceptions there is a positive correlation between R&D investment and proportion of turnover coming from new products. One exception is the chemical industry (including the pharmaceutical industry) and a likely explanation is the long development times for things like drugs, combined with the great longevity of a successful drug. This implies that the turnover for pharmaceutical companies derives largely from drugs which have been introduced onto the market more than three years previously. According to AstraZeneca, the average development time for a drug is 12 years with the average development costs running to approx. USD 900 million.[19] In other words, there is also a correlation between the longevity of the industry's products and the proportion of turnover coming from new products.

Innovative performance of Swedish industry in a global perspective

The CIS study only covers Europe and there are no comparable studies in other countries. When comparing the innovativity of countries, the patenting of inventions is often used as an indicator of technical development and innovations. However, as an indicator of innovation, patent data is often encumbered with problems. An initial problem is that inventions and innovations are not always patent-protected. Occasionally for example, it is

[19] http://www.astrazeneca.se/Forskning/versikt.aspx?l1=6&l2=4&l3=&l4=1&pid=16324

more important for the company to quickly get a good or service out on the market than to wait for the invention to become patent-protected. This is particularly common in fields with short product lifespan and the result is that patent data does not capture all the innovations that have taken place in an economy. Thus, in this case, patent indicators underestimate the innovativity of companies.

Another problem of utilising patent statistics as an indicator of innovativity is that not all inventions which are patent-protected become commercialised.[20] At this point therefore, the indicator overestimates corporate innovativity. Patenting frequency is also dependent upon changes in corporate patenting strategies. Many companies such as Ericsson and ABB have changed their patenting strategy in recent years and partially abandoned the strategy of bombardment with patents in favour of being selective about what should be patented.[21]

In order to achieve international comparability, it is important to compare patenting within one and the same patenting system, for example at the European Patent Office (EPO) or patents at the United States Patent and Trademark Office (USPTO). At USPTO, the US is the country which dominates patenting activity both in terms of absolute figures for patents and related to the population.[22] If patenting activity is studied in relation to the size of population, Japan comes in second place close after the US, followed by Switzerland and Finland (figure 1.1.6). Sweden comes in fifth place with just under 160 patents per million inhabitants. In 2004, the Swedish proportion of patents, out of all patents granted at USPTO, was around 1%. Countries which, in relation to their size, are highly placed in

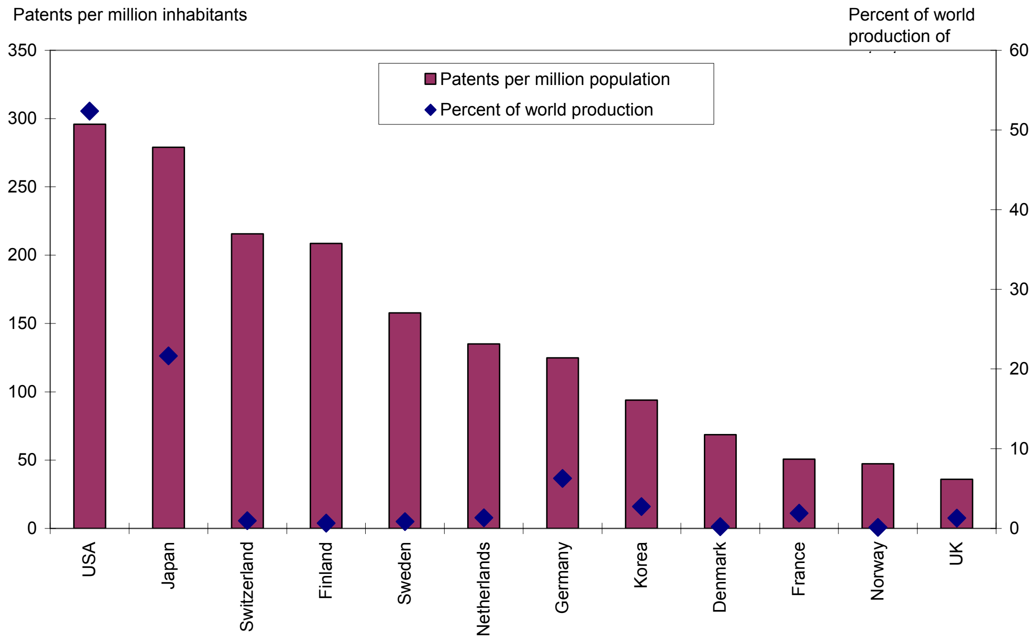
[20] A common reason for this is that the commercial value of patents is often too little for commercialisation to be economically profitable. Another reason for a lack of commercialisation is that the patent has been taken for defensive purposes in order to protect a company's existing products. A lack of commercialisation need not therefore mean that the patent is valueless for the patenting company. This problem is related to a general problem to do with the fact that not all patents are equally valuable. On the contrary, economic value varies greatly from patent patent. Empirical studies have shown that patents of very great economic value only comprise a very small proportion of the total number of patents.

[21] http://www.nyteknik.se/art/26673

[22] However one problem here is that it is more common for a company to apply for a patent in its immediate vicinity than in areas a long way from its location. This phenomenon is generally known as home market advantage and means that in patent data analyses from USPTO for example, patents from the US and countries with close ties with the US are overestimated relative to countries where ties to the US are weaker. Correspondingly, the patenting of European countries is overestimated relative to countries with weaker ties to the European market.

regard to patenting correlate with those countries which are well-placed in the various innovation indices presented in section 1.1.[23]

Figure 1.1.6 Granted USPTO patents in relation to population and as a proportion of all granted USPTO patents in 2004.



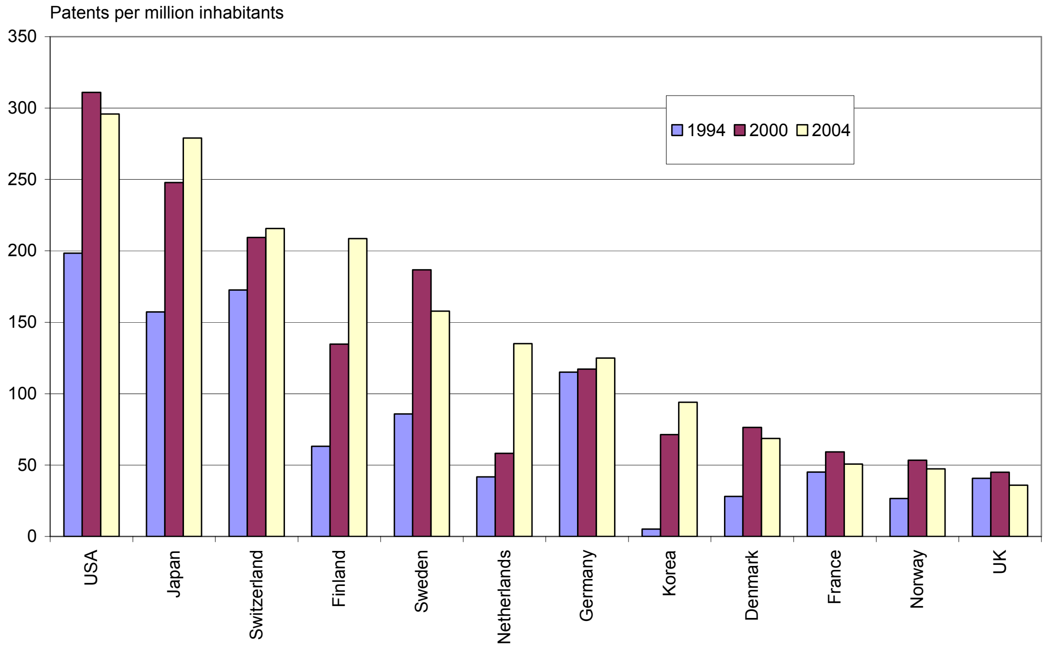
Source: OECD Patent Database

Over time, there has been an increase in patenting at USPTO in the majority of countries.[24] During the period 1994-2004 Finland more than trebled its patenting relative to the population, meaning that it overtook both Sweden and Germany. The majority of the increasing patenting from Finland can be attributed to the ICT field. Swedish patenting at USPTO more than doubled during the period 1994-2004. Here too, increased patenting in the ICT field comprises an important explanation for the increase in total patenting activity, just as is the case with countries like Finland, the US, Japan and Korea. However, Swedish patenting at USPTO in the ICT field has levelled off and even somewhat reduced in the last few years (figure 1.1.7).

[23] A partial explanation for this is that patents are an indicator often included in the innovation index.

[24] Time series analyses of patients are encumbered with a number of problems. In the first place, changes to patent regulations can mean that patenting increases or decreases over time. In many countries, the patent protection has strengthened over time. Furthermore, certain countries have also introduced the right to software patents, which is also a contributory explanation for the increase in patenting which has taken place over time. In addition, a time series analysis of patenting is sensitive to changes in corporate strategies.

Figure 1.1.7 Granted USPTO patents in 1994, 2000 and 2004 in relation to population.



Source: OECD Patent Database

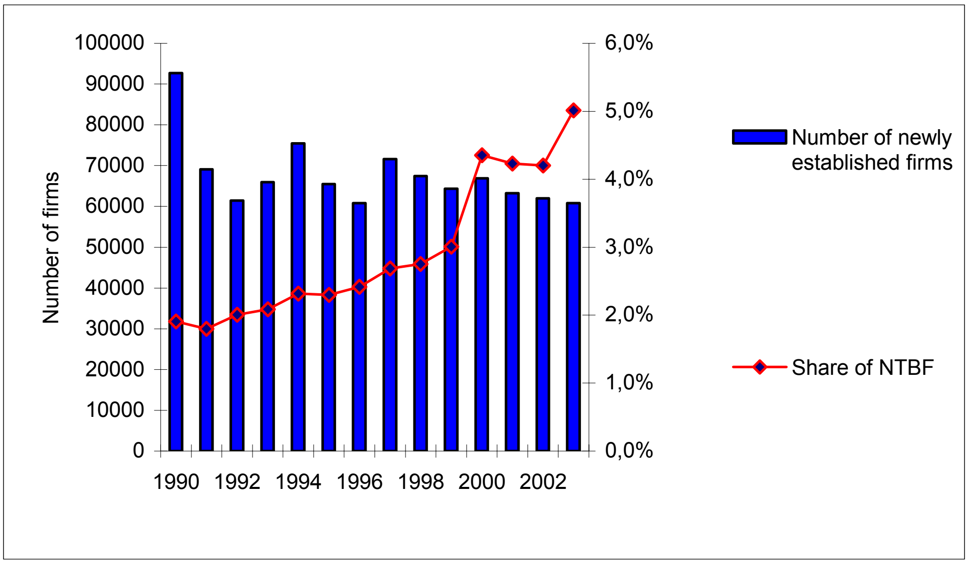
1.2 Innovations through new firms

The indicators of Swedish corporate innovativity shown in the stated CIS study have the limitation of relating to existing companies. Innovations can also be launched through the establishment of new firms. There are statistics on the annual extent of new firms, but none on the extent to which established firms means new products being introduced on the market. On the other hand, there are statistics on new technology based firms (NTBF).[25] A NTBF is used here as an indicator of an innovation being launched. At VINNOVA, a method has been developed to identify NTBFs.[26]

New technology-based firms comprise only a small proportion of the total established firms, but its proportion has increased between 1990 and 2003 (figure 1.2.1). In 1990 NTBFs comprised approx. 2% of all new firms companies and in 2003 the proportion had more than doubled to comprise approx. 5%. This year, the number of NTBFs was just over 3,000, as compared with 1,800 in 1990.

[25] A new firm is characterised as technology-based if the proportion of scientists and engineers (with at least a first degree) amounts to at least 20% of the company's workforce.
[26] The so-called FAD method is used to identify new firms. (For a description of the FAD method, see Ullström, J. 2005).

Figure 1.2.1 Annual number of new firms and share of NTBFs 1990-2003



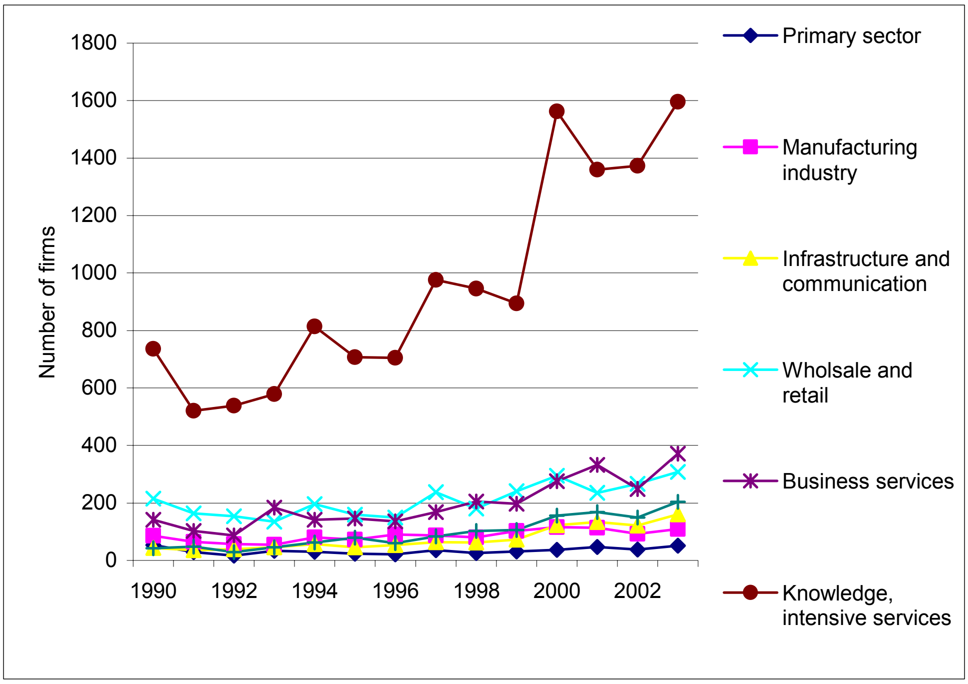
Source: VINNOVA

The majority of NTBFs since 1990 is within the service sector. The number of such firms within manufacturing was small over the entire period, with only around 100 establishments annually. Knowledge-intensive services have accounted for a large proportion NTBFs. These services include e.g. data processing activity, advanced consultancy services, financial services and research and development. In 1990, the number of NTBFs amongst them was 736 and in 2003 it was 1,596. Knowledge-intensive service companies thereby accounted for over half of the NTBFs in 2003. The annual establishment figures in most other sectors show a weak upward trend during the period (figure 1.2.2, page 22).

Establishing a new firm is risky and many new firms close down after a few years. Table 1.2.1 (page 23) shows employment growth in all NTBFs formed in 1990 and existing in 2001. Only 195 of the 1,769 NTBFs established in 1990 were still operational in 2001. Thus, the survival rate was only 11%. The proportion is similar for all annual NTBFs groupings. Accordingly, the majority of firms disappeared over time. The most common reasons were bankruptcies and liquidations, or winding down of activities. A small number were acquired by other companies. Of the NTBFs established in 1990, 35 merged with other companies.[27] The low survival rate need not mean that the contribution of NTBFs to innovation is of marginal significance, since innovation can live on in another company, e.g. through acquisition.

[27] Ullström, J. 2005,

Figure 1.2.2 Annual number of NTBFs 1990-2003 distributed by industries.



Source: VINNOVA

The employment growth in NTBFs which did survive was small. The 195 surviving NTBFs of those established in 1990 had a total of 538 employees in 2001, i.e. only 176 more people were employed by them in 2001. In other words, in 11 years they had employed slightly less than one person on average. The development for 1990's NTBFs in the manufacturing industry was weak to say the least. Of approx. 100 companies formed in 1990, only two remained in 2003. In addition, employment in them had barely increased at all.

Table 1.2.1 Number of NTBFs established in 1990 and existing in 2001 and their number of employees distributed by industries

	Number of NTBFs	Number of emploees		Change
	1990/2001	1990	2001	
Primary sector	2	3	4	1
Manufacturing industry	2	3	4	1
Infrastructure and communication	7	19	38	19
Business services	16	23	70	47
Wholsale and retail	24	55	103	48
Knowledge intensive services	127	236	271	35
Public services, education and others	3	4	5	1
Unspecified	14	19	43	24
Totalt	195	362	538	176

Source: VINNOVA

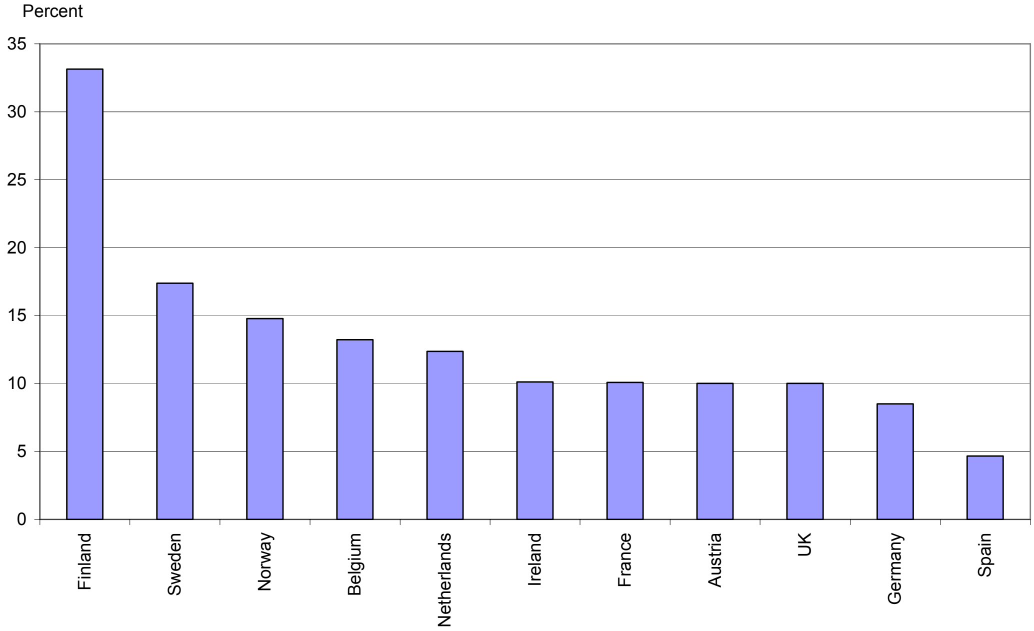
2 Contribution of research to innovations

As a rule, ideas for innovations combine a need (articulated or possible to create) and knowledge of what is – or ought to be – technologically possible. A small share of all innovations has their origin in new technical possibilities and a smaller share of these is based on research results. Innovations also combine knowledge from many different quarters and Schumpeter defined innovation as "new combinations of familiar knowledge". A new product and its production process are a combination of knowledge from a range of different sources: technology, market, design etc. The product often integrates a range of different technologies, which in themselves are based on a range of sources of knowledge, one of which may be research. Furthermore, a specific technology may need to incorporate knowledge from several different research fields. The link between a specific innovation and a certain field of research is therefore highly indirect.

Our knowledge about the extent of the contribution of research to corporate innovations is almost non-existent. However, there is information in the previously described Community Innovation Survey (CIS) about the extent of collaboration between companies and university research aimed at achieving innovations. Of the innovative companies in Sweden, 43% stated that they had collaborated with other organisations (customers, suppliers, universities etc.) in innovation activity. In a European comparison, this means a larger proportion of Swedish innovative companies have some form of innovation collaboration than is the case in other countries. Only in Finland does the proportion of innovative companies with innovation collaboration exceed the proportion of the Sweden (appendix 4, figure 1).

In 2002-2004, approx. 17% of the innovative companies in Sweden had research collaborations with universities. In a European comparison, this is one of the highest proportions and only Finland shows a higher proportion (figure 2.1).

Figure 2.1 Proportion of innovative companies that collaborated in research with universities 2002-2004.

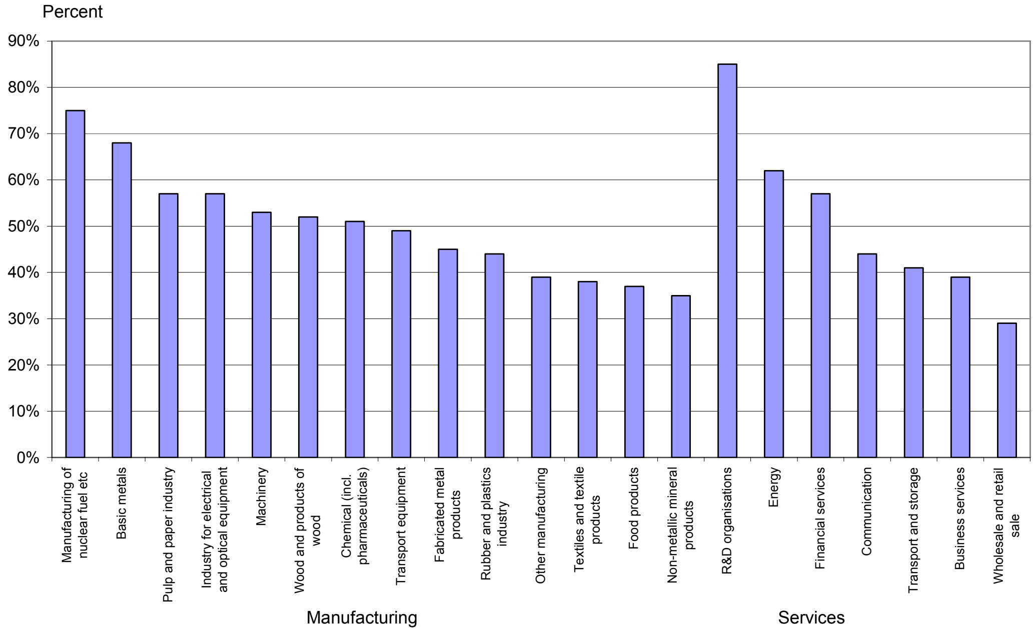


Source: http://ec.europa.eu/eurostat/

Research collaboration with universities is more common amongst companies operating in the manufacturing sector (23%) than for companies in the service sector (12%). This also applies to other European countries. There are also major industrial differences. The industry in Sweden showing the highest proportion of innovative companies with university research collaborations is R&D organisations (figure 2.2).[28] The manufacturing industry has the highest proportion within nuclear fuels followed by electrical and optical equipment and chemicals (including pharmaceuticals).

[28] Other studies have reported similar patterns. They indicate that the extent of knowledge transfer from universities to companies in connection with the development of innovations is relatively small compared with other sources of knowledge, such as companies' own R&D activity, suppliers and customers. The majority of knowledge used is developed internally in the company. Large companies use universities more than small companies and the transfer is more comprehensive in industries based on so-called research-based technologies such as information technology, biotechnology and new materials. The importance of university research to corporate innovation activity is great when companies are entering into fields of knowledge and technology which are new to them (NUTEK, 1998).

Figur 2.2 Proportion of innovative companies in Sweden that collaborated in research with universities 2002-2004 distributed by industries



Source: SCB 2006

An as-yet unpublished report from the Swedish Research Council shows that, apart from contributing to innovations in industry and society, "collaborative research" between universities and industry also maintains a high level of scientific quality.[29] By studying field-normalised citation rates it can be seen that scientific publications where there are authors from both Swedish companies and Swedish universities are cited to a greater extent than if the publication only has authors from Swedish companies or if the publication only has authors from Swedish universities.[30] During the 2000s, field-normalised citation rates for joint publications between Swedish companies and Swedish universities was around 1.2, implying that these journals are being cited 20% above the world average.

[29] The Swedish Research Council, "Vetenskapligt publiceringssamarbete mellan svenska företag och högskolor". Universities also have a lot to gain from contacts and collaborations with companies. Companies bring industrial problems into university research, which can enrich the research. In a number of cases, the "innovativity" of research has even depended on collaboration with industry. In fields such as information technology and biotechnology, collaboration between academia and industry has become crucial if important research is to take place (Sandström U och Hällsten M, 2003). For a similar discussion, see also Mowery D och Rosenberg N, 1989.

[30] Field-normalised citation rates mean that a global citation rate value is calculated for each year, research field and type of publication. The number of citations a publication recieves is divided by this global citation value. A value equal to 1 means that the publication is cited to the same extent as the world average, whilst a value of 2 means that the publication is cited at twice the world average.

2.1 Knowledge-exchange between companies and universities

There are many channels through which knowledge generated at universities is utilised in corporate innovations.[31] Research-generated knowledge can be transferred through:

- scientific journals and technical reports
- public scientific conferences and meetings
- informal contacts
- recruitment
- researcher exchange
- purchase of patent licenses
- commissioned research
- joint research projects

Above all, companies use informal contacts, conferences and scientific literature to acquire knowledge from universities. However, licensing, commissioned research and joint research projects are also important channels. Recruitment of researchers, either directly from universities or from other companies, is a particularly important channel when a company is entering into a new field of knowledge and/or technology.[32]

It is difficult to judge the respective channels' extent and significance to corporate innovation activity since statistics in this field are poorly developed. Some information are available in Sweden regarding research collaboration, commissioned research, researcher exchange, researcher recruitment and newly established enterprise. This means that only a part of the total flow of knowledge is included in the following account.

Commissioned research

One channel which companies use is to commission research. An example of this is SCA's funding of structural chemistry research at Chalmers aimed at understanding the amazing capability of jellyfish to bind water. The knowledge resulting from this research might possibly be used to improve the company's nappies and dressings.

In 2005, university revenues from companies for commissioned research totalled just over SEK 810 million, with companies in Sweden responsible

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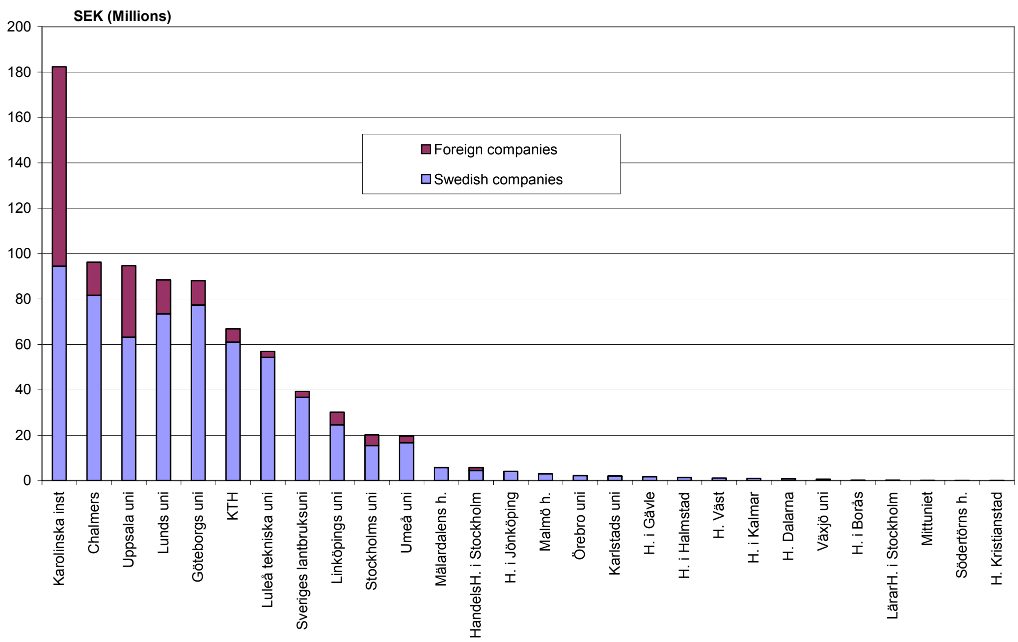
[31] NUTEK, 1995:18

[32] NUTEK, 1998. The channels are mutually dependent. Research collaborations have a greater chance of succeeding if they are based on previous personal contacts, since the participants then know each other's capabilities and have realistic expectations of the collaboration.

for just over 75%.[33] Swedish corporate funding of just over SEK 600 million is equivalent to slightly below 1% of corporate R&D investments in 2005.[34]

Amongst the universities, Karolinska Institutet generated the largest revenue from commissioned research on 2005 (figure 2.1.1). Chalmers University of Technology, Uppsala University, Lund University, Gothenburg University and the Royal Institute of Technology (KTH) also had relatively large revenues from commissioned research. The 10 largest universities accounted for just over 90% of the total volume of commissions. Where it concerns revenues from foreign companies, almost 50% went to Karolinska Institutet.

Figure 2.1.1 Revenues from company commissioned research in 2005 distributed by universities.



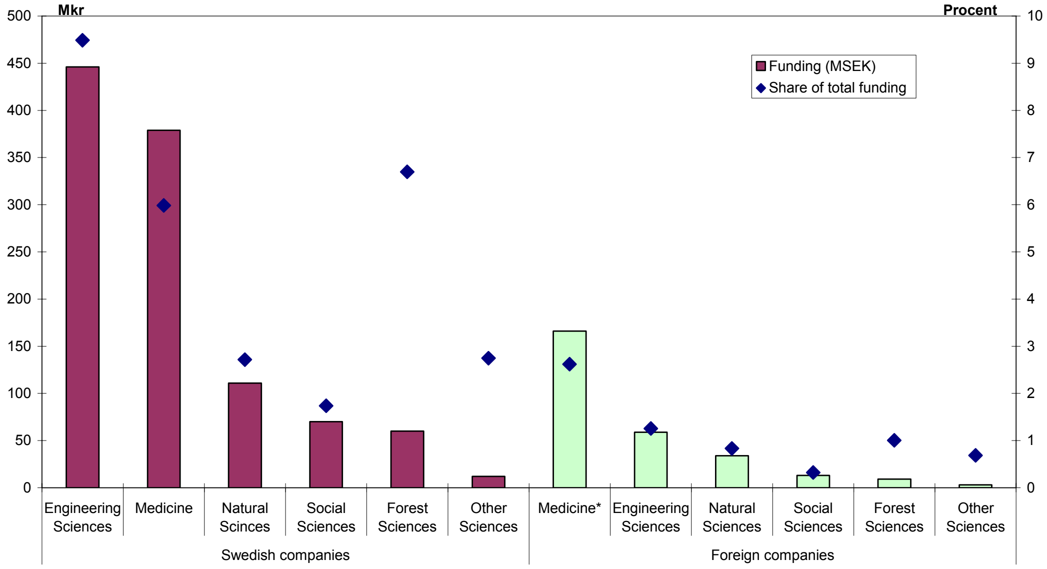
Source: HSV, NU-database, 2006

It was chiefly engineering and medical research at universities which was funded by companies, measured both in SEK millions and as a proportion of total R&D funding of subjects (figure 2.1.2). One difference between companies in Sweden and abroad is that the former primarily fund

[33] HSV [the Swedish National Agency for Higher Education], NU database, 2006. Commissioned research is defined in Statistics Sweden's statistics as "fee-funded research for which the university provides certain services to the principal as a consideration." In this context, a company in Sweden is defined as a company with a Swedish corporate identity number.
[34] For corporate R&D investments, see section 3.1.

commissioned research into areas of engineering, whilst the latter primarily funded medical research with the major proportion going to Karolinska Institutet. The commissioned research proportion of total R&D funding at universities is small. Only within engineering and medicine does approach 10%.

Figure 2.1.2 Company funding of research in universities distributed by scientific subjects and as a share of each subjects total research funding in 2005.



SCB, 2007. Modified by VINNOVA, 2007.

Researcher exchange

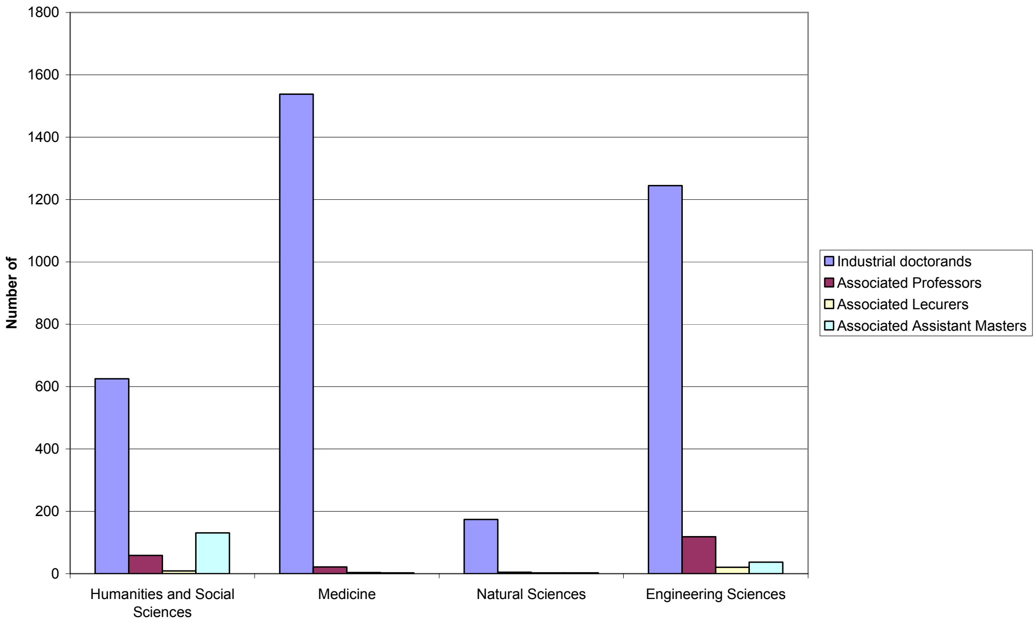
Industrial PhD students and various types of associated posts are forms of researcher exchange.[35] In 2005, the number of industrial PhD students was just over 3,600, equivalent to slightly under 17% of the active PhD students. The majority of industrial PhD students are within engineering and medical

[35] Official statistics do not show industrial PhD students. According to the Swedish National Agency For Higher Education, which is responsible for a major part of the research statistics, the definition of the concept is also unclear. However, PhD students whose professional activity lies outside the university and who are conducting research training within the framework of their professional activity may be identified in the statistics. Industrial PhD students defined as those with more than 50% of their support from professional activity outside the university. By this definition, an industrial PhD student may come from both a company and the public sector. It is not possible to identify from where he or she receives their remuneration. An associated post at an university means the person is sharing their working time between the Academy and the organisation where he or she is employed. There are associated posts for professors, senior lecturers and assistant masters.

subjects. The number in medicine has reduced somewhat, whilst it has increased within engineering subjects since 1998.[36]

Through questionnaires to Swedish universities the Industry Committee charted the industrial PhD students employed in industry in 2005. At the 10 universities which responded to the questionnaire, approx. 700 industrial PhD students were employed in industry (figure 2.1.3).[37]

Figure 2.1.3 Number of industrial PhD students in 2005 and associated posts in 2004 distributed by subjects



Source: Industrikommittén 2006.

In 2004, there were slightly fewer than 450 associated posts at Swedish universities. This means a marked increase since 1999, when the figure was 258. The increase is chiefly in lecturers and the associated professors reduced somewhat during the period. The majority of the posts are within engineering subjects, social sciences and humanities. The number of associated professors funded by industry in 2005 was 200. There were 46 at Chalmers, followed by Lund University Faculty of Engineering, Luleå University of Technology, the Institute of Technology at Linköping,

[36] VINNOVA, VA 2006:01

[37] The Industrial Committee, 2006. The universities which responded to the questionnaire are: KTH, Chalmers, Lunds University Faculty of Engineering, Luleå University of Technology, the Institute of Technology at Linköpings University, Uppsala University, Mälardalen University, Karlstad University, Umeå University and Mid Sweden University. At KTH, there were 227 industrial doctorands, at Chalmers 150 and at Lund University Faculty of Engineering 100.

University and the Royal Institute of Technology (KTH) with between 25 and 38 associated professors.[38]

Recruitment to corporate R&D

A third channel used by companies to benefit from university research is recruitment. By recruiting researchers, the company has access to the researcher's skills as well as their network of contacts. Unfortunately, there is very little knowledge about the extent and significance of researcher recruitment to corporate innovation activity as studies and statistics in the field are poorly developed. However, the number of R&D man-years (FTE) conducted in companies by PhD graduateas can be used as an indicator of the significance. Table 2.2.1 shows that only a small amount of R&D man-years are conducted by PhD graduated researchers.

Table 2.1.1 Number of R&D man-years (FTE) and R&D man-years carried out by PhD graduates in 2003 and 2005.

	R&D man-years carried out by PhD graduates		Total R&D man-years	
	2003	2005	2003	2005
Primary sector	31	41	231	204
Manufacturing sector	3093	3631	38748	40446
Service sector	1201	1786	9134	15456

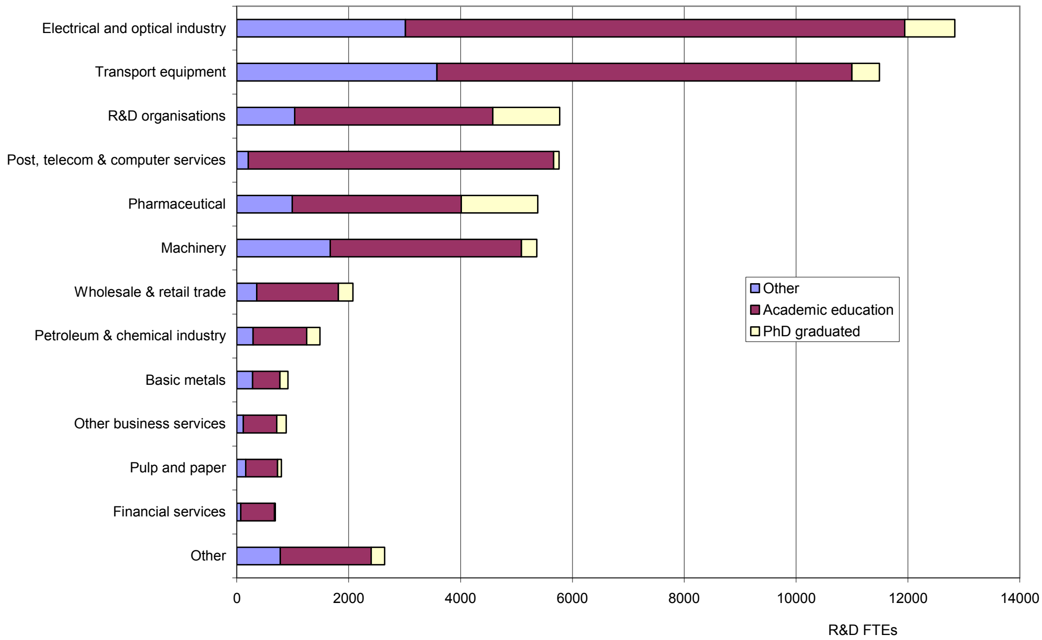
Source: SCB, 2005 och 2006. Forskning och Utveckling i företagssektorn 2003 and 2005

Note: FTE = Full Time Equivivalent

The majority of R&D man-years by PhD graduated researchers are carried out in the manufacturing sector, but in relative terms a larger proportion is found in the service sector. The number of R&D man-years conducted by qualified researchers varies greatly between industries (figure 2.1.4). Pharmaceuticals, R&D organisations, electrical & optical equipment and transport equipment have the highest numbers. Also conducted in them is approx. 75% of the corporate sector's total R&D man-years of PhD graduates

[38] VINNOVA VA 2006:01. The statistics only cover associated posts where the universities supply financial compensation. There is no information on any associated posts where companies were responsible for the full cost. Information from a few universities which have such information indicates this is not very widespread. However, we do not know how many of the people conduct their other activity in the corporate sector, since the public sector also makes use of assiciated posts.

Figure 2.1.4 Number of R&D man-years (FTE) in 2005 distributed by industries and level of education (PhD graduates, academic education at least 3 years and other education) in 2005



Source: SCB, Forskning och Utveckling i företagssektorn 2006

Corporate utilisation of university research through recruitment is not limited to employment of PhD graduates. Employment of individuals with first-degrees, such as engineers, also means that research is contributing to corporate innovation activity. In 2005, PhD graduates and people with an academic degree (of at least three years' duration) accounted for almost 80% of all R&D man-years in the corporate sector. The proportion varies between industries from just over 96% in post, telecom and computer services, to just below 70% in the transportation equipment industry and machinery.

2.2 New firms with roots in academic research

The channels discussed above relate to transfer of knowledge to existing companies. Research can also be commercialised through establishing new firms. This can be illustrated by a research group at KTH.[39] The group worked on commercialising knowledge which came about in their research. Initially, the researchers used a licensing strategy. It was not difficult for the group to sell licences to companies, but in the end, the patent lead to innovations in only three cases. A new strategy was designed meaning that companies were formed with a patent included. Venture capital for product

[39] VINNOVA VF 2002:1

manufacture was then sought on the basis of that patent and personnel employed. Studies in other countries have shown that it is not altogether uncommon for research findings to be commercialised through new firms being started by academic researchers.[40]

University spin-offs can come about in different ways. Researchers can leave their posts to start a new firm based on research results. In other cases, the researcher can “sell” their idea to others who start up and run the new company. Available statistics on new firms do not contain information about their origins. On the other hand, information exists about where personnel in a new firm were in the year before the firm’s establishment. That information can be used to identify companies with “personnel roots” in academia. The following is an account of new firms with personnel roots in Swedish universities.

Annual new firms with personnel roots in Swedish universities has varied since 1990 and exceeded 500 companies only in the first year (figure 2.2.1). NTBFs with personnel roots in universities have varied around 100 companies per year. By and large, annual employment follows annual new firms, meaning that start-ups with roots in Swedish universities were small in the year of their establishment. The majority of the new firms were service companies, and above all knowledge-intensive service companies.[41]

New firms with personnel roots in academia comprise only a very small proportion of the total number of new firms (appendix 4, figure 2). Furthermore, the proportion of NTBFs with personnel roots in universities constitutes a relatively small in relation to such spin-offs from other organisations. The annual proportion has varied around 4% since the start of the 1990s. The annual proportion of new firms with personnel roots in academia constitutes approx. 0.5% of all new firms.

The annual number and proportion of new firms and NTBFs with personnel roots in the research institute sector is much lower than those with roots in academia. The research institutes’annual proportion of NTBFs has varied around 0.3% since 1990 and their annual proportion of new firms has varied around 0.02%.[42]

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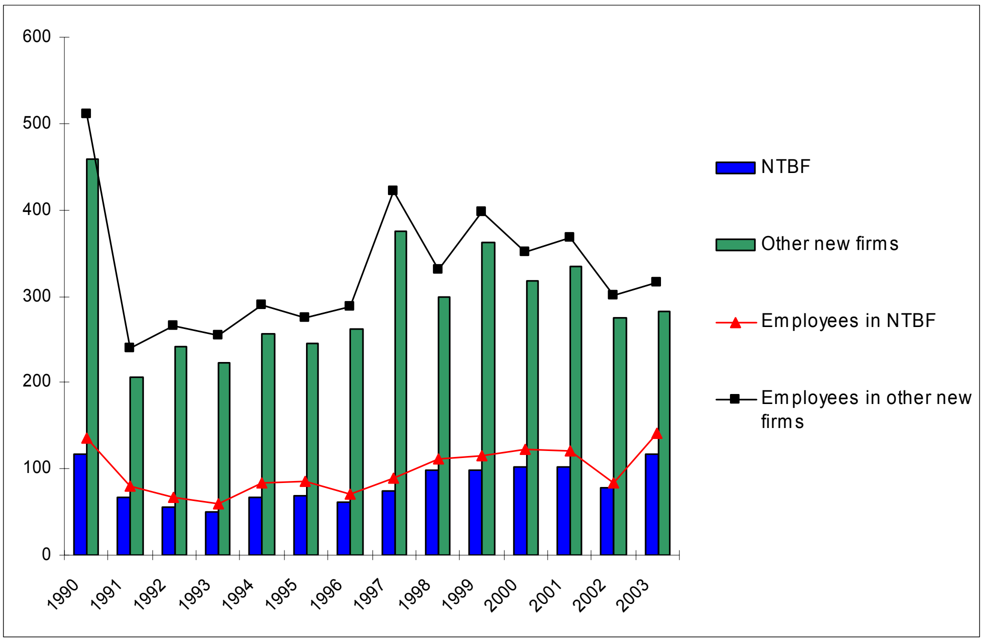
[40] Acs, Z. J., Audretsch, D. B. and Feldman, M.P., 1992
[41] Ullström, J. 2005
[42] Ibid.

Figure 2.2.1 Number of NTBFs and other new firms with personnel roots in universities and their employees 1990-2003

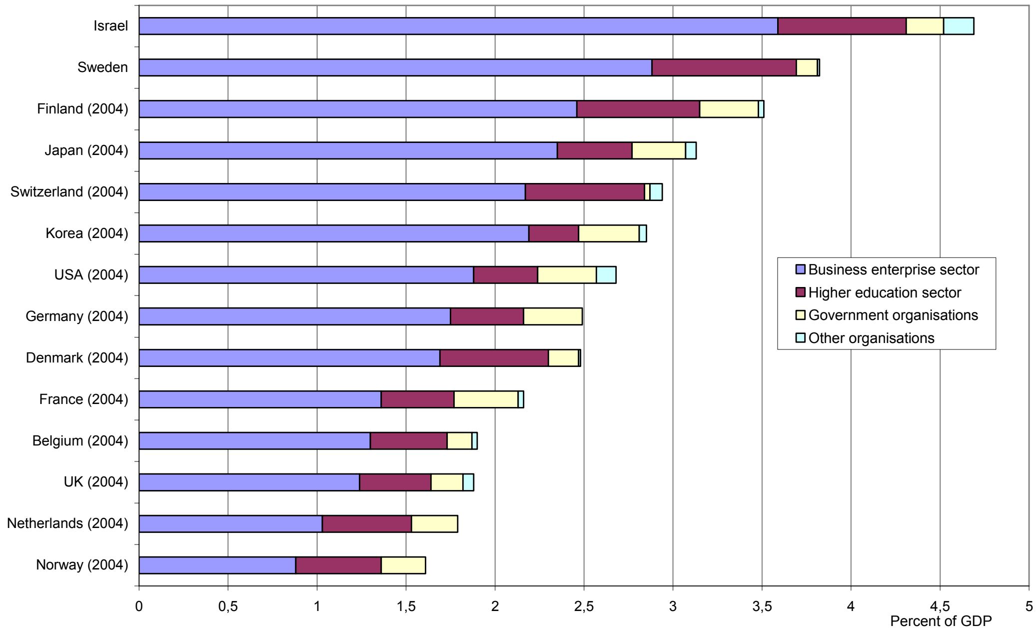


Source: VINNOVA

3 The Swedish R&D landscape

In an international comparison, Sweden invests major resources in research and development (R&D) in relation to the size of its economy. In 2005, R&D investment in Sweden totalled SEK 102 billion, equivalent to 3.8% of GDP. Only in Israel is R&D investment greater, in relation to size of economy (figure 3.1).

Figure 3.1 R&D as a share of GDP distributed by category of performer 2005



Source: SCB for Sweden and OECD for other countries

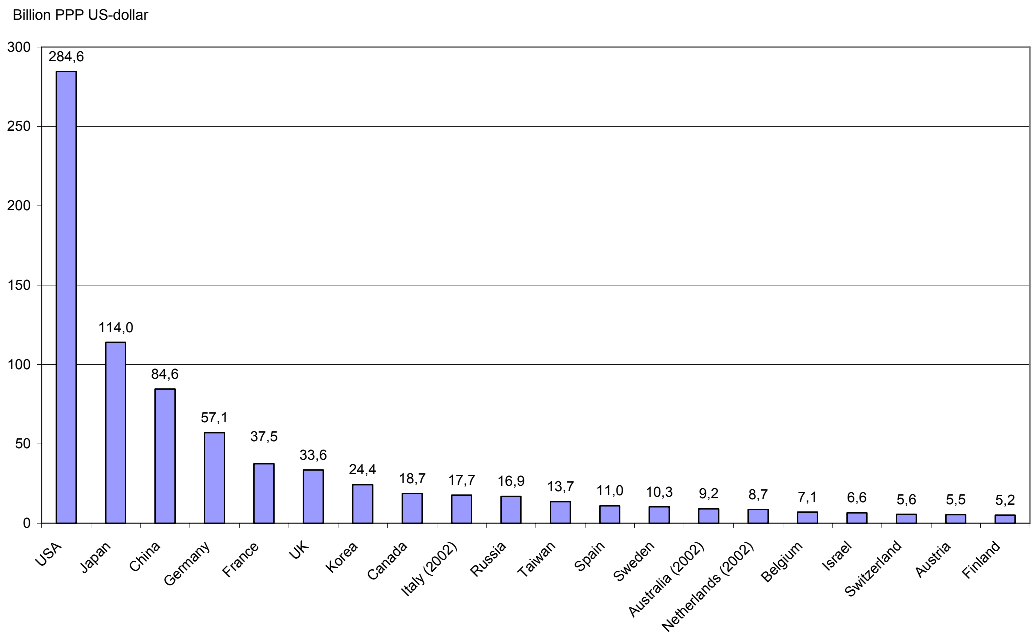
In Sweden, R&D is conducted in a more or less bipartite structure. In 2005, 75% of research was conducted by companies and 21% by universities. Companies largely fund their own R&D (86% in 2003) and only 5% comes from government sources. Funding of research in universities comes principally from government sources (77% in 2003). Private funds and foundations funded approx. 10% and companies around 5%.[43]

Accordingly, Sweden occupies a top world position when it comes to R&D investment relative to size of economy. However, in absolute terms they are relatively small in a global context. In figure 3.2 have countries' R&D investments in 2003 been converted into purchasing power-adjusted American dollars. In this "common" currency, the Swedish R&D

[43] SCB 2005, Forskning och Utveckling I Sverige 2003

investments only end up in 13th place. R&D investments in the US were almost 28 times larger, in Japan 11 times larger, in China eight times larger and in Germany just under six times larger. Out of the OECD countries' total R&D investments, the Swedish proportion constitutes only approx. 1.5%.

Figure 3.2 R&D investments in some OECD countries 2003



Source: OECD MSTI 2006

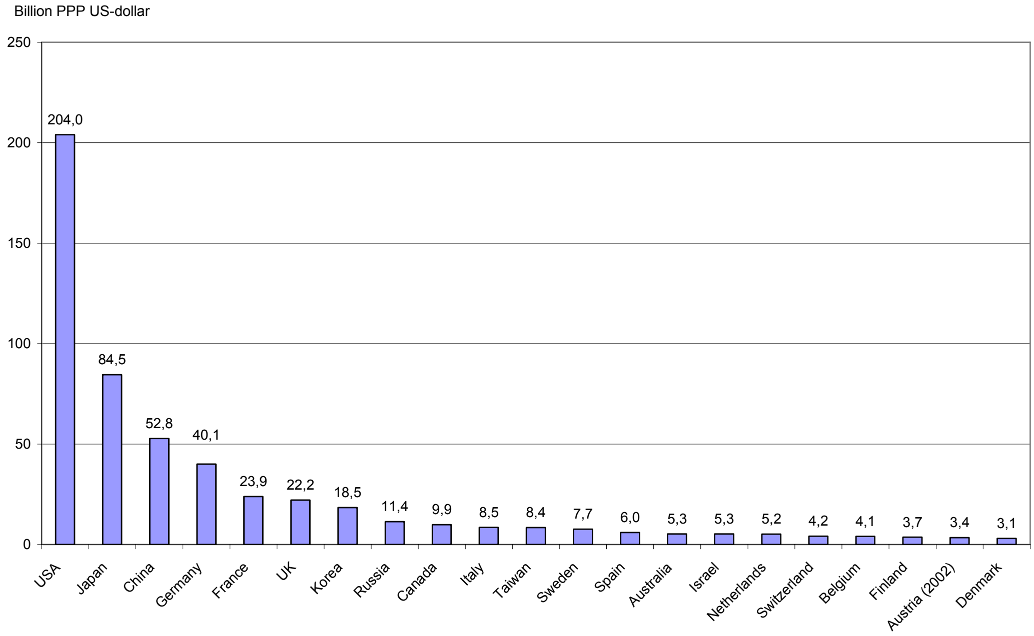
3.1 Corporate R&D

In 2005, companies active in Sweden invested around SEK 77 billion in R&D. Two years previously, this sum was just under SEK 72 billion and measured in R&D man-hours, was equivalent to over 52,000 man-hours.[44] In 2003, corporate R&D investments comprised just under 3% of GDP which can be compared to the EU average, 1.25% of GDP.[45] In the US, the investment level reached 1.79% of GDP in the same year. However, in absolute terms the Swedish R&D investments are not as impressive (figure 3.1.1).

[44] Statistics Sweden, 2005 and 2006, Research and development in the corporate sector, 2003 and 2005. There is no data for R&D man-hours for 2005

[45] Relates to the EU average, 15 years 2003.

Figure 3.1.1 R&D investments in the business enterprise sector in some OECD countries 2003.



Source: OECD MSTI 2006

It is important to be aware that the R&D investment shown above relates to that portion which companies carry out in each country. Many companies, above all the large multinationals, carry out part of their R&D in countries other than their home country. Between 1995 and 2003, the 20 largest Swedish-and multinational companies increased their R&D investments from SEK 36 billion to just over SEK 47 billion. However, R&D investments in Sweden were on about the same level in 2003 as they were in 1995, which means that the entire increase took place abroad. In 1995, the foreign proportion was 22%. In 2003, the proportion had increased to 43%. The most common method of increasing the foreign share was through acquisitions of companies abroad. The Swedish corporations mainly perform their foreign R&D activity within the EU15 area, where 60% of the foreign R&D man-hours in 2003 were carried out, 15% was conducted in the US and 3% in non-OECD countries such as China and India.[46]

In 2003 around 45% or SEK 32.6 billion of companies' R&D investment in Sweden was invested by foreign-owned companies. In 1999, the proportion was 36%. The majority of the R&D invested in Sweden by foreign-owned companies came from companies based in Great Britain and the US; 40% and 33% respectively. It was also companies from these two countries which were responsible for the greater part of the increase between 1999

[46] ITPS, 2003

and 2003. The primary reason for the R&D share for foreign-owned companies having increased over time is the acquisition of Swedish companies. Another important reason for investing in R&D in Sweden is the need to gain access to research at Swedish universities and research institutes.[47]

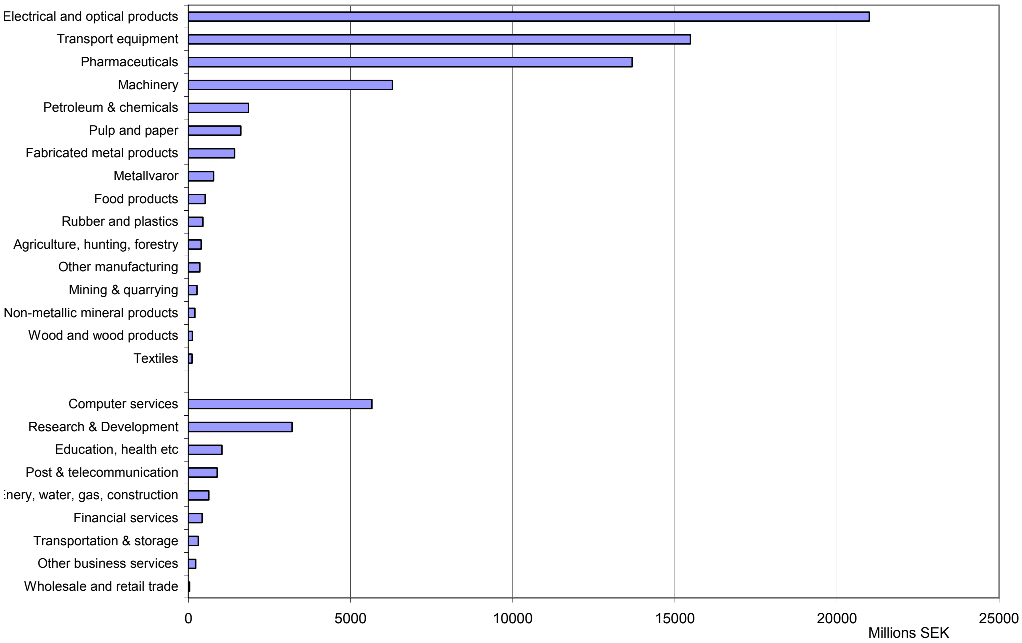
The corporate sector's R&D activity is concentrated in a few multinationals. In 2005, the 20 largest companies accounted for just over 60% of the corporate sector's total R&D expenses and in the same year, 67% of all R&D in the corporate sector was conducted by companies with more than 1,000 employees. If companies with fewer than 250 employees are also included, the proportion rises to almost 79%.[48]

The manufacturing sector accounted for a smaller share, or 18%, of industrial employment in 2003. Concerning R&D activity, the picture is almost the opposite, since the manufacturing sector accounted for around 80% of R&D investment in the same year.[49]

R&D investment is to a large extent concentrated in a few industries: electrical and optical equipment, transport equipment, pharmaceuticals and machinery. Approximately 75% of the total R&D investments can be attributed to these (figure 3.1.2).

[47] Ibid. The localisation of R&D activity is governed by certain needs. Three important ones are market adaptation of products, support for production units and access to research and innovation environments.
[48] Statistics Sweden excludes companies with fewer than 50 employees in its ordinary R&D surveys of corporate sector R&D activity; this implies that the manufacturing sector's percentage has been somewhat overestimated. According to Statistics Sweden, R&D investments for companies operating in Sweden and with fewer than 50 employees totalled SEK 7 billion for 2000. For further information, see also VINNOVA, VA 2006:02.
[49] The proportion fell to 75% in 2005. This is because Statistics Sweden included companies with 10-49 employees that year, which has previously not been included in the R&D statistics.

Figure 3.1.2 Corporate R&D investments in Sweden in 2005 distributed by product group



Source: SCB 2006, Forskning och Utveckling i företagssektorn 2005

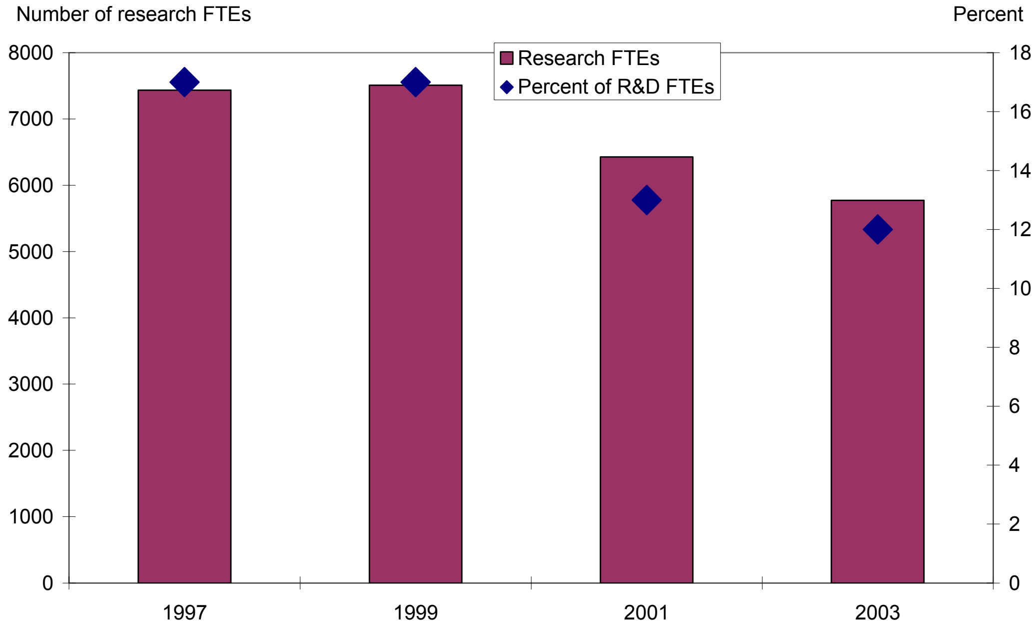
Research comprises a minor part

Although there is no clear-cut divide between what is counted as research and what is counted as development, only a small part of the business sector’s total R&D activity is research. In addition, the research proportion of total R&D activity industry has diminished somewhat over time. In 2003, research comprised just under 12% of corporate R&D activity (figure 3.1.3). This compares with 1997 and 1999 when the research proportion was 17% of R&D activity.

Research in manufacturing companies entails seeking new technological knowledge not directly connected to new and/or improved products and processes. The results of the research are chiefly technological solutions but also instruments and methods. In turn, the technological solutions can be used to develop new and or improved products and manufacturing processes, or to generate concepts for new ones. Results can also be “shelved” for future use. Ideas for research projects have several sources, such as previous internal research projects (research generate new research problems), monitoring of external research (scientific journals, collaborative projects etc.) and internal development projects (new problems).[50]

[50] NUTEK, R 2000:24

Figure 3.1.3 Number of research man-years (FTE) and its share of total R&D man-years (FTE) in 2003.

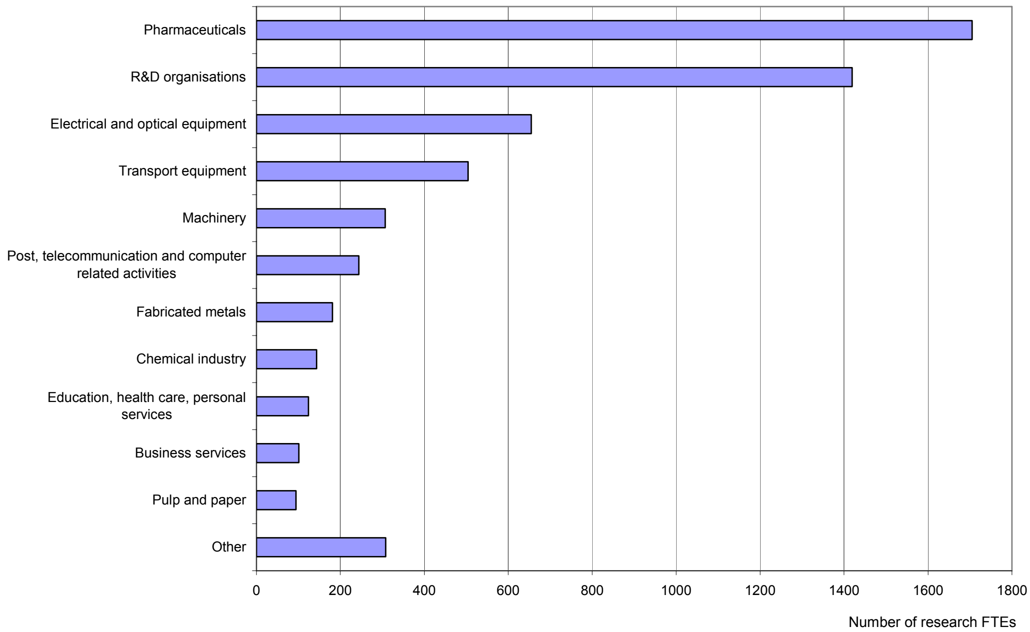


Source: SCB 2005, Forskning och Utveckling i företagssektorn 2003

Development activity in companies is aimed at generating new and or improved products/processes, plus new applications of technologies used in existing products/processes. Development projects start from a marketing or production need. In an initial phase, the company seeks a technological solution to that need. This means scanning possible technological solutions. One source of these is the previously “shelved” technological solutions. Other sources are external to the company, such as patent databases and academic researcher contacts. In the next phase, the selected technological solution is applied to the problem/need; in other words, development of products/processes.

Access to in-house research is an important condition for collaborating with university researchers. The scale of research varies greatly between industries, with pharmaceuticals and R&D organisations at the top (figure 3.1.4).

Figure 3.1.4 Number of research man-years (FTE) in 2003 distributed by industries.



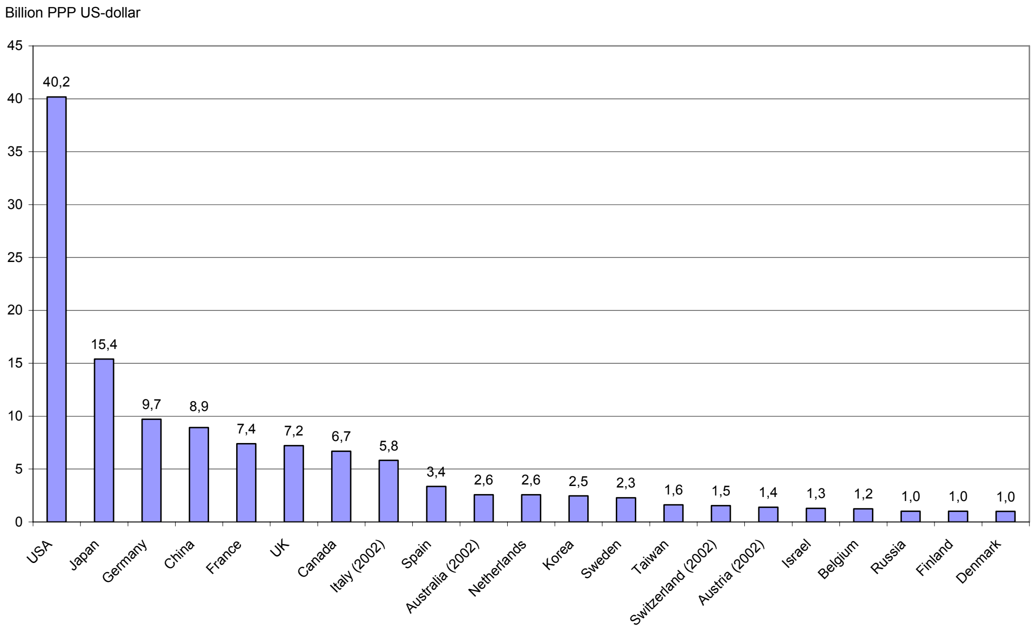
Source: SCB 2005, Forskning och Utveckling i företagssektorn 2003

3.2 Research at universities

The volume of research at Swedish universities in 2005 totalled just over SEK 21 billion, equivalent to just over 0.8% of GDP. In an international comparison, this percentage is the highest. After Sweden come Israel, Canada, Finland and Switzerland. The fact that Sweden is so highly placed is partly the result of political priorities which have meant that public research resources are concentrated to the universities. As a consequence, research in research institutes is small by international comparison.

However, in absolute terms, Swedish university research in 2003 only came in 13th place. In the US, the volume of research in universities was just over 17 times greater than in Sweden, whilst in Japan it was just almost seven times greater (figure 3.2.1).

Figure 3.2.1 Volume of university research in 2003 (billion PPP US dollar)



Source: OECD MSTI 2006

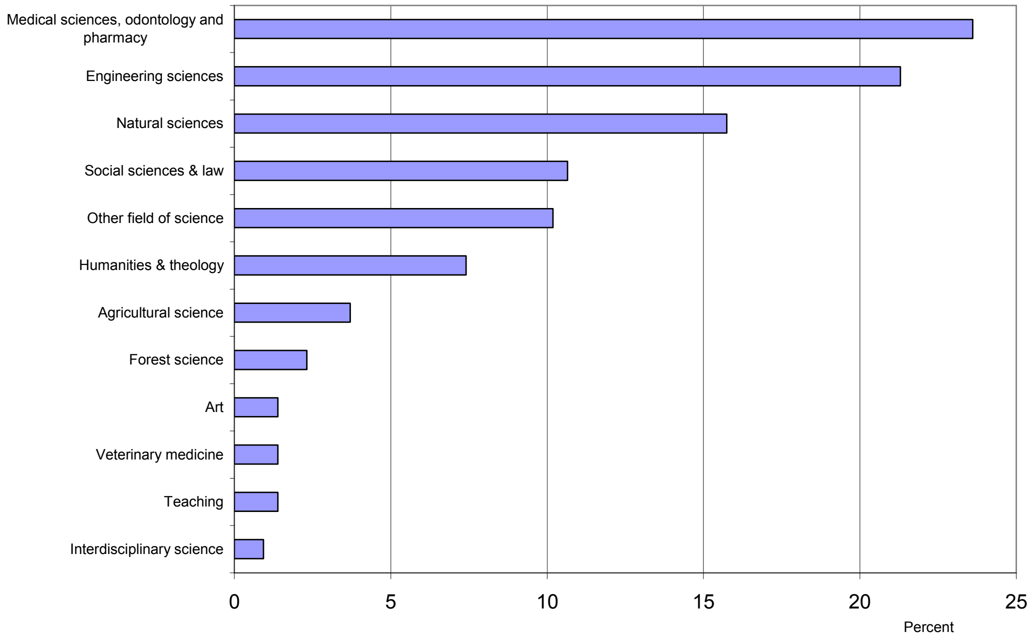
Taken as subject fields, around 60% of all research in Sweden is conducted within the fields of medicine, natural science and engineering (figure 3.2.2).[51]

Even though there are a large number of universities, the research is relatively concentrated and carried out chiefly at the major universities. In 2003, the 10 largest received just over SEK 17 billion or close to 90% of the total R&D funding. In the same year, the Universities of Lund, Uppsala, Stockholm, Gothenburg and Karolinska Institutet accounted for just over half of all research man-years.[52]

An ever-increasing proportion of both research and researcher training is being funded by external funds. At the start of the 1990s, approx. two thirds of grants came direct from the government budget, whilst the proportion in 2005 was less than 50%.[53]

[51] Statistics Sweden, 2005, “Research and development in the university sector 2003”.
[52]Of a total of 21,495 research man-years, 11,150 were carried out at the Universities of Lund, Uppsala, Gothenburg and Stockholm and at Karolinska institutet. Statistics Sweden, 2005, “Research and development in the university sector 2003”.
[53] A large proportion of the external funds consist of public funds from primarily research councils. In 2003, public funds accounted for almost 80% of R&D funding at universities. HSV, http://www.doktorandhandboken.nu/om_utbildningen.html 2005-07-04

Figure 3.2.2 Proportion of R&D man-years (FTE) at Swedish universities in 2003 distributed by subjects.



Source: SCB, "Forskning och utveckling inom universitet och högskolesektorn 2005"

3.3 Research at institutes

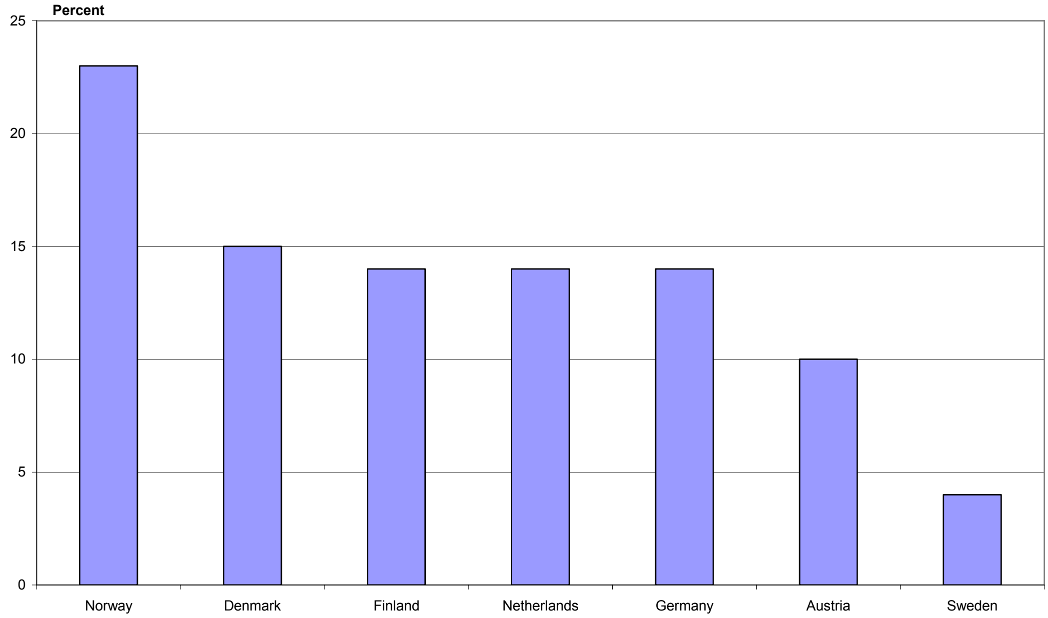
The political prioritising of universities as the public research resource has affected the size of the research institute sector. In official OECD statistics, it is not possible to compare the size of this sector between countries, since the classifications of research institutes vary. A comparison of the research institute sector in a small number of countries in 2001 show the Swedish institute sector to be relatively small (figure 3.3.1).[54]

The Swedish system of cooperative research institutes is rooted in an Inquiry from the beginning of the 1940s,[55] and on the mutual research needs of industries. Institutes which were formed later do not have such a strong industrial connection but are more oriented towards generic technologies. In Sweden, there are some 30 research institutes, 16 of which are organised into an umbrella organisation, IRECO.[56] Both government and industry

[54] The Ministry of Education and Research, Norway. Will to research. Norway 2005
[55] Sörlin, S. 2006.
[56] A major proportion of industrial research institutes have been formed in four robust corporations which can meet the stipulated requirements for an efficient and competitive institute system. The restructuring of institutes has meant groupings around the following industries, materials and technologies: Fibre, paper, packaging and printing technology (STFI-Packforsk AB), Materials and engineering mechanics (Swerea AB), Information and communications technology (Swedish ICT Research AB) and Biotechnology, environmental and building technology (SP Technical Research Institute of Sweden)

back the IRECO institute and contribute financially to operations. The government's basic funding is motivated by the necessity of maintaining a high level of attractive research skill and the need for public funding of long-term, high-risk projects.[57]

Figure 3.3.1 Research institutes proportion of total R&D in 2001.



Source: Ministry of Dducation and Research, "Desire for Research", Norway, 2005

The primary task of industrial research institutes is to support technological development in Swedish industry by refining and mediating research results which can generate products and processes for commercialisation. Research institutes have three roles in the R&D system. They are research partners, technology suppliers and a source of recruitment to other research implementers and companies.[58] Industrial research institutes fulfil these roles by offering corporate customers various services such as:

- *Joint research projects*: Research open to all interested parties and funded collectively (basic funding, service fees etc.)

[57] The IRECO institute's R&D funds are as follows:
Skills development funds aim to build up long-term knowledge and skills and are necessary for the renewal and development of institutes' skills. These funds come from governmental agencies.
Project funding relates to activity often jointly funded by industry and public funds. The public funds may be channelled through state bodies and other agencies; in the first instance, VINNOVA. Project activity is the dominant activity in institutes.
Commission funding relates to assignments which are 100% funded by the principal (as a rule, a company).
[58] INNO 2002

- *Multi-customer projects*: Companies, international or Swedish, are invited to participate in projects with co-financed research and development through cost sharing.
- *Commissioned activity*: Project ordered by an individual company. In this case, the company is solely responsible for funding the project.
- *Service provision/Information*: Industrial research institutes offer certain information free of charge; other information and services are paid for by the individual company.

4 State R&D funding

The types of state R&D funding are:

- Non-competitive direct government grants (faculty appropriations)
- Competitive grants through research councils
- Competitive grants through public research foundations
- Competitive grants through government agencies

Another way of dividing up R&D funding is to begin with who determines the direction of the research and the problems it tackles. Faculty appropriations and grants from research councils are controlled by the research community; so-called curiosity-orientated research. The major proportion is comprised of faculty appropriations distributed by the universities. Grants from government agencies other than the research councils and public research foundations are controlled by need in industry and society; so-called needs-driven research. This is dominated by research for defence needs.[59]

According to the budget, in 2006 the Swedish state's R&D funding was SEK 26.4 billion.[60] Converted into GDP terms, this means that state R&D funding was 0.94% of GDP (figure 4.1). Publicly funded civil R&D was about 0.73% of GDP the same year. The public research foundations funded research worth just under SEK 1.7 billion, equivalent to 0.06% of GDP, whilst defence-driven state research totalled just over SEK 4 billion, or 0.15% of GDP.

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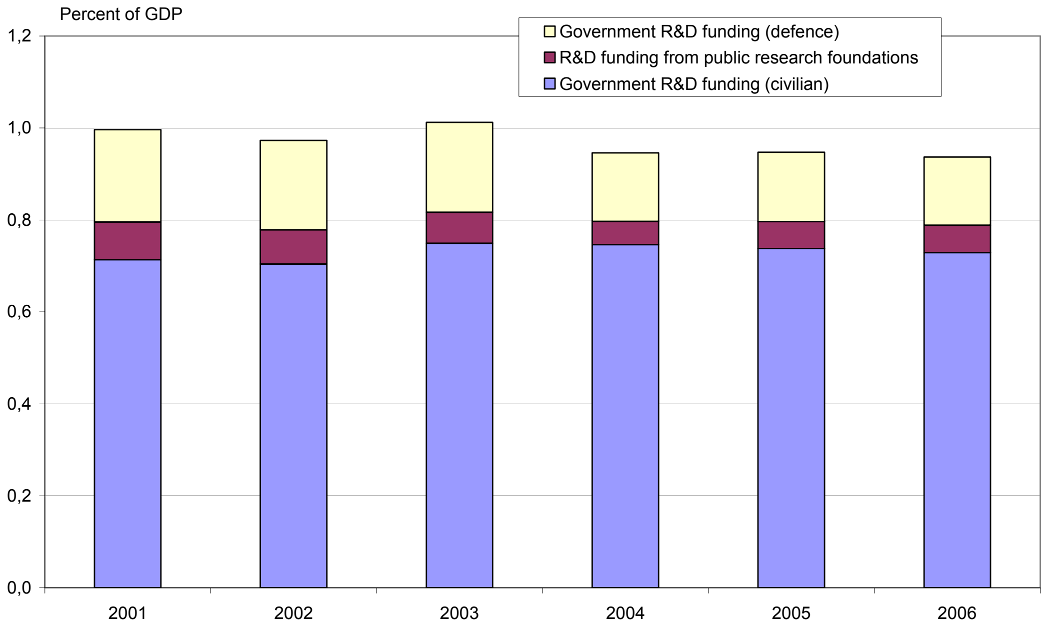
[59] Scientific quality comprises two issues: research into the right questions or using the right methods to answer the research questions. What distinguishes curiosity-orientated research from needs-driven research is who determines the questions, not how the questions are answered. However, to say that it is always need which should determine the questions is too simple. In in many cases, it is a matter of defining a research field (a collection of research questions) which, if worked on, can open new opportunities for development of new practically interesting technology. This requires a combination of visions for technical opportunities and needs.

[60] Statistics Sweden, 2006. "State grants to research and development, 2006". The total also includes R&D funding from the seven research foundations created with wage earners' funds. In 2006, R&D funding from these totalled SEK 1.7 billion.

Figure 4.1 State funded R&D in Sweden 2001-2006 as a share of GDP



Source: SCB, 2006. Statliga anslag till forskning och utveckling 2006

4.1 Direct government grants and research council funding

Government R&D funding is dominated by direct grants to universities. In 2006, these totalled SEK 10.8 billion equivalent to just over 40% of the total state R&D funding, or 0.38% of GDP.

In 2001, the Swedish research council structure was reorganised to create three state research councils. Currently, the largest of the state research councils is the Swedish Research Council (VR). The other two are the Swedish Research Council Formas and the Swedish Council for Working Life and Social Research (FAS).

Research councils base their funding on researcher-controlled priorities as to the direction of ventures and researcher-controlled assessments of research applications. Research projects are generally performed entirely by researchers at universities without the direct involvement of industrial or social organisations. In the main, this research takes a direction which concentrates on existing research disciplines. In 2006, the budgeted R&D funding from VR, FAS and Formas totalled just over SEK 3.6 billion, equivalent to 14% of public R&D funding or 0.13% of GDP. If direct state grants to universities are added to the R&D funding from the three research councils, the portion which can mainly be characterised as curiosity-orientated research amounts to 55% of state R&D funding, or 0.51% of GDP.

Compared to Finland, these are high proportions. In Finland, direct grants to universities in the same year totalled EUR 427.5, equivalent to approx. 25% of state R&D funding. If direct research grants to university hospitals and R&D funding from the Academy of Finland are also included, the portion of research which can mainly be designated as curiosity-orientated comes to EUR 733.6, equivalent to 44% of the total R&D funding, or 0.45% of GDP.[61]

4.2 Agency and research foundation funding

Government agencies other than research councils also fund research. In connection with the major reorganisation of public R&D funding in 2001, the Swedish Governmental Agency for Innovation Systems (VINNOVA) was created by merging three previous agencies. VINNOVA's R&D funding is directed at research for the needs of industry and the public sector. The research which is funded is prioritised and implemented in close collaboration with universities and industry/public sector. In 2006, VINNOVA's grants totalled approx. SEK 1.4 billion, equivalent to approx. 5% of total government R&D funding and as a proportion of GDP, approx. 0.05%. Other agencies funding civil needs-driven research include the Swedish National Space Board and Swedish Energy Agency. In total, grants in 2006 for research and development from these three agencies totalled SEK 2.7 billion, equivalent to around 10% of the total public R&D funding, or 0.1% of GDP.

In the mid-1990s, seven independent research foundations were set. They were given the task of funding strategic research for social development. These foundations are not state-controlled, but are independent bodies. However, the government appoints and dismisses all members on the boards and determines who will chair them. The research they fund is often conducted in tandem with researchers in universities and industry and in 2006 the volume was SEK 1.7 billion, equivalent to approx. 6% of public R&D funding.[62]

In Sweden, a relatively large proportion of research investment goes into defence-driven R&D. This R&D funding has a clear emphasis on technological R&D and is strongly driven by an interaction between the

[61] OECD, MSTI 2006

[62] The seven foundations are: the Swedish Foundation for Strategic Research (SSF), the Knowledge Foundation (or KK foundation), the Foundation for Strategic Environmental Research (MISTRA), the Foundation for Baltic and East European Studies, the Vårdal Foundation for Health Care Sciences and Allergy Research (the Vårdal Foundation), the Swedish Foundation for International Cooperation in Research and Higher Education (STINT) and the International Institute for Industrial Environmental Economics (IIIEE).

defence authorities and major Swedish industrial concerns. The majority of state-funded defence research is carried out in industry. It also constitutes the major part of government funding which goes into industry. In an international comparison, Swedish government investment in defence-driven R&D is great, even in relation to GDP.[63] In 2006, state funding of defence research totalled SEK 4 billion, equivalent to approx. 0.15% of GDP.

In 2006, the R&D funding from these financiers totalled SEK 8.6 billion, equivalent to approx. one third of the total state R&D funding, or 0.31% of GDP.

VINNOVA and the public research foundations initiate and fund R&D programmes in which companies, universities and research institutes can participate. In the majority of programmes, researchers at universities and research institutes in conjunction with companies are invited to apply in competition. The funding goes to universities and institutes whilst companies fund their own end. From the companies' perspective, participation in such R&D programmes has a number of advantages. It provides access to a broad spectrum of technological skills. It also increases the volume and breadth of the company's own research. Programmes build up knowledge and skills at universities which are relevant to companies. In addition, participation in them facilitates recruitment of university researchers. The company gets to know its researchers and the researchers get to know the company. This makes it easier to decide whether an individual researcher is suitable for the type of research being run in the industry. These experiences also make it easier for the researchers to decide whether research in industry is of interest to them.[64]

Needs-driven, state-funded R&D programmes have the potential to increase industry's research contacts and/or improve research collaborations between universities/institutes and industry, since their design requires industrial involvement. They aim to create good conditions for industrial renewal, i.e. innovativity in traditional industries and the growth of new industries, by generating new knowledge and skills (including researchers qualified in their research field). Naturally, the realisation of this knowledge and skill as innovation requires further activities on the part of companies.

[63] The substantial defence cutbacks which have been ongoing for quite a long time and which are now being further reinforced, plus the restructuring of the military, are highly likely to mean a substantial reduction in the scope of defence-driven state R&D. The possibility of steering this R&D funding towards civil needs-driven research for industry and society should therefore be a central research policy issue.

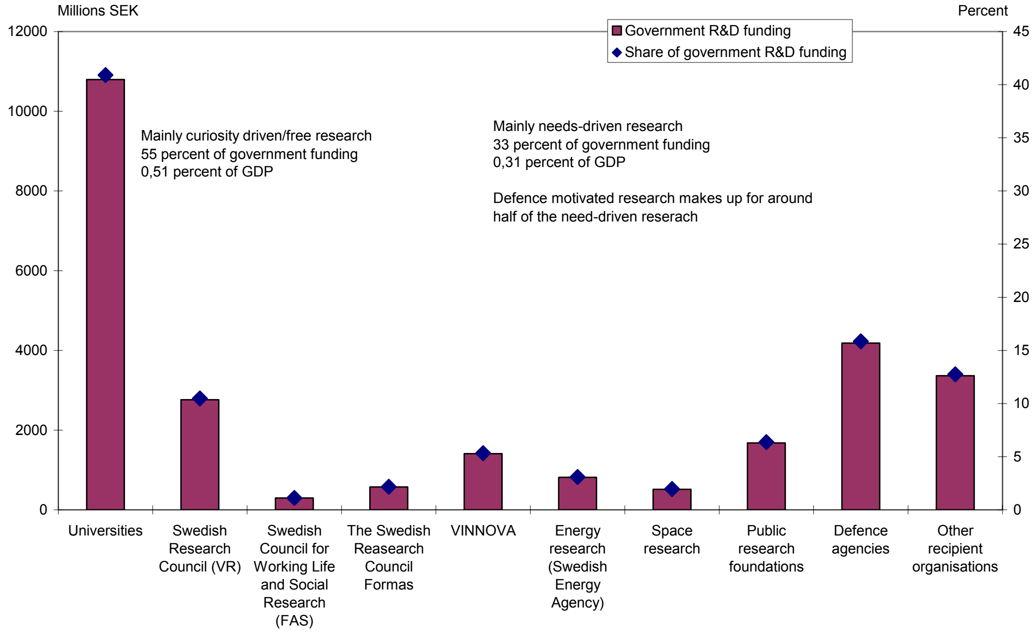
[64] NUTEK R 2000:24

The various types of state R&D funding should not be seen as mutually exclusive, but rather as supplementary. This is clear from the perspective of the research group. The research of a research group within the field is usually funded from a number of sources: faculty appropriations and research councils, agencies and occasionally also companies.

4.3 State R&D funding in Sweden and Finland

Of the Swedish state R&D funding, 55% goes to curiosity-orientated research, either through direct state grants or through funding from research councils (figure 4.3.1).[65] One third of the state's R&D funding goes to needs-driven research of which just under half consists of defence-driven research. There is then a remainder of approx. SEK 3 billion, comprised of funding to other agencies such as the Swedish International Development Cooperation Agency (SIDA), the Swedish Road Administration, the National Institute for Working Life (ALI), the Swedish Environmental Protection Agency etc. It is reasonable to suppose that the majority of their funding can be characterised as needs-driven.

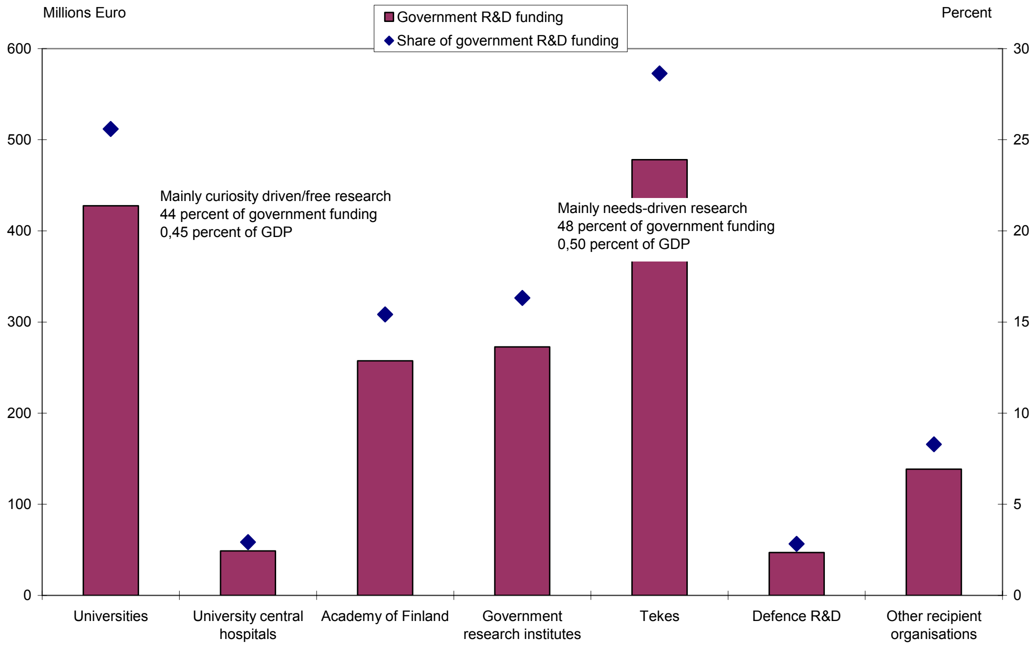
Figure 4.3.1 State funded research in Sweden 2006 distributed by source.



R&D funding by the Finnish state in regard to recipient players is distinct from the corresponding Swedish structure (figure 4.3.2).

[65] Data for Sweden from Statistics Sweden and for Finland from Statistics Finland.

Figure 4.3.2 State funded research in Finland 2006 distributed by source



In Finland, direct government grants to universities are just under 30% of state R&D funding. The Academy of Finland, which is equivalent to the Swedish Research Council, accounts for approx. 15% of the Finnish state's R&D funding.

The funding, which principally relates to needs-driven research, consists of funds to the state research institutes, with VTT as the largest player plus the Finnish Funding Agency for Technology and Innovation (TEKES, Finland's equivalent to VINNOVA), plus defence research. This totals half the state R&D funding.

Although there is no clear-cut divide between curiosity-orientated and needs-driven research, this indicates that Finnish state R&D funding relates in the main needs-driven research. Swedish state R&D funding on the other hand, relates mostly to curiosity-orientated research.

An alternative to starting with state financiers' grants in order to assess the distribution between curiosity-oriented research and needs-driven research is to use the aims/ends division used to classify research in official statistics. The OECD Frascati Manual contains guidelines for division according to purposes. Although this also has delineation problems, it is customary to use the purpose of "General advancement of science" as an indicator of research which is primarily curiosity-orientated. This also includes research aimed at raising knowledge levels within a distinct subject field but which is not of immediate significance to or attributable to any specific objective. The remainder of the research is divided according to the objectives which the research is intended to support. Examples of objectives are: defence research, research for industrial activity, energy supply research, research into transport and telecommunications etc.

In Sweden, General advancement of science constitutes 55% of state R&D funding. Research for purposes other than defence constitutes 30% of state R&D funding and defence research 15%.[66] In Finland, General scientific development constitutes 41% of the Finnish state's R&D funding. Research for purposes other than defence constitutes 56% and defence research 3%.

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[66] If it is assumed that the majority of undistributed state funding is chiefly composed of needs-driven research, these proportions are relatively consistent with the division made earlier in respect to recipients.

5 Needs-driven R&D programmes in four sectorial innovation systems

Converting a concept into a successful innovation requires expertise in a range of different fields: Who are the customers and how do we get in contact with them? What is the customer willing to pay for? What is the simplest way we can produce this? What rules do we have to take into account? What research and development needs to be carried out? A company or individual seldom has cutting-edge expertise in all these fields. Therefore, most innovations come about in collaboration between a numbers of different organisations: companies with different specialist skill, consultants, researchers, research financiers etc. A number of conditions must be fulfilled for such a collaboration to come about: There must be links between the various players. They must be aware of each other's existence, have confidence in each other's ability and want to collaborate. They should have a common vision of what can be achieved which is the driving force for the collaboration. Additionally, institutions such as laws, regulations, taxes etc., should encourage collaboration and renewal. This also means it is the content of the concept which determines which players are relevant. A concept for a new drug requires different companies and research implementers to a concept for equipping a new model of car with a navigation system. Organisations who take part in developing, producing and using innovations plus institutions which affect their will to innovate make up components of a sectorial innovation system.[67]

It is on such a sectorial system level that state-funded R&D programmes are carried out and have opportunities to promote innovations. Accordingly, a sectorial innovation system is defined as those players who develop, produce or use technology/product X, plus official and private institutions and institutions which affect their actions. The sectorial innovation systems dealt with in the four sections of this chapter are of two types. Nanotechnology and Biotechnology are technological innovation systems defined by a technology and its application in the products of a number of industries. The automotive and ICT industries are industrial innovation systems defined by "one" product and the technologies upon which that product is based. For each innovation system, there is a description of

[67] Through analysis work within OECD, innovation systems have become an important concept in the design of policy for renewal in most developed economies. An important lesson from OECD's work is that there is no "right way" to design innovation systems. The important thing is that the various parts – players, links and rules of play – fit together.

industrial structure, research base and state-funded, needs-driven R&D programmes.

The four innovation systems are at different stages in their industrial development. Nanotechnology is the youngest system and the technology is being applied industrially in a number of fields. A “nanoindustry” has begun to grow. Some 30 companies are basing their activity on nanotech products and a further 50 or so companies are using nanotechnology in some degree; these include major international companies such as Sandvik and ABB.

Biotechnology is a somewhat older innovation system. It began forming at the beginning of the 1990s and in 2003 there were just over 200 biotech companies operating within various industries. The largest application field was pharmaceuticals and biomedical engineering.

The ICT industry’s innovation system dates back further than biotechnology and the industry is of major significance to the Swedish economy. ICT products are used throughout industry including in the public sector. The industry is also responsible for a major proportion of industrial R&D.

The automotive industry’s innovation system is the oldest of the four and the industry is of major significance to the Swedish economy. Automotive companies also conduct comprehensive R&D activity. In terms of volume, the automotive and ICT industries are the largest R&D investors in Swedish industry.

Innovations emerge in slightly different fashions in the four systems. In nanotech and biotech, new firms, often with roots in universities, is an important way of introducing new products to the market. In the ICT industry and above all the automotive industry, innovations are largely launched by existing companies.

The potential for further innovations is great within all four systems. Within biotech and nanotech, technical development provides new innovation opportunities. To some extent, this is also true of the ICT and automotive industries, but competitive pressure and market demand are also strong incentives there.

Research at universities and research institutes within the four innovation systems are differently sized in terms of volume; as well as in terms of volume and objectives of government funded research. Curiosity-orientated research is funded through faculty appropriations and grants from research councils. Needs-driven research is funded through grants from agencies and research foundations. Both forms are significant, but in different ways, to the innovation activity of the four systems. However, only the needs-driven R&D funding aims to promote and stimulate innovation.

Government funded and needs-driven R&D programmes can be divided into a number of types according to the degree of industrial influence and participation. In *Industrial R&D programmes*, there is a specific industry which largely initiates, controls the direction of and implements a project. In *Technological R&D programmes*, influence over the direction of the programmes is shared between financiers, academia and industry. The research is carried out at universities and companies can participate in research projects. In recent years, a third type of R&D programme has increased in scope, known as C*entre programmes*. These are programmes aimed at building, in international terms, Centres of Excellence in research and innovation where research is conducted jointly by industry and academia. In the innovation systems which were surveyed, industrial R&D programmes have only been implemented in the automotive system. Technology R&D programmes and Centre programmes exist in all four systems.

Within the nanotech and biotech innovation systems, the content of a large proportion of R&D programmes has been aimed at the development of technologies for new applications, generating new companies and supporting the commercialisation of research-based products in small companies. Within the ICT innovation system, programmes have also concentrated on the research and recruitment needs of existing industry. This has also been the main focus within the innovation system of the automotive industry.

The roles of R&D programmes vary according to the development level of innovation systems. In the older and more mature industrial innovation systems with large companies, there are many programmes where research projects are implemented jointly between companies and academia with the aim of generating new knowledge and training researchers who can be recruited by industry. The role of the programmes is to strengthen existing companies' innovation capacity. In the younger technological systems, R&D programmes also have the role of promoting industrial renewal through research-based newly established enterprise.

The role of industrial R&D programmes is to strengthen companies' innovation capacity in a specific industry. The role of R&D programmes is also to strengthen companies' innovation capacity, but as a rule these are not directed at a specific industry but towards technologies which can be used in several industries. Centre programmes are also intended to strengthen the innovation capacity of industry, but they are also intended to create knowledge conditions for industrial renewal, through newly established enterprise for example. The challenge for research financiers is to find the "right" balance between the various types of R&D programme over time in a given innovation system.

Financiers of needs-driven R&D programmes have a number of issues to address. Firstly, which research fields within a given innovation system may prospectively need state-funded R&D programmes? In technological innovation systems, the question for research financiers is which direction(s) of application R&D programmes should encompass. In industrial innovation systems, the question becomes which of a large number of possible technologies programmes should encompass.

The next question is which type of R&D programme should be implemented. The answer is largely determined by the development level of the innovation system. In younger systems, where the industrial activity is still in its infancy, R&D programmes and Centre programmes are relevant. It may even be the case that such programmes can create knowledge conditions for new innovation systems. In older innovation systems with comprehensive industrial activity, sectorial industry R&D programmes are important to strengthen the innovation capacity of the industry. However, this does not eliminate the need for renewal which both other types of programme can promote.

The following description of the four innovation systems shows that they have clear connections with each other. Nanotech companies, for example, can be found within the ICT and biotech industries. For their part, ICT companies operate in a range of industries, including the automotive industry. Innovations within electronics/IT for the automotive field may anticipate nanotech research. Innovations within the automotive field may anticipate materials research, which in its turn may anticipate nanotech research and so on. Such dependencies between different sectorial innovation systems are important to observe when designing needs-driven R&D programmes. Centre programmes and R&D programmes can therefore occasionally be directed towards technologies which are used in multiple systems and industries.

5.1 Biotechnology

The world “biotech industry” has the wind very much in its sails. Total revenues for the listed biotech companies around the world in 2005 totalled USD 63.1 billion. Revenues for Europe’s quoted biotech companies increased on the previous year by 17%, to USD 7.9 billion. An increasing amount of capital is being invested in the biotech industry and interest in quoting new companies has increased. During 2005, 23 new companies were quoted in Europe, compared with only eight in the previous year. The total value of these quotations totalled USD 691 billion.[68]

Biotechnology is a generic technology, meaning that it has many fields of use. The OECD definition of biotechnology is:

> *"Application of science and technology to living organisms or parts, products and models of living organisms in order to change living or non-living material for the purposes of producing knowledge, goods and services."*[69]

5.1.1 Industrial applications of biotechnology

Biotechnology has multiple fields of industrial application. In Sweden, it is chiefly applied within:[70]

- Pharmaceuticals/Biomedical engineering
- Equipment/Instruments
- Foods
- Agriculture and forestry
- Environmental technology

Pharmaceuticals & Biomedical engineering

Biotechnology is used within the pharmaceutical industry to identify suitable target molecules involved in disease mechanisms. Pharmaceutical substances are then identified which can affect the function of these target molecules. The target molecules are normally relatively large proteins whilst the pharmaceutical substances are often small synthetically produced molecules. To an increasing extent, drugs are now biotechnically produced molecules and biotechnology is thereby used in the entire development and manufacturing process. The number of registered drugs based on complete utilisation of biotechnology is on the increase. Also, increasingly advanced methods as to how drugs should be administered to patients have been developed, so that the active substance is absorbed in the best way by the body.

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68 http://www.ey.com/global/content.nsf/International/Biotechnology_Report_2006_Beyond_Borders

69 This includes such technologies as genetic engineering, genomics, sequencing/synthesis of and technologies based on DNA/RNA, proteins and peptides; proteomics, protein isolation/separation and purification, cell/tissue culture, vaccines/immune stimulating agents, fermentation using bioreactors, biobleaching, bioremediation, biofiltration, gene therapy, viral vectors, bioinformatics and application of nano/micro-fabrication processes and tools for the manufacture of equipment to study biosystems, and applications for drug administration, diagnostics etc. OECD, 2006. "OECD Biotechnology Statistics – 2006"

70 The following description of the applications is taken from VINNOVA VP 2005:2.

Biotechnology is also used within diagnostics and biomedical engineering. Genetic diagnostics means that for a few diseases, it is possible to identify genetic changes which can be linked to a certain disease, e.g. a predisposition to breast cancer. There are many other types of biomolecular analysis for the diagnosis of various conditions. Within biomedical engineering, patients' own skin cells have long been cultured for transplants in the event of burn injuries and antibacterial substances are being used in such things as dressings. There are many more examples of biotechnical applications within healthcare.

Equipment & Instruments

In this application, biotechnology may entail analytical equipment used to study the structure, interaction and function of biological molecules. Products used in bacterial and cell cultivation, bioseparation and synthesis when biological molecules, cells and microorganisms are produced. Also included in this category are IT solutions for bioinformatics, as are used in database management and visualisation of collected structural and functional data.

Foods

It is anticipated that biotechnology will be utilised to an increasing degree in all industries working with biological raw materials. Developments in the food industry are often based on interdisciplinary approaches with medical research, nutrition, new packaging and materials, microtechnology and sensors. Biotechnology is variously applied in so-called functional or smart foods and in relation to analyses of foods for quality and safety, such as the occurrence of harmful bacteria.

Agriculture and forestry

Examples of biotechnology applications in agriculture are biological biocides consisting of naturally occurring bacteria and other microorganisms to protect seeds and plants against harmful insects and parasites.[71] Where it concerns genetically modified (GM) crops, such things as a GM potato species for the production of starch have been developed in Sweden. Also currently under development in Sweden is a species of blight-resistant potato, which should reduce the use of chemical biocides and make the crop easier to cultivate[72].

[71] Within agriculture, the world market for biocides has been estimated at USD 30-35 billlion and growth at 1-2% per year. The world market for biological biocides has been estimated at USD 600 billion with an annual growth of 10-20%.
[72] Each year, blight destroys potatoes worth SEK 20 billion around the world.

Environmental technology

Companies in this industry are developing technologies for and working with land decontamination, waste management, water purification and laboratory analyses. Customers may be municipalities, construction companies and industries, e.g. to purify water used in the manufacturing processes of pulp and paper companies.

Other applications

So-called white, or industrial, biotechnology deals with biotechnical applications in the production of chemicals, materials, paper, pulp, fodder and fuels.[73]

Industrial structure and development of the industry

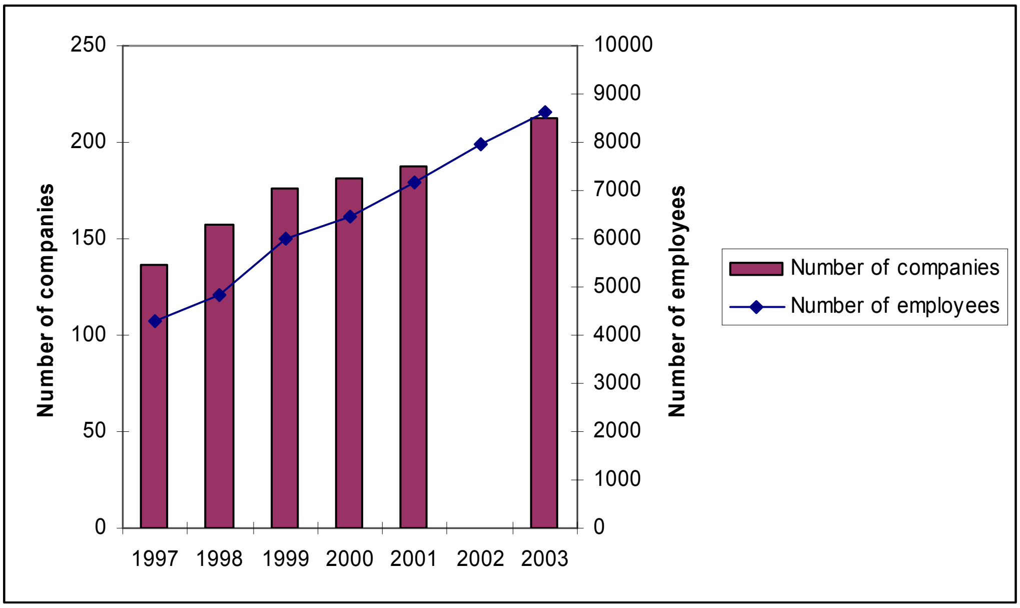
The majority of comparative studies of Sweden's biotech industry have been compiled by consultancy companies who do not state which companies are included in the studies. Ernst & Young maintain that only Germany, Great Britain and France have more biotech companies in Sweden. One study commissioned by EuropaBio, the European umbrella organisation for national biotech sector organisations, arrived at the same result. The study shows that in terms of number of employees, Sweden is in 7th place as, besides the above three countries, Denmark, Switzerland and Ireland also have more employees than Sweden.[74]

Since 1997, both the number of biotech companies (excluding AstraZeneca and Pfizer, formerly Pharmacia) in Sweden and the number of employees in them has increased. In 2003, there were a total of 213 companies in these industries with 8,632 employees (figure 5.1.1).

[73] The consultancy firm, McKinsey predicted some years ago that by the year 2010, 10-20% of all chemicals would be produced with the aid of biotechnology and that the value would total USD 120 billion. In 2000, the US Congress decided that 20% of all industrial products and all energy coming from fossil raw materials that year should be produced using renewable resources in 2020.

[74] Europa Bio, Biotechnology in Europe: 2006 Comparative study.

Figure 5.1.1 Number of companies and employees in Swedish biotech industry 1997 - 2003



Source: VINNOVA VA 2003:2 och VA 2005:2

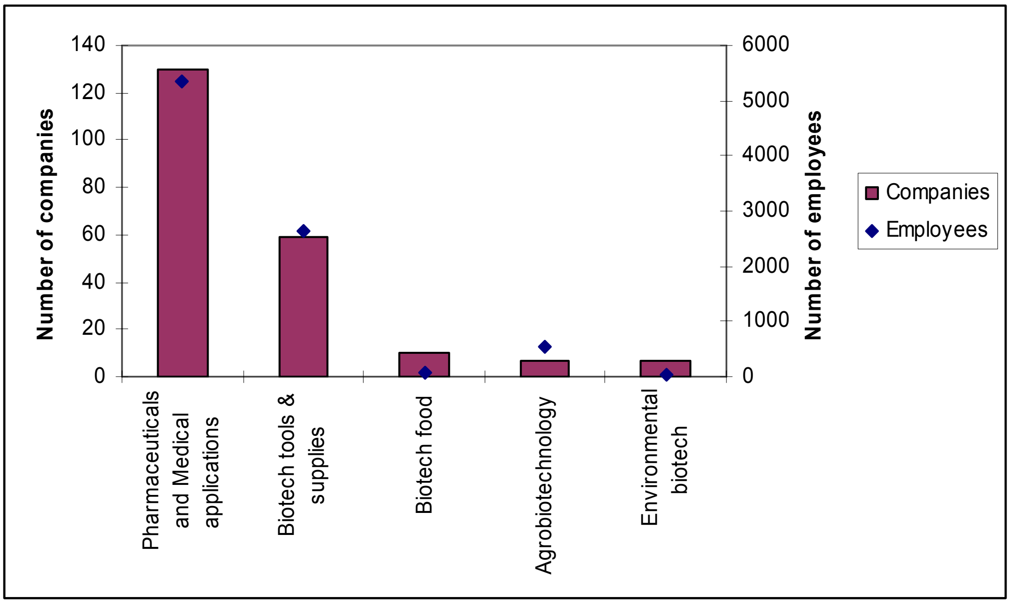
Note: Information on the number of companies in 2002 is lacking

In Sweden, biotechnology has so far made major penetration within Pharmaceuticals & Biomedical engineering and within Equipment & Instruments (for life science research and development as well as biotech production). Additionally, there are a smaller number of biotech companies within the food, agriculture and forestry and environmental engineering industries (figure 5.1.2).

The pharmaceutical diagnostics and biomedical engineering industries constitute a successful example of the growth of knowledge-intensive industry in Sweden. Net exports of pharmaceuticals have made notable positive developments since the 1980s, the like of which does not exist in any other product group. Pharmaceuticals currently account for around 20% of Sweden's total net exports and biomedical engineering just over 2%. Between 1997 and 2003, the growth in the number of employees within pharmaceuticals and biotechnology has been slightly less than 5.5% per year in AstraZeneca and 3% per year in Pharmacia-sphere companies. Those companies which in their research and development largely use biotechnology include AstraZeneca (not included in the statistics in the above graph), Biovitrum, KaroBio, Active Biotech, Medivir, Sangtec Molecular Diagnostics, NeuroSearch (formerly A Carlsson Research AB) and Cellartis.

Biotech production of pharmaceuticals is the subsidiary area of white, or industrial, biotechnology which has so far come furthest in Sweden. Sweden was amongst the first countries in the world where genetically modified bacteria were used for pharmaceutical production and today, production also takes place in mammalian cells. Large-scale production currently takes place at Pfizer in Strängnäs but other companies such as Biovitrum, BioInvent, AstraZeneca, SBL vaccines and Octapharma also run such operations in Sweden.

Figure 5.1.2 Number of biotech companies and employees distributed by fields of application in 2003



Source: VINNOVA VA 2005:2

Sweden has long had a competitive industry in equipment, instruments and services for life science research, development and production (biotechnical tools). Examples of companies are GE Healthcare and Biacore (recently acquired by GE Healthcare) and younger companies like Biotage and Gyros.

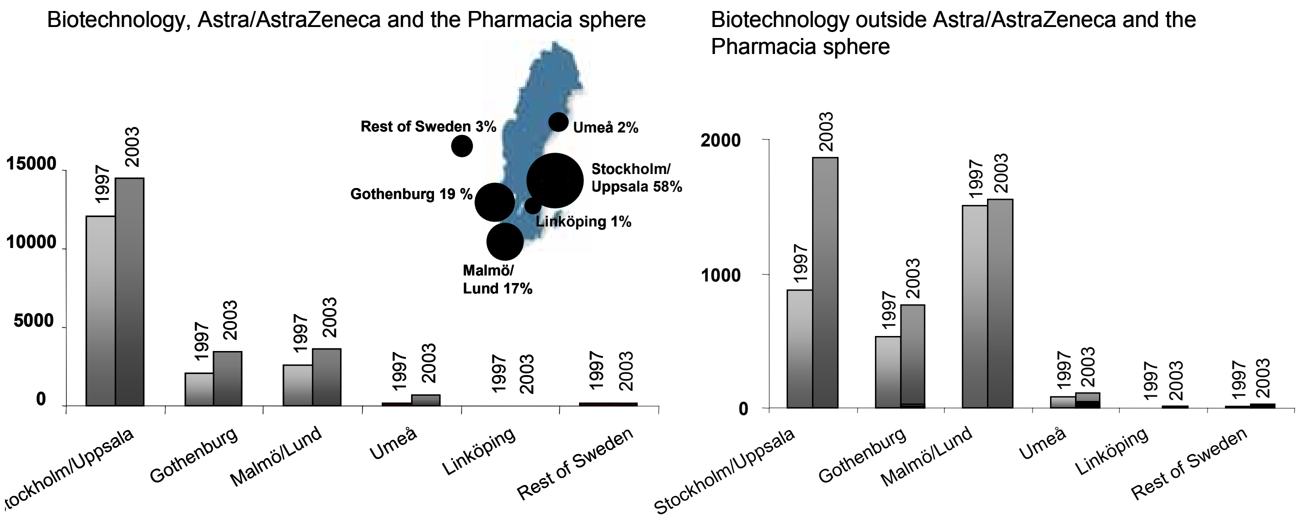
Within the food industry, development is being driven forwards by small, innovative companies which provide a bridge between scientific development and mature industry. Quality and safety are profile areas for the Swedish food industry and life science research can contribute such things as new knowledge about the connection between diet and health, as well as methods of analysing food quality. There are currently only a few biotech companies concentrating on the food industry, such as Biogaia and Probi and a few mature companies have been their customers and partners in the development.

There are few companies in agrobiotechnology. The larger ones using biotechnology in their research and development are Svalöf Weibull AB and Syngenta Seeds AB. The forestry industry and agricultural companies are currently not driving the application of GM, but there are a few small innovative companies. Two companies whose activity includes the development of GM products are Plant Science Sweden AB, a subsidiary of the German company BASF and Svalöf Weibull, and SweTree Technologies, a spin-off primarily from research in Umeå and Stockholm. Similarly, there are few companies in biological biocides and competition from the major chemical companies is stiff.

Biotech companies in environmental engineering are also few in number. They have not increased over time, although new companies have arrived as others have disappeared. They are not particularly large, measured buy number of employees. The largest companies in 2003 were AnoxKaldnes AB within sewage purification and Pegasus Lab AB within such areas as microbiological analyses, e.g. identification of fungi and moulds in the indoor environment.

A study from 2005 showed the regions in which biotech companies which existed in 1997 and 2003 were located.[75] Figure 5.1.3 describes how the number of employees is distributed across the regions around the most important biotech centres in Sweden.

Figure 5.1.3 Number of employees in Swedish biotech industry distributed by regions in 1997 and 2003



Companies often collaborate with universities in their research and many have originated in research and universities. This largely explains why the majority of employees are found in regions with comprehensive life science research. By and large, the distribution of industries between regions correlates with the regional distribution of research within the life sciences, measured in R&D expenses for bioscience at universities in different

[75] VINNOVA VA 2005:2.

regions for 2003 (figure 5.1.9 page 69). In 2003, the Universities of Stockholm and Uppsala accounted for approx. 57% of Swedish universities' total life science research; almost exactly the same proportion as for employment in industry. The corresponding figures for the universities of Gothenburg and Lund/Malmö were in both cases approx. 15%, i.e. somewhat lower than those regions' proportion of industrial employment. Conversely, in Umeå and Linköping, with approx. 8% 3% respectively of the life science research, the research proportion was many times greater than the proportion of industrial employment.[76]

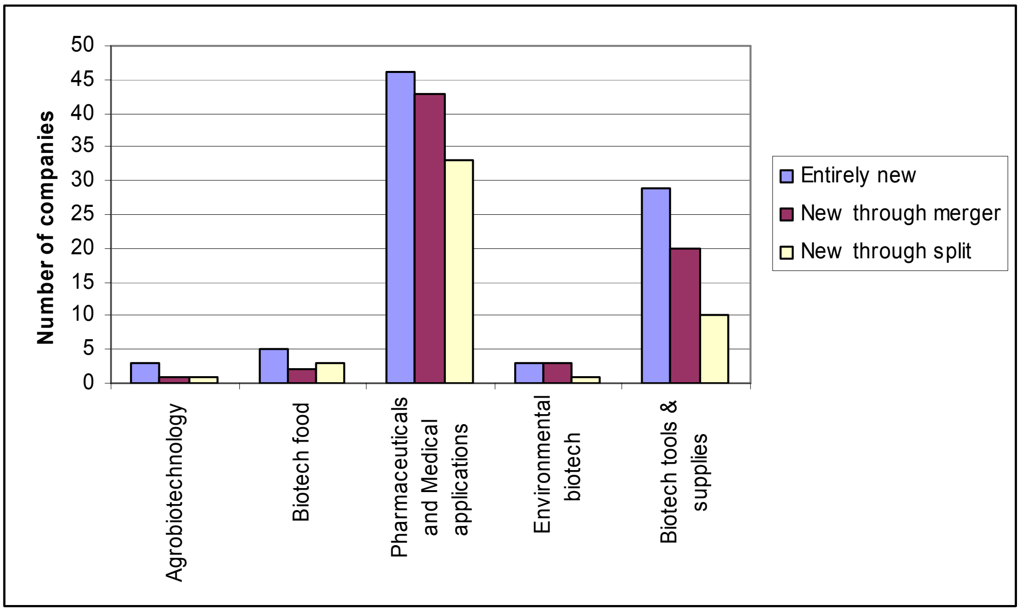
New firms

The proportion of biotech companies in Sweden started to grow during the 1990s and the growth really took hold at the end of the decade. Of the companies in existence in 2004, just over 90% were formed after 1990 and the majority, or 63%, after 1999. Biotech companies were formed either by the merger of two companies, the division of one company or they were entirely new. Slightly less than 60% of companies originated with other companies. Thus the dynamic of newly established enterprise is largely dependent on splits and mergers between companies.[77]

The majority of the newly established enterprise is within Pharmaceuticals & Biomedical engineering as well as Equipment & Instruments (figure 5.1.4). The most common of the three forms of establishment was "entirely new companies" within all applications except environmental engineering.

[76] VINNOVA, VP 2005:02
[77] The proportions have been determined for 219 of the 227 biotech companies which existed in 2004 Of those 219, 16 had been started before 1990.

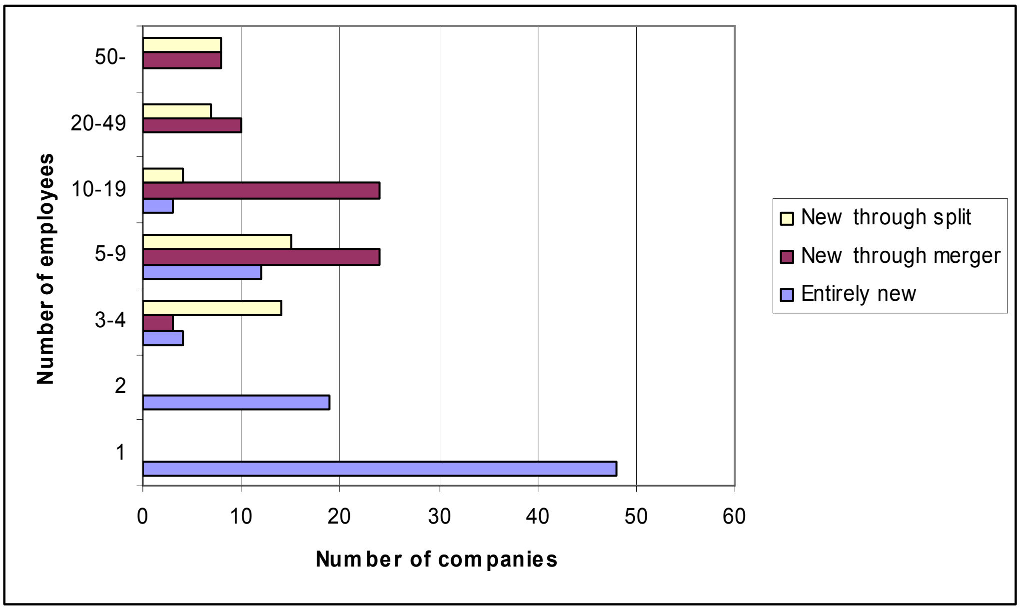
Figure 5.1.4 Number of new biotech companies established between 1990 and 2004 distributed by fields of application and manners of origin



Source: VINNOVA

The size of the new companies in the year of their formation is distinct between the three types of establishment. Those companies which originated with other companies were larger than the entirely new ones (figure 5.1.5).

Figure 5.1.5 Distribution of biotech companies by size classes and manners of origin at the time of establishment



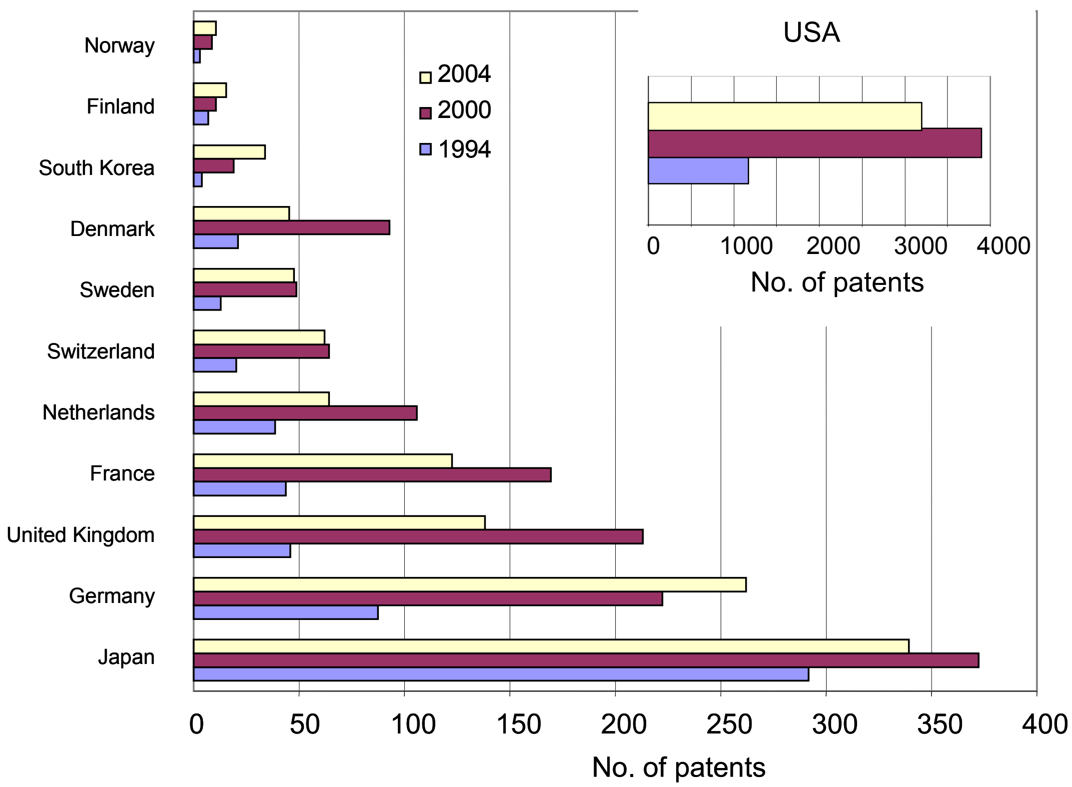
Source: VINNOVA

5.1.2 Innovations

Information on new products and processes introduced is absent for all types of company, not just biotech companies. Companies' patenting is often used as an indicator of innovation. Amongst other things, patent statistics are difficult to analyse as there are groups of patents applicable to the same innovation. Also, many patents lead to one innovation. Patents are therefore more an indicator of *innovation potential*.

In the fields of pharmaceuticals and biotechnology, Sweden has increased its proportion of the volume of patenting in recent years.[78] Figure 5.1.6 shows the number of patents for different countries at USPTO in biotechnology for 1994, 2000 and 2004. In 2004, the US had almost 10 times as many patents granted as Japan and just over 60 times as many as Sweden.

Figure 5.1.6 Number of patents granted by USPTO within biotechnology 1994, 2000 and 2004



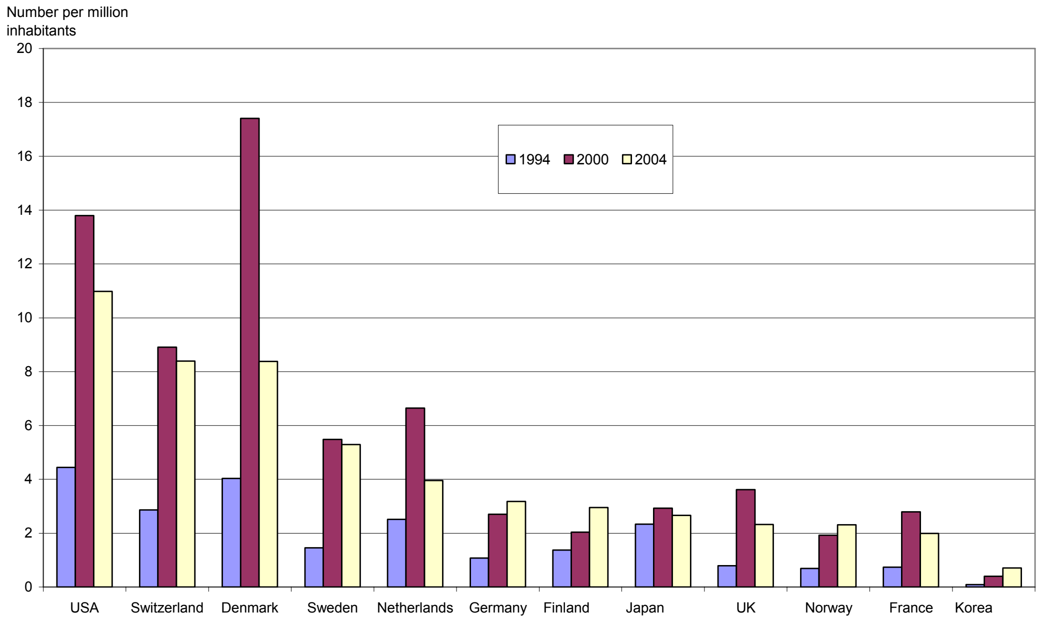
Source: OECD Patent Database

[78] Patent data also shows that international collaboration is a common occurrence in biotechnology.

There is no information as to which Swedish players are responsible for patents, but a previous study showed that the largest companies, AstraZeneca and forerunners plus the former Pharmacia (now Pfizer and several spin-off companies), accounted for around 20% of the patents within biotechnology and more than 30% of the patents within pharmaceuticals.[79]

When Swedish patenting at USPTO is taken in relation to number of inhabitants, then Sweden came second only to the US, Switzerland and Denmark in 2004 (figure 5.1.7). As with a number of other countries, the proportion is lower in 2004 than 2000, but the difference for Sweden is marginal.

Figure 5.1.7 Number of USPTO-patents within biotechnology per million inhabitants 1994, 2000 and 2004



Source: OECD Patent Database

The potential for future innovations based on biotechnology is great.[80] Those sections of industry in which biotechnology has already made major penetration are Pharmaceuticals, Diagnostics, Biotech Biomedical Engineering, Equipment & Instruments, Bioproduction, Agrobiotechnology, Environmental Biotechnology and Biotech Foods. With the rapid development of new knowledge, there is a major expectation for new goods and services within these fields. In the long term, biotechnology is also important to much larger sections of Swedish industry. Environmental

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[79] VINNOVA VA 2003:2

[80] Unless otherwise stated, the remainder of this and the following section is based on infomration in VINNOVA, VP 2005:02,

arguments and opportunities to develop new functionality and thereby increase refinement value are pushing development in such industries as foods, forestry and chemicals as well as agriculture.

Pharmaceuticals & Biomedical engineering

The penetration of biotechnology within the healthcare field has been comprehensive even whilst there is still major potential for new drugs, vaccines, diagnostic tests and treatments. In the future, it may provide new opportunities to prevent and treat such things as cancer, cardiovascular disease, obesity, diabetes, infectious diseases and allergies. New diagnostic methods are possible, partly because of the new knowledge about our genes but also due to the fact that the field of diagnostic imaging and physiology has developed strongly. Better diagnostics are providing increased opportunities for early and preventative treatment. Life science development is also providing the opportunity to develop new methods of treatment based on newly discovered mechanisms such as the mapping of the human genome and research into functional genomics and proteomics. One biotech field within biomedical engineering where great things are expected is regenerative medicine where, it is predicted, a combination of stem cells, growth factors and biomaterials will lead to methods of repairing, regenerating or replacing damaged tissue either in situ in the body or outside the body for subsequent transplantation.

Equipment & Instruments

New technologies and methods of analysis for life science research and development are developing rapidly. Many of the discoveries which lead to new products and applications are generated by academic research environments and a key factor for this field is multidisciplinary work. There is great potential for the development of innovations in fields like biomolecular analyses and cell biology which can lead to applications in a number of industries.

Foods

Within the field of foods, products which are developed can be based on designer raw materials, or contain health-promoting additives. It is anticipated that it will be possible to produce products with improved shelf life and flavour, increased bioavailability and containing fewer allergens and toxins. There are also opportunities for developing foods to increase well-being and prevent illness. There are few products within functional or smart foods on the market today, but more are under development and the market potential is considered good.

Agriculture and forestry

Life science and biotechnology have provided entirely new knowledge and new tools for investigating and better exploiting the properties of plants. This has led to more efficient conventional cultivation, but also the opportunity to introduce entirely new properties into the plants. This biological knowledge has afforded new opportunities to understand and better exploit natural biological variation. It is anticipated that gene technology will lead to increased yields on fields, opportunity to exploit new farming environments as well as facilitating the development of less environmentally harmful farming systems. Another application is to use new plants to control nitrogen fixing and decontaminate polluted environments. New biological biocides will probably take on increased significance in agriculture.

Companies are anticipating that greater value added at the end of the value chain from seed to table will mean opportunities for higher revenues. Another strong incentive is the benefit which the new plants with designer nutritional content and good opportunities for high yields provide in developing countries.

Within forestry, it will be possible to grow modified or GM trees with a different fibrous structure, altered lignin content, different growth properties or modified structure to permit simpler stripping or an increased content of desirable components. Overseas, there are already limited plantation areas of genetically modified trees producing a variety of fibre qualities as well as various saw timbers for use in products with special needs profiles. However, this will be a long-term development. Internationally prominent research is under way in Sweden, especially at Umeå University. This research is being commercialised through a company affiliated to the research environments.

Environmental technology

Increased use of biotechnology in agriculture and forestry as well as industrial processes has great potential to reduce the use of harmful chemicals, lead to an increased use of renewable raw materials and increased use of biofuels. Thus biotechnology means an opportunity for reduced environmental harm. There is also potential within the production of biogas from waste broken down by naturally occurring bacteria in such things as dung heaps and marshes.

Other applications

Within the forestry industry, research in biotechnology is marginal but the field of industrial biotechnology is anticipated to increase in regard to biofuels. Within the pulp and paper industry, biotechnology has not yet made major penetration, but expectations are great. When knowledge about the genome of many microorganisms is produced, new enzyme systems are identified. It is considered possible to increase the use of enzymes in processes and to use new methods and new polymers for surface treatment and coating as well as developing new composite fibres. Using biotechnology, separation methods for the production of new fractions from renewable raw materials can be developed and techniques for such things as enzymatic treatment can give raw materials new quality characteristics. This creates the conditions for development of new materials and products from biological raw materials.

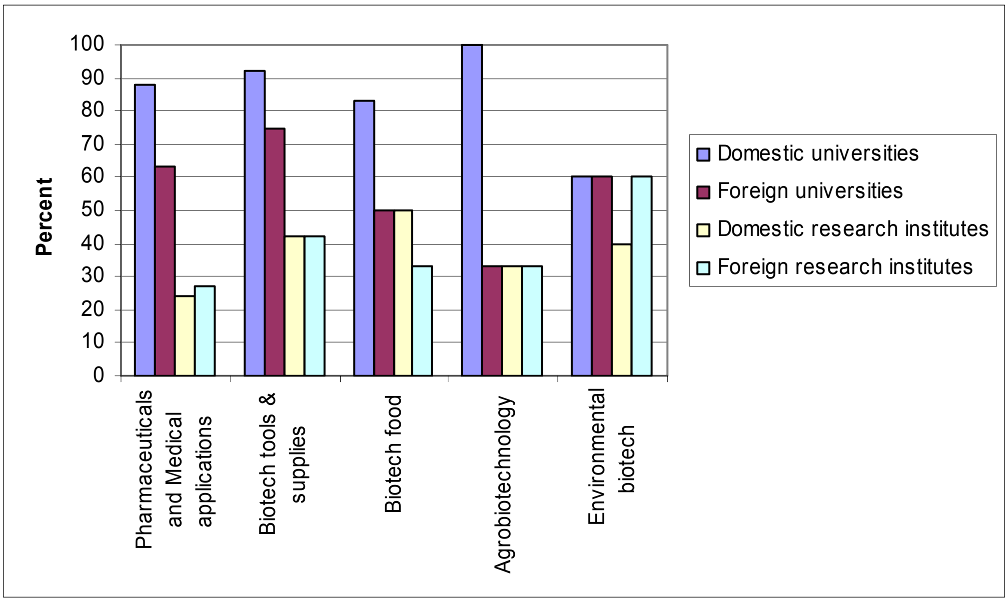
One field in which a great deal is taking place internationally is the development of renewable plastics, for example based on maize starch. Other product areas where increased use of biotechnology may be anticipated are drug intermediates, separation chemicals, paper chemicals, surfactants, polyoles, lipids and binding agents in dyes. It is anticipated that biotechnology in combination with other technologies, e.g. bioimaging, biomimetics, and bionics will have major market potential.

Corporate utilisation of research

The life science research base at universities and research institutes comprises an important source of ideas and technology around which new commercial activities in existing or start-up companies can be constructed. It also provides entry to international research networks and acts as a source of recruitment to companies. A strong Swedish research base increases the probability of companies choosing to develop their activity here and foreign companies finding it attractive to invest in research, development and production in Sweden.

There is no information on the extent of this knowledge exchange. That exchanges are taking place is indicated by the fact that biotech companies are collaborating with research groups at universities and research institutes. The huge majority of companies conducted such R&D collaborations primarily with Swedish universities (figure 5.1.8).

Figure 5.1.8 Proportion of biotech companies that collaborated with domestic and foreign universities and research institutes in 2000 distributed by fields of application



Source: VINNOVA, VF 2001:2

The fact that Swedish universities are important partners in the research and development activities of these companies is also noted in the statistics for scientific journals. About 75% of companies authoring scientific articles did so in conjunction with researchers from universities.

Academic research is also significant as a source of recruitment for people with cutting-edge expertise within various research fields. This is particularly pronounced in the biotech companies, since they employ many people with research training. In 2003 for example, the pharmaceutical industry accounted for 30% of all those with research training in the corporate sector's R&D activity and if biotech companies within other industries are included, the proportion becomes even higher.

5.1.3 Biotech research at universities and research institutes

Major investments are being made in the life science field in many countries. This is particularly evident in the US. For example, the budget for the National Institute of Health (NIH) has doubled in the last decade and is now approx. SEK 200 billion per year. In its investments, NIH has placed great emphasis on involving researchers from non-life science disciplines to work with life science problems. Another trend in NIH's endeavours is large projects combining expertise from many different research groups distributed over the entire US and with branches outside the US. In addition to the changes which have taken place within NIH, private foundations and donations have also played an important role.

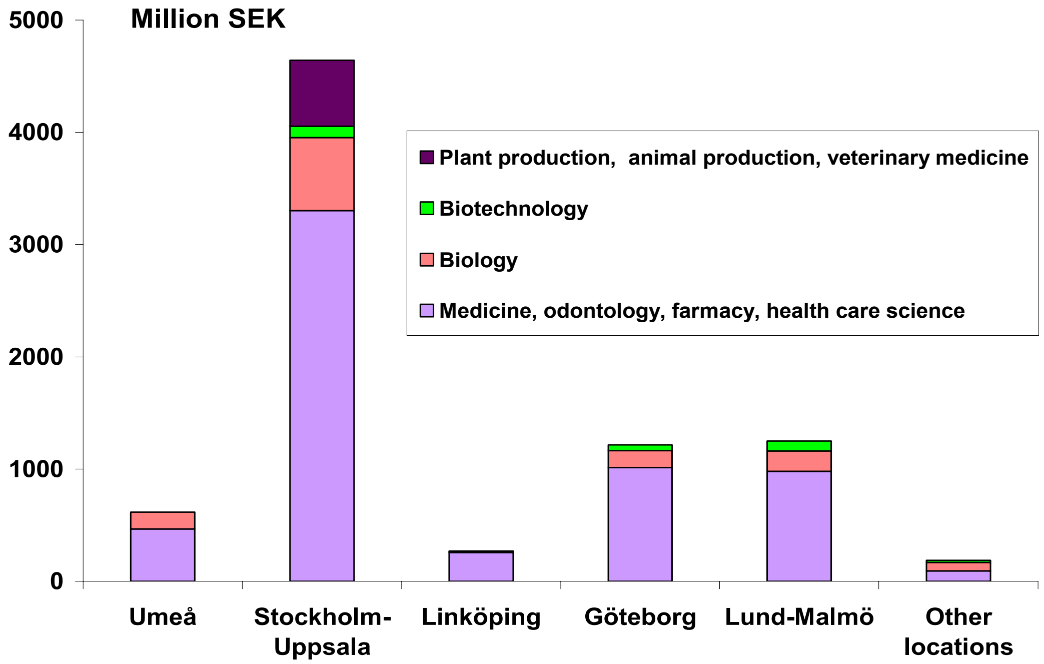
After Japan played a relatively obscure role in the international "Human Genome" project, a national mobilisation was inaugurated at the end of the 1990s aimed at getting Japan to play a more central role in functional genomics and related fields. Great Britain, Canada, Australia, France and the Netherlands are some other countries who have made major investments in life science research and particularly genome research. A number of countries which have not previously focused on life science, such as Singapore and South Korea, have also in recent years prioritised this field. Amongst the Nordic countries, Finland and Norway have increased their investment.

Life science research accounts for almost 40% of all research at Swedish universities, which is comparable with the share by volume in other countries. Based on Statistics Sweden's R&D studies for universities, the total cost of life science research, if a very broad delimitation is used, is estimated at around SEK 8 billion for 2003 (see figure 5.1.12, page 72). There is further research with life science content in other subjects, but the volume is difficult to estimate. Life science research is also conducted at some research institutes.

As a result of proposals in the research policy bill, "Research for a better life" (Bill 2004/5:80), a broad estimate shows that the total state funding of life science research during the period 2005-2008 will increase by between SEK 900 and 1,200 million, equivalent to between 17 and 23% of the level of total state funding for life science research in 2003.

A major section of the research expenditure for 2003 on life sciences was in the Stockholm-Uppsala region, particularly where it concerns medical research (figure 5.1.9). This can be explained by the fact that Sweden's largest universities in the field, Karolinska Institutet, is in this region, as is the comprehensive medical research at Uppsala. Moreover, it can be noted that with a few exceptions, the distribution correlates well with the distribution of industry in Sweden (see page 62).

Figure 5.1.9 Life science research expenditures at universities in 2003



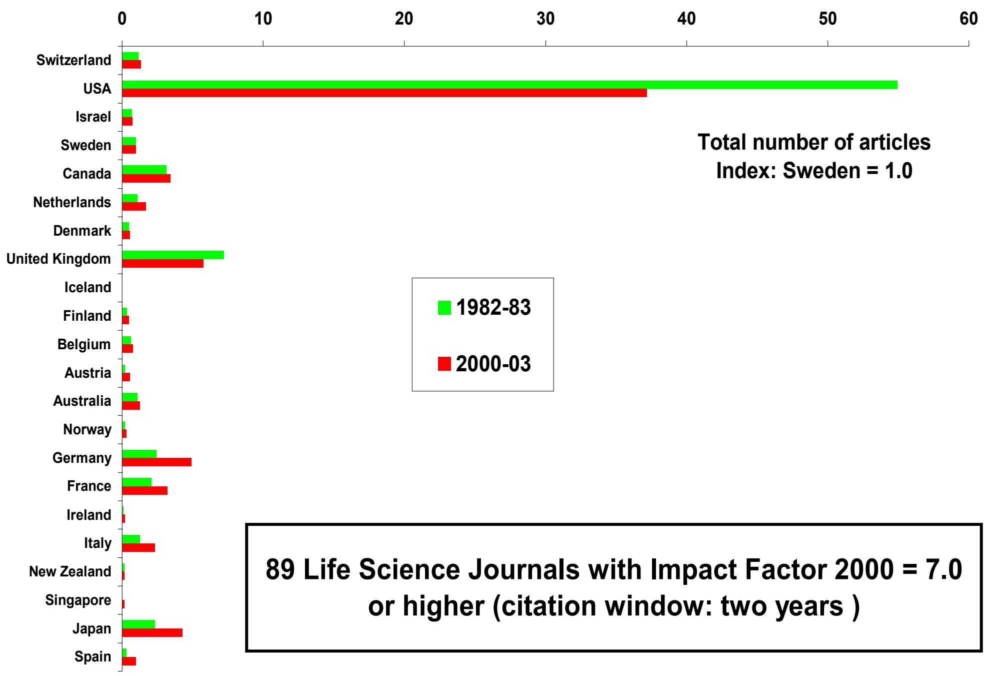
Source: VINNOVA

International competitiveness of life science and biotech research

Swedish biotech research occupies an advanced position, but the majority of other countries are expanding their research more quickly than Sweden. In relation to the size of its economy, Sweden is one of the leading countries in life science research. Where it concerns publication in scientific journals in relation to national populations, Sweden makes a good showing both quantitatively and qualitatively. However, publication data is not an exact measurement of volume and quality and should therefore be interpreted with caution.

Figure 5.1.10 shows a comparison based on an analysis of 89 life science journals which all have a so-called “Journal Impact Factor” of at least 7.0. The Impact Factor is a means of ranking journals according to how much the articles in the journal is concerned are quoted on average. Researchers, particularly within the life sciences, normally strive to publish in journals with a high Impact Factor, thereby giving a certain indication of the quality of the journal and the articles published in it.

Figure 5.1.10 Number of articles in life science journals 1982-1983 and 2000-2003



Source: VINNOVA

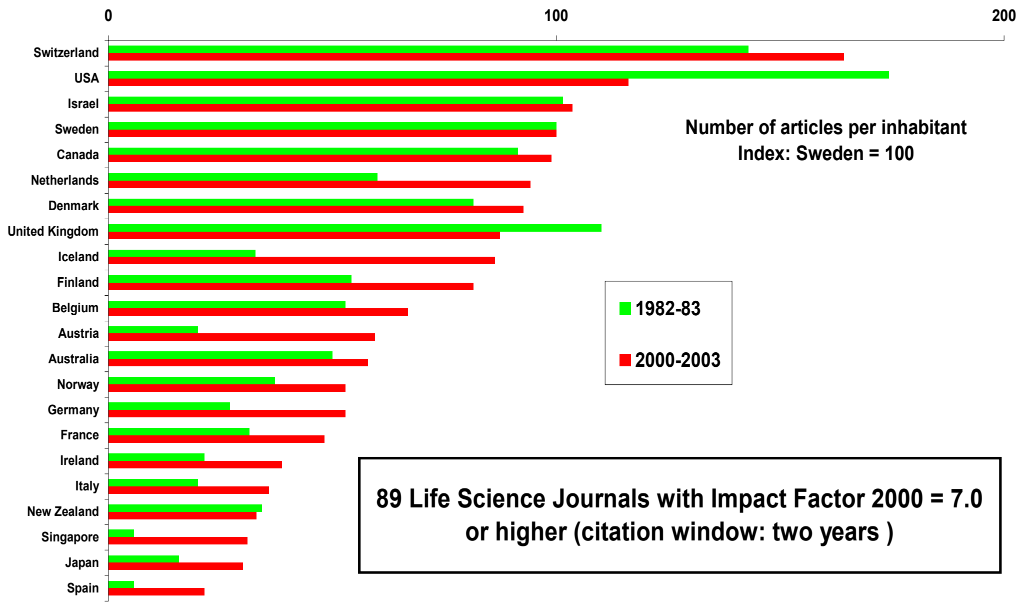
Just as was the case regarding patenting in biotechnology, the picture in high-quality life science publication statistics is dominated by the US. Researchers in the US are involved as authors in 60% of all articles in the journals surveyed during the period 2000-2003, as compared with 33% from some of the countries in the expanded EU.[81] Germany and Japan, which 20 years ago had a total publication of volume only about one third the size of Great Britain's, are today only lower by 15% and 25% respectively and are now making a significant contribution to international publication in the life sciences.

When the publication volume in the selected journals is taken in relation to population, the picture changes (figure 5.1.11). Measured in this way, only Switzerland, the US and Israel are on a higher level than Sweden. A further six countries are directly below Sweden's level: Canada, the Netherlands, Denmark, Great Britain, Iceland and Finland. The figure also shows corresponding data the preceding 20-year period. With a few important exceptions, the huge majority of countries have advanced their positions compared with Sweden. Notable amongst the exceptions are chiefly the US and Great Britain, whose position was already highly advanced 20 years

[81] Since authors from more than one country may contribute to an article, the total percentages for different countries or regions is greater than 100%. However, the stated proportion for the EU has been calculated for the EU countries as a group.

ago. Of particular note amongst the top-ranking countries which have closed in on Sweden's advantage at the start of the 1980s are the Netherlands and Finland.

Figure 5.1.11 Number of articles per inhabitant in life science journals 1982-1983 and 2000-2003



Source: VINNOVA

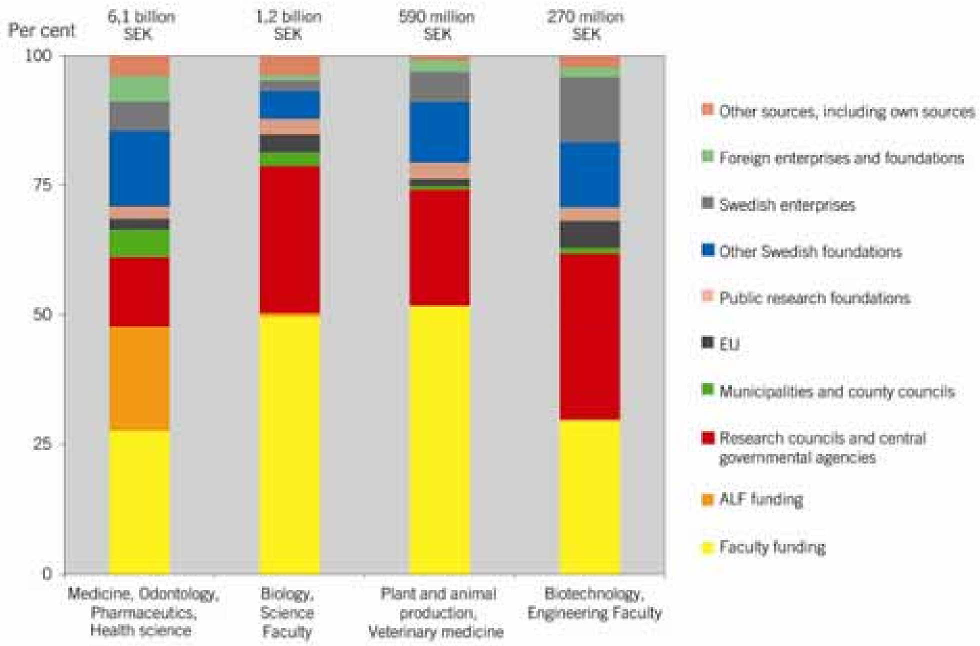
Relatively speaking Switzerland, Israel, the US, Canada and Iceland made a better showing than Sweden in journals with a high Impact Factor than in journals with a lower Impact Factor. This can be interpreted to mean that articles from these countries maintain a higher average quality than articles from Sweden.

5.1.4 State-funded R&D programmes

The development of biotechnical industrial applications is largely taking place through continuous contact with scientific research. The life sciences are currently developing very rapidly, largely due to the fact that a torrent of new research and technologies are being produced. The international joint project organised to chart the human genome was a watershed entailing a breakthrough for large-scale biological research. The conditions for life science research have changed. Costs have increased greatly. Investments in large-scale technological platforms have become a central issue. Physicists, chemists, technicians, computer scientists etc. are gaining a greater role in life science research and life science research projects are characterised by greatly increased size and breadth of expertise.

Life science and biotech research have many funding sources. A large section is accounted for by faculty appropriations and funds from research councils and agencies (e.g. VINNOVA). Other important financiers are state and private research foundation such as companies. Within medical research, state ALF funds are an important source for training doctors and health care personnel (figure 5.1.12).

Figure 5.1.12 Funding sources for life science and biotech research at Swedish universities in 2003



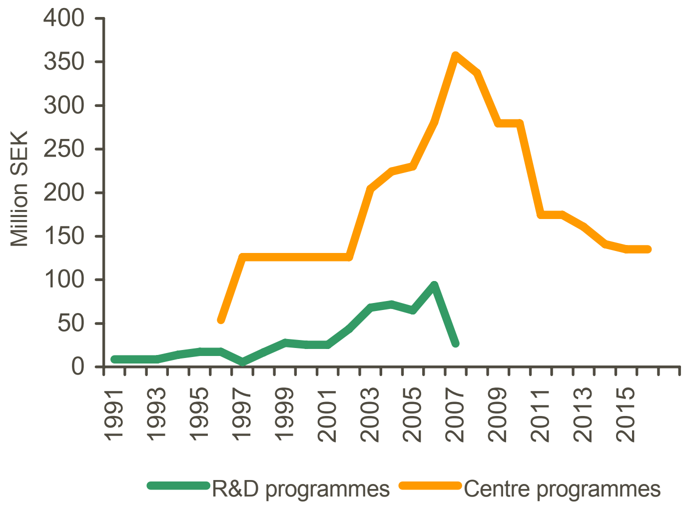
Source: SCB, 2005, Forskning och utveckling inom universitets- och högskolesektorn 2003, Statistiska Meddelanden UF 13 SM 0401

The part of state funding distributed by research councils, plus other agencies and research foundations, is in the form of R&D programmes. However, there is no information about their number and volume. Figure 5.1.13 shows only those funded by research councils, the Swedish Foundation for Strategic Research (SSF) and VINNOVA. Programmes are divided into Centre programmes and R&D programmes. Centre programmes aim to create Centres of Excellence in research, which are funded by research councils and SSF, or Centres of Excellence in research and innovation, which are funded by VINNOVA. In R&D programmes, needs-driven research is conducted with the aim of strengthening the innovation capacity of industry. VINNOVA and SSF fund this type of programme. However, the figure only includes VINNOVA's R&D programmes.[82]

[82] The examples are the VINNOVA programmes Pharmaceuticals and Diagnostics, BioNanoIT, Innovation in foods and Research&Grow. The last of these programmes is

In the figure, the annual funding of 2006 is calculated on the basis of the remaining portion of the programme's total budget and the number of years they have left. New biotech centres and R&D programmes will be started in the next few years, for which reason the annual state funding from 2007 and onwards will be greater.

Figure 5.1.13 Annual state funding of R&D programmes and Centre programmes in the field of biotechnology 1991-2016 (current prices)



Source: VINNOVA

Note: Annual funding has been calculated by dividing total programme budget with the number of years the programme runs.

The funding volume in both types of programme has increased since the 1990s and very robustly in recent years. The state funding in part of the Centre programmes and in R&D programmes does not constitute the programme's entire budget. In VINNOVA's R&D programme, contributing companies normally provide match-funding with VINNOVA. In the Centre programme, the state proportion varies, but in a number of them universities and companies also fund parts of the research.

Figure 5.1.14 shows how Centre funding in biotechnology is distributed between research councils, SSF and VINNOVA between 1996 and 2016. VINNOVA was first to fund a Centre programme. Research councils and SSF only commenced this type of R&D a few years ago. Today, the Centre programmes of the three financiers are equal in size, measured by annual funding volume. Currently, the Swedish Research Council and Formas

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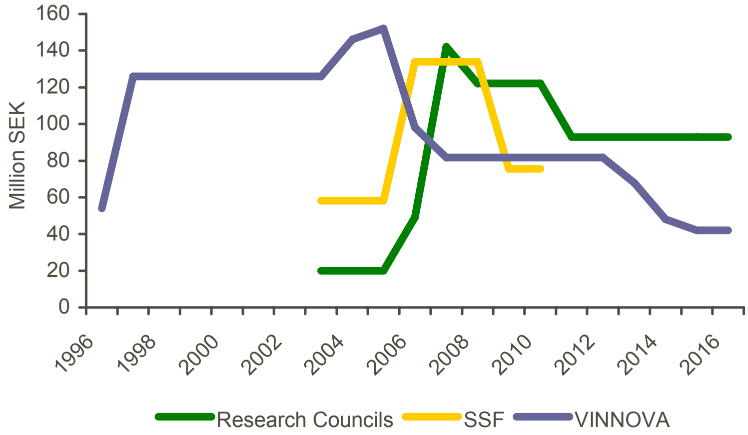
aimed at small and medium-sized enterprises in general, but in the figure only the programme's biotech projects have been included.

jointly fund 10 and SSF funds 15 Centre programmes within the life science field.[83]. For VINNOVA's part, there are 20 biotech Centre programmes.[84].

Figure 5.1.14 Annual funding of Centre programmes (current prices)



Source: VINNOVA

A research strategy

There is great potential for biotech innovations. The research prerequisites to realise that potential are: a strong research base; good collaboration and exchange of knowledge between universities, research institutes and companies; and a well-functioning commercialisation of research through newly established enterprise.[85]

During 2005, on the instructions of the Government Offices of Sweden, VINNOVA commenced the task of drawing up a growth strategy for the biotech industry.[86] Presented in it were a number of proposed measures regarding the research base and research utilisation, which are given below.

Countries and regions are competing for corporate investment in research, development and production, with favourable terms and good conditions for industry. Global changes and the actions of other countries aimed at strengthening competitiveness must be met by measures by companies and

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[83] VR/Formas' Centre programmes are seven Linné Centres and three Berzelii Centres jointly with VINNOVA.

[84] Seven competence centres, three Berzelii Centres (attributed to the research councils and the figure), five VINN Excellence Centers, two Institute Excellence Centers jointly with SSF and the Knowledge Foundation (attributed to VINNOVA in the figure) plus 3 VinnVäxt programmes within the biotech field: Innovations in bordering countries, Uppsala Bio and Biomedical Development in Western Sweden.

[85] Naturally, there are other conditions than those related to research and these are also described in VINNOVA, VP 2005:02.

[86] Ibid.

other organisations in Sweden. Major investments are currently taking place in countries such as the US, Japan, the UK, Canada, Australia and the Netherlands but not in Sweden. A number of countries have also come close to or surpassed Sweden in the publication statistics. For research within the life sciences field to be able to contribute to the competitiveness of industry requires volumes to increase. The report also proposes that the state should stimulate the growth of Centres of Excellence in research and strengthen collaborations between them.

The industry which can apply life science research is often dependent upon research in other fields in order to develop innovations. Research in which biotechnology is combined with other technologies is required in order for biotechnology to find increased use in industry. Comprehensive investment in such interdisciplinary research is taking place in other countries, but there are few examples in Sweden. According to the report, the volume of state R&D programmes addressing industrial problems should be increased. In the long term, they should fund interdisciplinary research in collaboration with companies. Such R&D programmes thereby stimulate the application of biotechnology in more industries than currently so that new products are developed and manufactured in Sweden. They also contribute to an increase in expertise at universities on how projects are run in industry and to providing industry with the opportunity to follow scientific development.

Newly established enterprise has been extensive within the "biotech industry", accounting for a major proportion of corporate growth. The potential for research-based newly established enterprise is still considered to be great. The report therefore proposes a programme for the verification of concepts/technologies and increased investment in successful specialised life science incubators.

5.2 Nanotechnology

Nanotechnology is a relatively young technology and commentators see great potential for it in industrial applications.[87] Within the Swedish Technology Foresight project, nanotechnology has also been highlighted as a future opportunity for Swedish industry. The US has also taken a cohesive approach to the development of nanotechnology in what it calls the National Nanotechnology Initiative. In some 30 countries, some form of "nanotechnology initiative" has been initiated, e.g. in Great Britain, Germany and Japan and in Sweden's neighbouring countries of Denmark and Norway. The European Commission has also laid out a nanotechnology

[87] By 2015, it is estimated that the nanotechnology market will be worth USD 100 billion. Roco, M.C. 2004.

strategy for the EU. In Sweden, The Royal Swedish Academy of Engineering Sciences (IVA) took the initiative in 2005 to draw up a national strategy for nanotechnology, which was presented in December of 2006.[88]

There is currently no generally accepted definition of nanotechnology.[89] Nano is a unit of measurement spanning the interval $(0.1\text{-}100)*10^{-9}$m. There are the terms “nanoscience” and “nanotechnology”. Nanoscience studies phenomena and properties arising, on an atomic and molecular level, and nanotechnology applies nanoscience in order to create new materials, structures and interactions between molecules. Thus, definitions of nanotechnology include a manipulation aspect.[90] Nanotechnology is defined here as:

the understanding and controlled manipulation of structures and applications on a molecular and atomic level.

There are two fundamental ways to approach the nanometre level. One is to start with a larger element and use controlled processes to create nanometre-sized structures. This can be achieved through lithography for example, which has been the normal inroad to nanotechnology in fields such as electronics and materials technology. Another method is to create nanometre-sized structures by adding one molecule or one atom at a time. Epitaxy is an example of this, whereby researchers use structured growth of a crystalline film to create nanometre-thick surfaces. [91]

5.2.1 Industrial applications of nanotechnology

Nanotechnology is already in use in a number of applications and has potential to be used in even more. In the field of electronics, nanotechnology is being used in TVs and displays. In so-called FEDs (Field Effect Displays), carbon nanotubes are used to save energy and improve the image. The potential applications in the materials field are very great, e.g. textiles with windproofing and waterproofing properties, as well as for lighter vehicle materials. In the medical field, nanotechnology is being applied in pharmaceuticals and in certain diagnostic instruments.

In Sweden, there are currently “nanocompanies” in four fields of application:

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[88] Strategy for a Swedish Nanosystem in Europe, IVA 2006

[89] From a narrow definition relating only to “ atomic handicraft “ to definitions based on measurement size and including a broad spectrum of technical fields, some of which only exceptionally operate at nanometre level. Karhi, 2006.

[90] Karhi, 2006. At

[91] VINNOVA, VA 2007:01, “Nanotechnology Innovation Systems “. This chapter is largely based on this report. Unless otherwise stated, it is the source of information presented.

- **Biotechnology:** Technical utilisation of organic molecules and biological systems, such as cells and cell constituents, at nanometre level to produce or modify products.
- **Electronics:** Control of electron movement at nanometre level to produce electronic components in such things as radio, data technology and communication.
- **Instruments & Tools:** Manufacturing of precision tools or apparatus for measurement and analysis at nanometre level, such as sensors, spectroscopes and other measurement devices and manufacture of equipment for the production of structures at nanometre level.
- **Material and Surface Technology:** Technical exploitation of inorganic materials so as to achieve desired properties in materials and on surfaces based on processing at nanometre level.

Industrial structure

There are currently no studies comparing the size of countries' "nanoindustries". However, a database is being constructed. In it, Sweden comes only 15th in the world, with 14 nanocompanies.[92] One reason for the low number of companies is that companies sign up to the database themselves which presumably means there are more "nanocompanies" both in Sweden and the other countries on the list. The report " Nanotechnology Innovation System" also identified many more; specifically, 85 nanocompanies in Sweden in the middle of 2006.[93] Of these, 34 were "pure" nanotechnology companies, i.e. companies basing their activity on the application of nanotechnology. The majority are small, young companies. The other 51 companies applied nanotechnology to a greater or lesser extent in their products, but nanotechnology was not the basis of their activity.[94] These include a number of well-known major companies: Sandvik, Tetra Pak, ABB, Saab, Volvo and AstraZeneca. The two types of company differ in terms of size; in general, the pure nanocompanies are smaller than other nanocompanies.

Nanocompanies are relatively evenly distributed across the fields of application, but the distribution differs between pure nanocompanies and others (figure 5.2.1). A major segment of the pure nanocompanies are active within Instruments & Tolls and Electronics, but there are a few within Materials & Surface Technology and Biotechnology.

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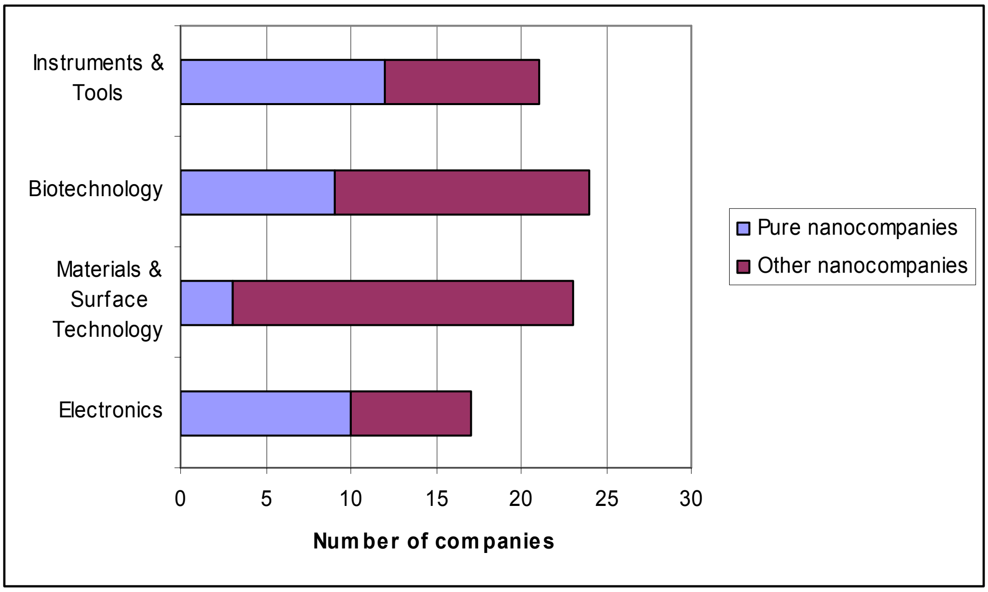
[92] http://www.nanovip.com. This is the first network for nanotechnology companies.
[93] VINNOVA, VA 2007:01
[94] There is no information on how great a proportion of their products are based on nanotechnology.

Figure 5.2.1 Number of nanocompanies in Sweden in 2006 distributed by fields of application.



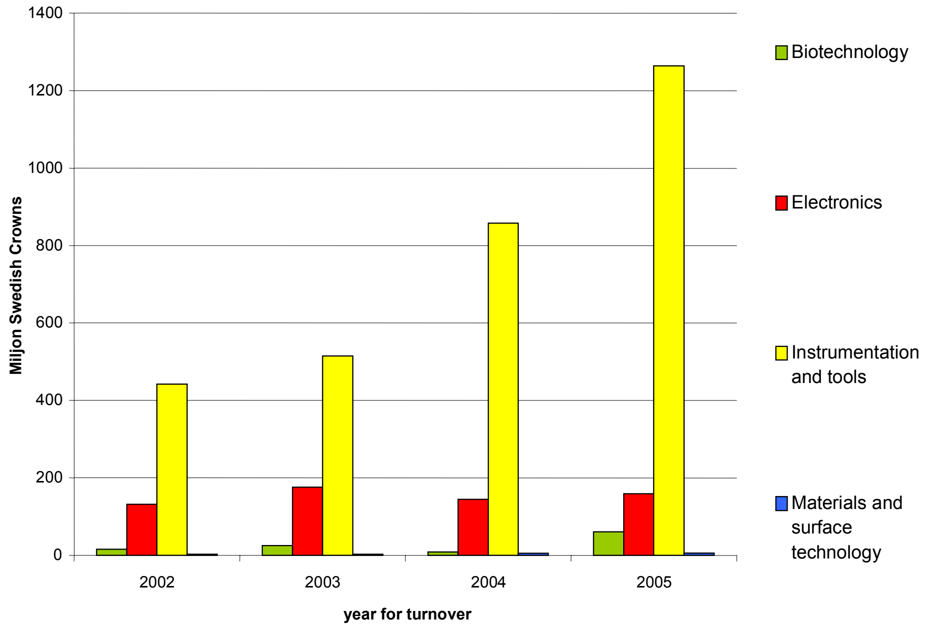
Source: VINNOVA, VA 2007:01

In 2005, the 34 pure nanocompanies turned over just under SEK 1.6 billion and employed 680 people.[95] Most people were employed in the application field Instruments & Tools, with 470 people. Micronic Laser Systems AB is the largest pure nanocompany in this field of application, with 280 employees and is also the only company with over 50 employees amongst the pure nanocompanies. Other major companies in the field are Gyros, Obducat, Piezo Motor and Q-Sense. In the application field Electronics, there were 120 employees and 84 in Biotechnology. The three companies within Materials & Surface Technology had a total of six employees.

During the last few years, the pure nanocompanies within Instruments & Equipment and Biotechnology have shown substantial growth in regard to turnover (figure 5.2.2). On the other hand, growth in the other two fields has been weak.

[95] Employees and turnover are not shown for other nanocompanies since it is not possible to see how large a segment can be attributed to nanotechnology.

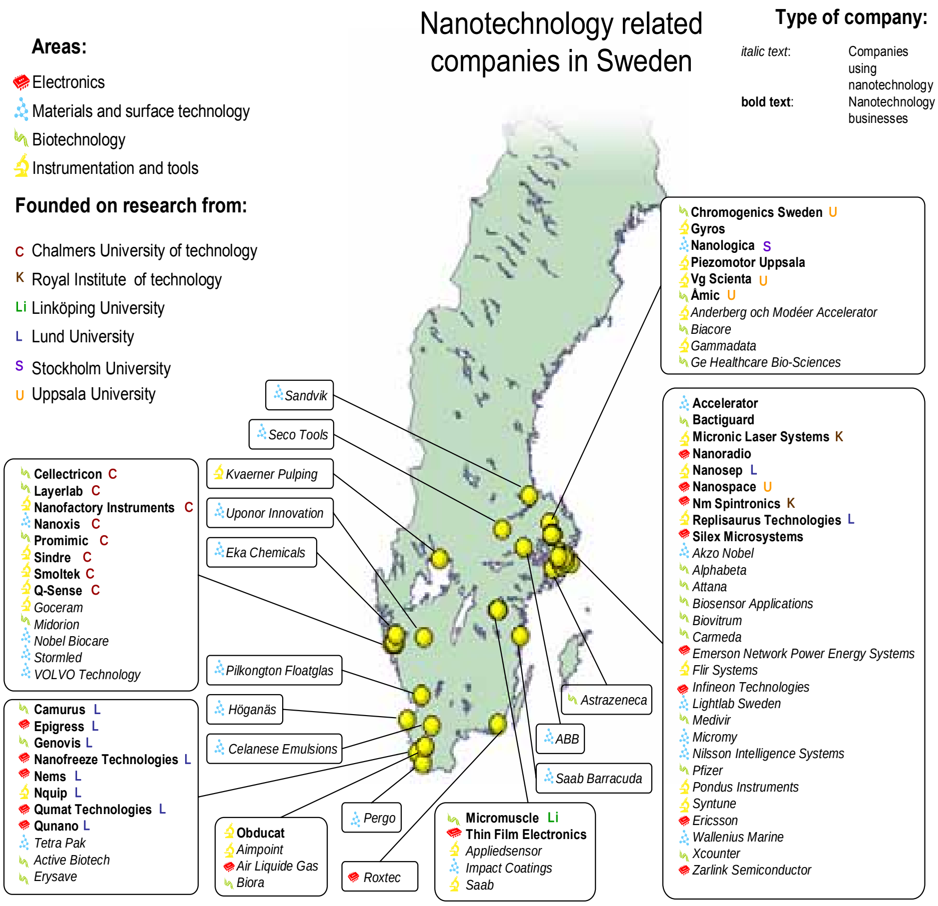
Figure 5.2.2 Turnover in pure nanocompanies distributed by fields of application, 2002-2005.



Source: VINNOVA, VA 2007:01

In terms of location, the nanocompanies are largely concentrated to Stockholm/Uppsala, Gothenburg and Malmö/Lund. One reason for this is that the majority of them are spin-offs from universities in these cities (figure 5.2.3).

Figure 5.2.3 Location of Swedish nanocompanies



Source: VINNOVA, VA 2007:01

New firms

Nanocompanies are largely a phenomenon which appeared in the 1990s and growth in the number of new companies really got going after 1999. Of the companies which existed in 2004, 90% were started after 1990 and the majority, or 57%, after 1999.[96] Those nanocompanies which were started from 1990 and onwards had been formed either through the merger of two companies, the splitting up of one company into several, or they were entirely new i.e. they had no background in other companies.[97] Around 2/3 of nanocompanies had a background in other companies.

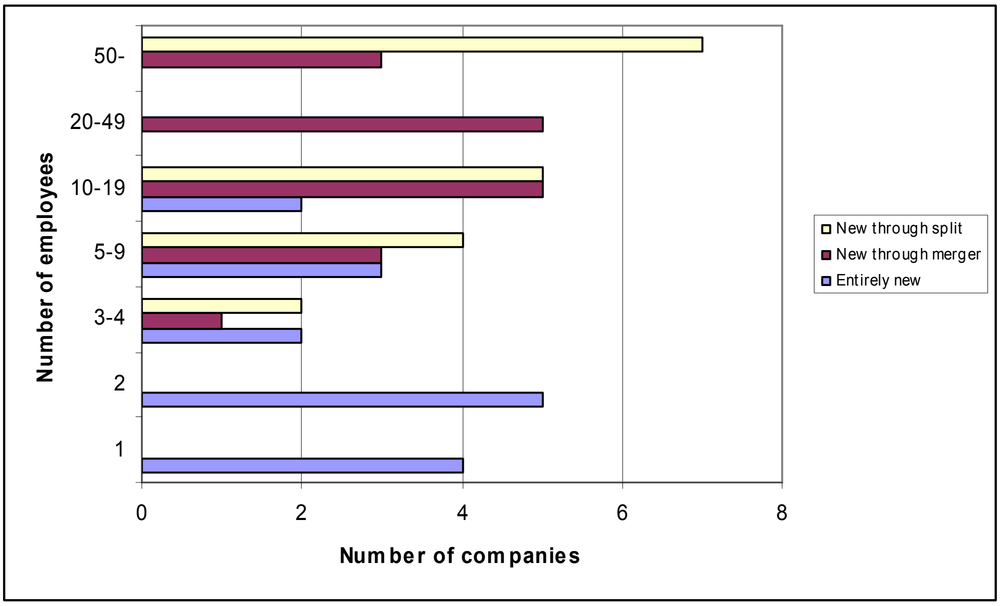
[96] These proportions are calculated on the basis of 56 and not 85 nanocompanies. A run was commissioned with Statistics Sweden to produce information on newly established enterprise. Prior to the commission, 69 nanocompanies had been identified. Statistics Sweden could not find 13 of them in its records. For this reason the total number of nanocompanies is only 56. Of these, 24 were pure nanocompanies and 32 other nanocompanies.

[97] See chapter 2.2 for a description of how corporate roots are identified.

The manner of origin is distinct between the two types of nanocompanies. A much larger proportion of the pure nanocompanies were entirely new compared with other nanocompanies, 54% compared with 10%, whilst the reverse was true for the division of one company into several, 13% compared with 55%. Around 30% of both pure and other nanocompanies originated through a merger of two companies. Of the entirely new nanocompanies, just under 90% were pure nanocompanies.

The majority of the entirely new nanocompanies are in the application fields of Instruments & Tools and Biotechnology (appendix 4, figure 3). Generally, the entirely new nanocompanies were smaller than the companies which had their roots in other companies (figure 5.2.4).

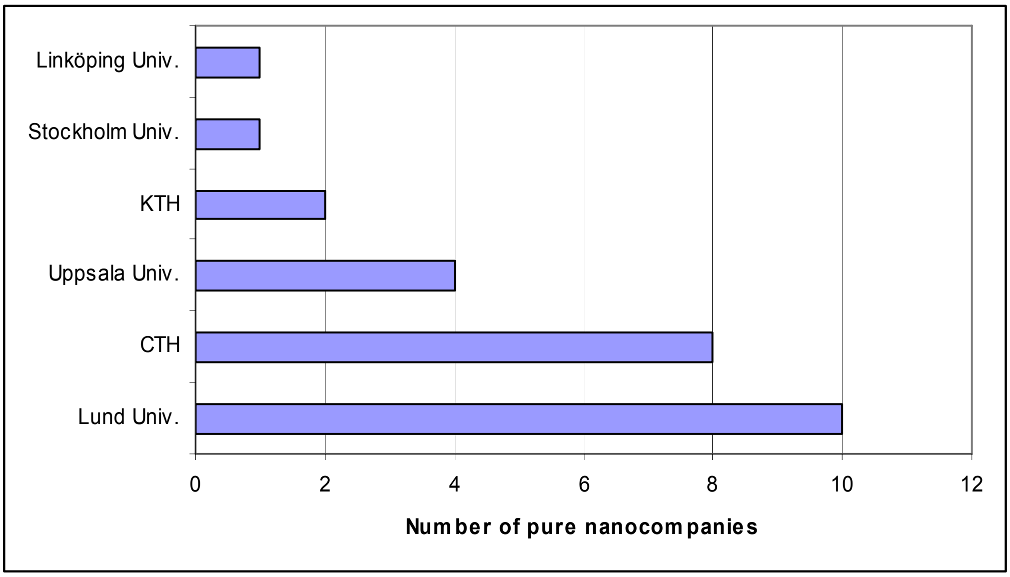
Figure 5.2.4 Distribution of nanocompanies by size-classes and manners of origin at the time of establishment.



Source: VINNOVA, VA 2007:01

Swedish universities have been an important source of newly established enterprises amongst the pure nanocompanies. Just over three quarters of them were based on a product concept from university researchers. Of these, a large section originated from Lund University and Chalmers (figure 5.2.5).

Figure 5.2.5 Number of pure nanocompanies with roots in universities.



Source: VINNOVA, VA 2007:01

5.2.2 Innovations

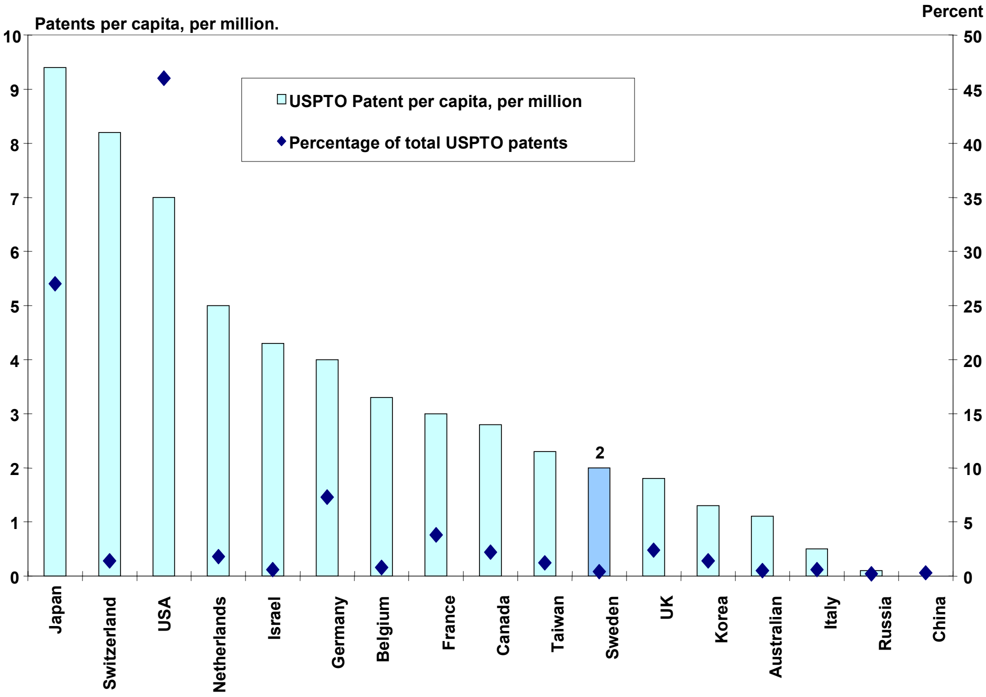
Information on newly introduced products is absent for all types of companies, not just nanotechnology ones. Corporate patenting is often used as an indicator of innovation, even though this is more an indicator of innovation potential.[98]

The accumulated total of Swedish "nanopatents" at USPTO increased from just under 30 in the mid-1990s to 141 patents in 2004. More than a hundred of them have been granted since 2000.[99] However, Sweden is not amongst the countries with a high patenting frequency in nanotechnology. Compared with countries like Switzerland, Israel and the Netherlands, Sweden's level of USPTO patents per million inhabitants is low (figure 5.2.6).

[98] Patenting as an indicator of innovation has certain weaknesses, see chapter 1.1. Due to the generic nature of nanotechnology, use of the standardised patent classes to identify nano-related patents is associated with certain problems. In other words, nanopatents exist in a majority of the traditional patent classes. Patents within nanotechnology have been identified using special search strings.

[99] Meyer M. 2005b.

Figure 5.2.6 Number of USPTO-patents per capita and proportion of total USPTO-patents 1992-2001

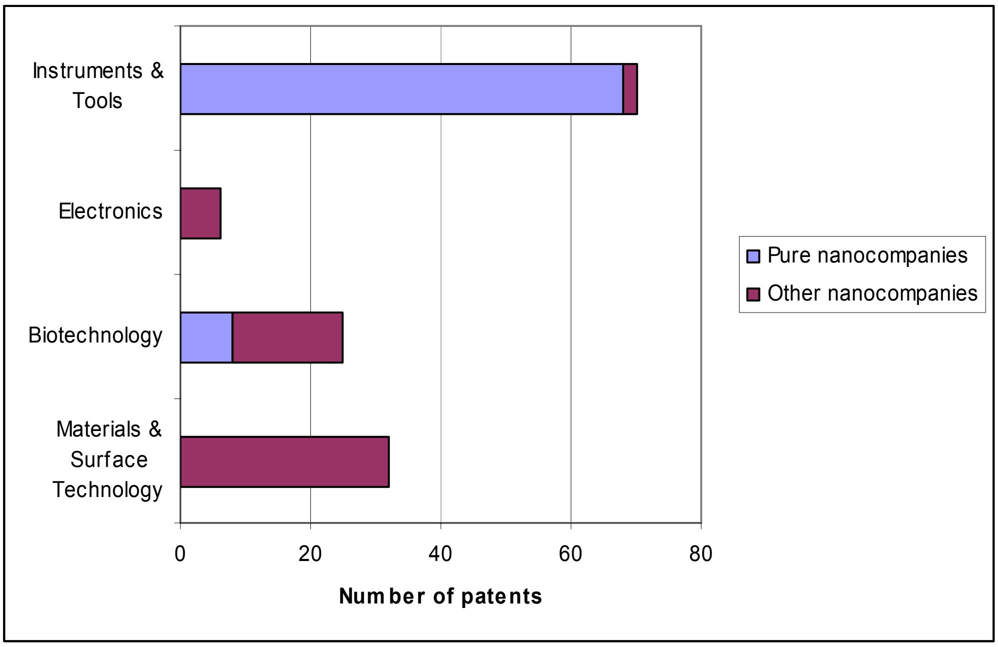


M.Mayer, "Nanotechnology in Sweden", 2005

Of the USPTO patents granted to Swedish companies during the period 1991-2004, pure nanocompanies held just under 60%.100 The majority of patents related to the application field of Instruments & Tools and the majority of these had been taken by pure nanocompanies such as Micronic (30 patents), Gyros (16 patents) and Obducat (9 patents). Pure nanocompanies did not hold any patents in the application fields of Electronics and Materials & Surface Technology. Other nanocompanies held patents in all fields of application, and the majority within the application fields of Materials & Surface Technology and Biotechnology. Of these companies, Sandvik held the highest number of USPTO patents (17) in the field of Materials & Surface Technology (figure 5.2.7).

[100] Ibid.

Figure 5.2.7 Number of Swedish nanopatents at USPTO (1991-2004) distributed by fields of application



Source: VINNOVA VA 2007:01

The potential for innovations based on nanotechnology is considered great, since nanotechnology is a toolbox providing opportunities for:

- Miniaturisation down to molecular and atomic level. It increases speed and reduces the size of products.
- New materials which appear as they are built up one atom layer at a time, with the possibility to change the chemical composition of crystals.
- New properties when a certain size is reached. Examples of this may be changes in light absorption capacity, conduction capacity, magnetism and hardness.

With companies seeking increased product performance, smaller and smaller structures are required. A molecule is nanometres in size. With the possibility to control and build from the smallest component, new and improved product properties can be created.[101] Currently, it is estimated that 0.1% of the value of all products on the world market comes from products containing nanotechnology. In 2014, that proportion is expected to be 15%.

[101] Applications within microelectronics are often highlighted as the most important incentive in the development of nanotechnology. Some examples are transistors, lasers and detectors for fiber-optic communication.

5.2.3 Nanoresearch at universities and research institutes

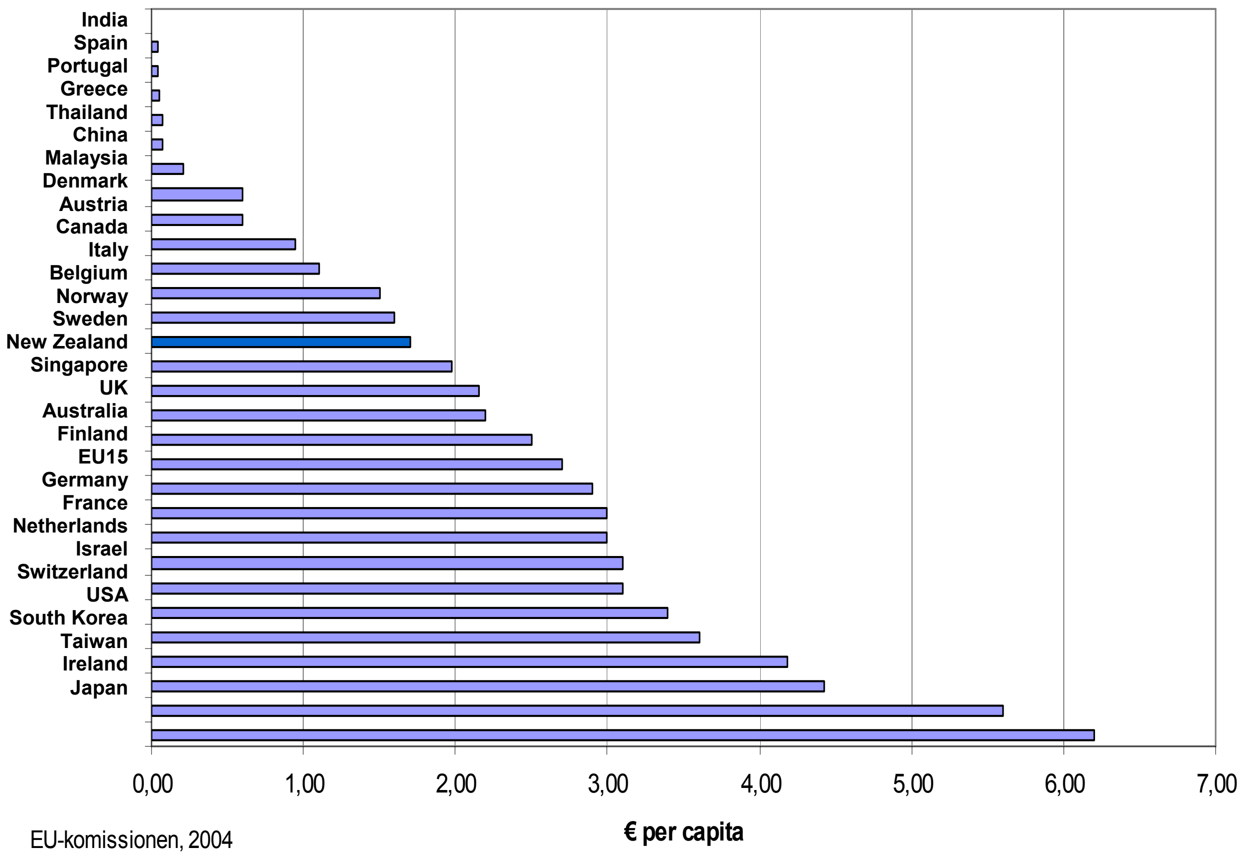
Nanotechnology is regarded as a generic or enabling technology, since it permeates a broad spectrum of sciences like physics, biology and chemistry and technologies such as electronics, photonics, materials technology and biotechnology. Researchers working at nanometre level study everything from drug delivery in cancer medicines to nanocarbon wires to increase the speed of electronic circuits. Researchers may start with natural material properties and structures when looking for new properties, known as biomimetics. One example is the use of the so-called lotus effect in which the water-repelling wax and nanostructure of the lotus flower is imitated in order to achieve self-cleaning surfaces.

Work at nanometre level has for a long time taken place within chemistry and physics. Thus, nanoscience is not really anything new. For instance, through gene technology biology has taken a stride into the field of nanotechnology. Research into electronics and materials technology has been a vital incentive in the development of nanotechnology. The hunt for ever smaller components to improve performance in electronic products has been important in order to reach down to nano level. Within materials technology, the incentive has been the search for new materials with new properties. An example is regenerative medicine in which damaged or sickly components in the human body are replaced with new ones containing nanotechnologically developed components. The ability of nanostructures to manipulate light in new ways has meant that nanotechnology is also being used within optics.

Nanoelectronics is a continuation of developments in microelectronics particularly concerning computers, dealing with considerably smaller units of scale. Nanobiotechnology combines nanotechnology and biology in order to manipulate living organisms and produce materials on a molecular level. One of the objectives within nanomaterials is to control the morphology of various substances and particles as exactly as possible in order to produce different materials at nanometre level. Within these fields, nanoscale microscopes are used to measure and modify extremely small structures.

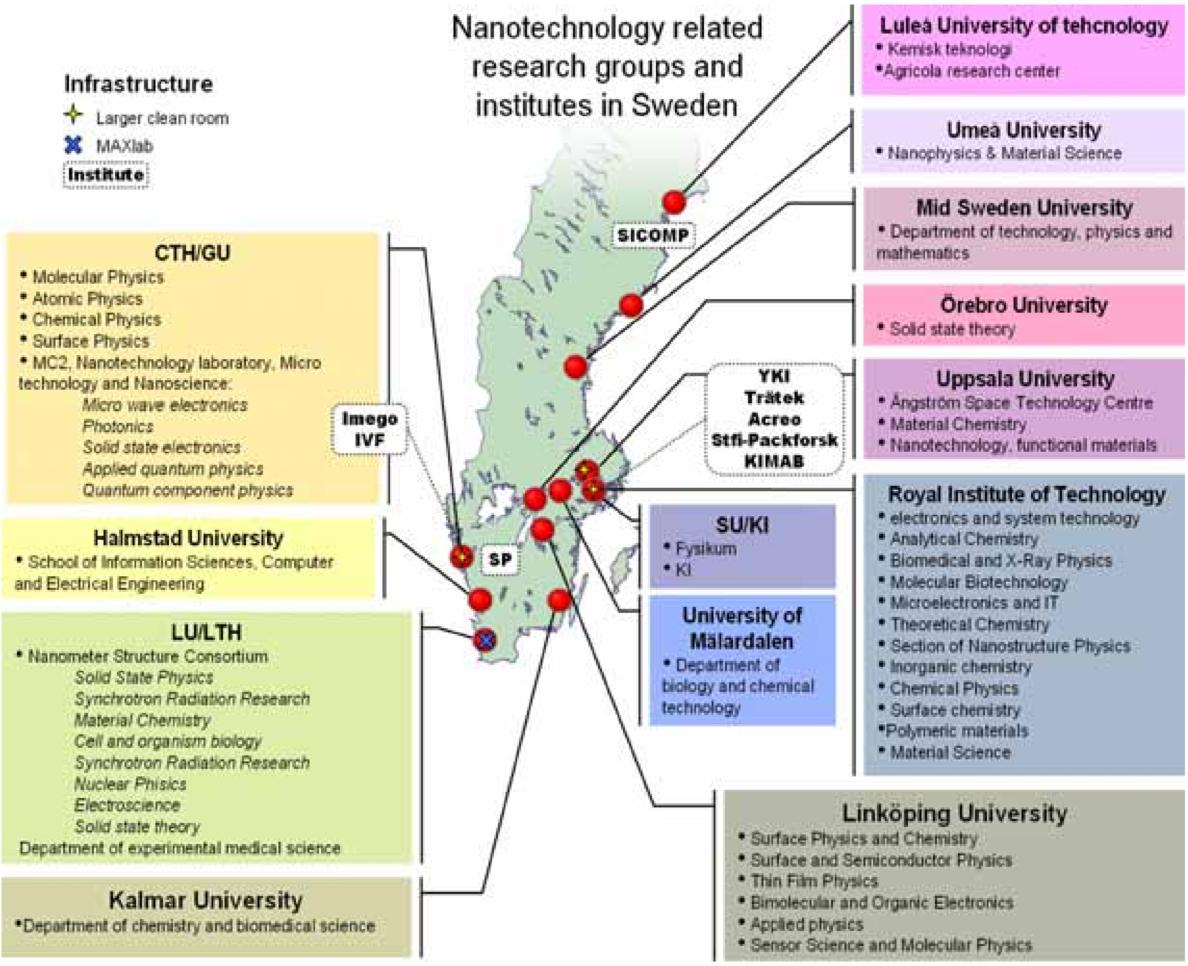
Swedish state funding in 2003 of research in nanoscience and nanotechnology is estimated by the European Commission at approx. EUR 200 million, or around EUR 1.7 per capita, which is just below the average for EU15. This places Sweden amongst those countries making small investments in nanoresearch (figure 5.2.8).

Figure 5.2.8 Volume (euro per capita) of state-funded research in nanoscience and nanotechnology, 2003



Fifteen Swedish universities and nine research institutes are conducting research in nanoscience and nanotechnology. Figure 5.2.9 shows which these are and their location. Also shown are some of the institutions and research groups involved in nanotechnology research at each university.

Figure 5.2.9 Swedish universities and research institutes conducting nanoresearch



Source: VINNOVA, VA 2007:01

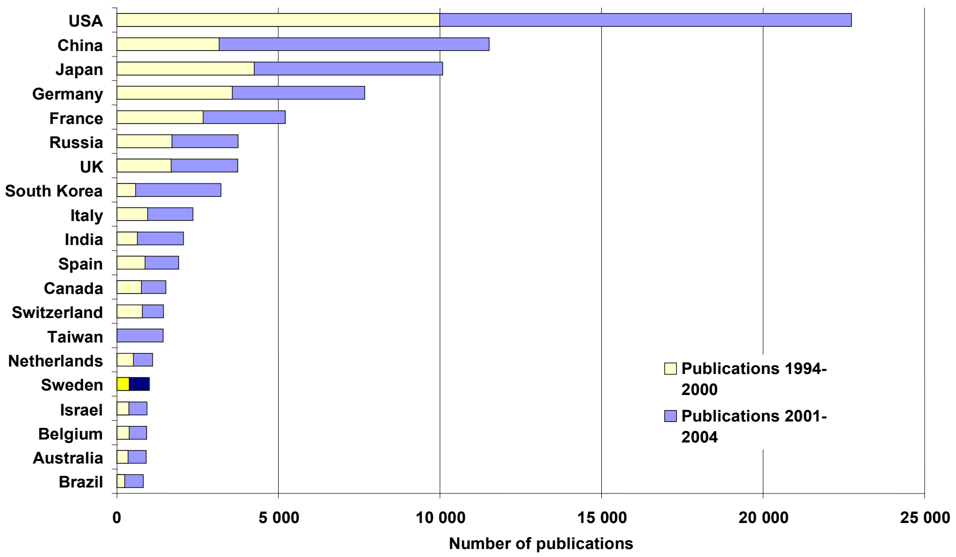
Research groups and their activities in Sweden are closely connected to the research infrastructure in the form of cleanrooms:

- Mc2 at CTH is a cleanroom profiled for the production of nanostructures such as nanolithography. The laboratory is run as an independent section but is linked to the university and well-connected with industry.
- The Elektrum Laboratory at KTH is a cleanroom profiled for semiconductor technology and photonics with a relatively broad spectrum of research. The Laboratory offers services to academia and established industry and supports start-ups.
- The Ångström Laboratory at Uppsala University is a cleanroom profiled for materials, energy technology, biotechnology and physics. Its research is typically interdisciplinary.
- MAX-lab in Lund is a national cleanroom for accelerator physics, synchrotron radiation and nuclear physics.

International competitiveness of Swedish nanoresearch

The publication of articles in scientific journals is used to measure research groups' international competitiveness within a scientific field.[102] An American study showed that publication activity within nanotechnology has increased explosively since the start of the 1990s.[103] Sweden is in 17th place with around 1,000 published articles in the period 1994-2004 (figure 5.2.10).

Figure 5.2.10 Number of nanoarticles 1994-2000



Source: Engineering and Physical Sciences Research Council (2005)

Another study of published nanoarticles for the period 1992-2001 which identified the articles differently, showed over 1,800 Swedish articles. This was equivalent to 1.8% of the total production of nanoarticles. Compared with 1992, the number of nanoarticles for 2001 was almost four times as many.[104] During the 10-year period, Sweden increased its share of the world's nanoarticles by 50%, as did countries such as the Netherlands, Italy, Austria, Spain and Israel. Measured in articles per capita, Sweden takes third place in this study (with approx. 206 journals per million inhabitants) after Switzerland and Israel.[105]

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[102] There are only a few scientific journals aimed at nanoscience and therefore, nanoscientific articles are published in a large number of other journals in such fields as material science, electronics or pharmaceuticals. This makes it difficult to measure frequency of publication in nanoresearch. For this reason, search methods vary.

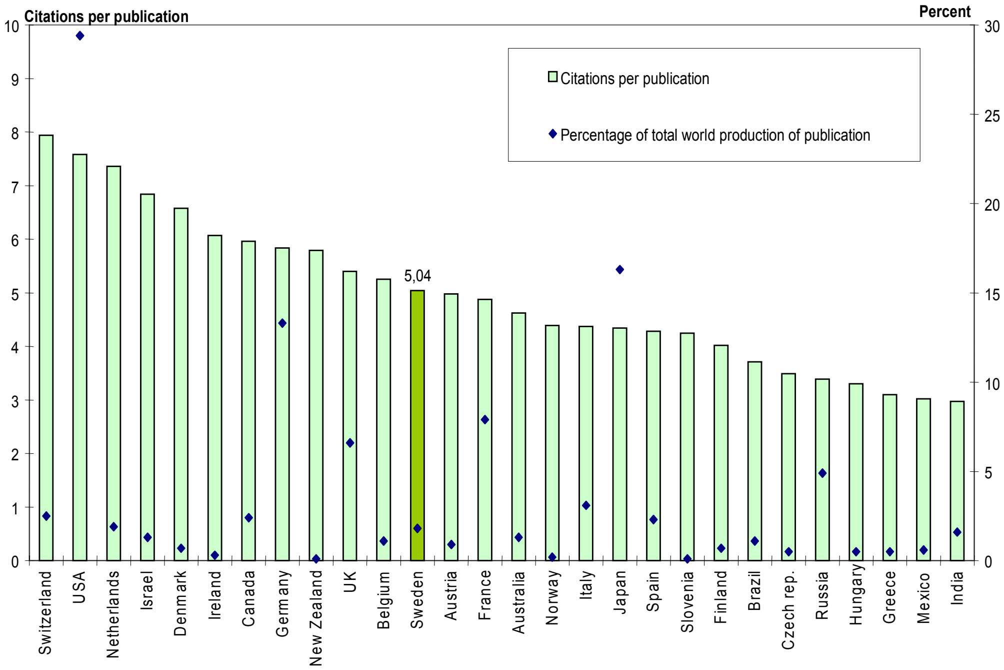
[103] Engineering and Pysical Sciences Research Council (2005) http://www.epsrc.ac.uk/CMSWeb/Downloads/Other/NanotechnologyThemeday2005.doc#_Toc118883223

[104] Meyer, M. (2005a)

[105] Ibid.

Swedish nanoresearch maintains good scientific quality. In fact, measured by article citation rates, an established indicator of quality, Sweden is 12th in the world (figure 5.2.11).

Figure 5.2.11 Article citation rates and proportions of all nanoarticles 1992-2001



M.Mayer, "Nanotechnology in Sweden", 2005. Number of citations per publication 1992-1999

Chalmers and Lund University are both amongst the 10 European universities with the highest publication frequency in the nano field for the period 1996-2001.[106] However, none of them are amongst the 10 European research organisations with the highest “quality”. Amongst them is Karolinska Institutet, with a citation rate of 7.4 per article. In a world ranking of those who published the most nanoarticles 1996-2001, CTH appeared on 24th place, Lund University in 32nd place, Uppsala University in 55th place and Gothenburg University in 72nd place.[107]

5.2.4 State-funded R&D programmes

The Swedish “nanoindustry” is relatively young and has emerged and grown during the past decade. Many of the companies are spin-offs from universities. The technology is developing rapidly and the assessment is that the potential for nanoinnovations is great and that the innovations of companies are dependent upon scientific research.

[106] Chalmers had 460 and Lund University 432 published articles.
[107] Noyons et al (2003), från databasen http://studies.cwts.nl/projects/ec-coe/cgi-bin/izite.pl?show=home

Swedish research funding organisations have shown great interest in nanoresearch. The Swedish Foundation for Strategic Research invested almost SEK 70 million in the field during 2005. The Swedish Governmental Agency for Innovation Systems (VINNOVA) invested over SEK 50 million the same year and the corresponding figure for the Swedish Research Council is SEK 40 million. The Knut and Alice Wallenberg Foundation have invested a great deal; it invested an estimated SEK 78.8 million in 2005, mainly in equipment.

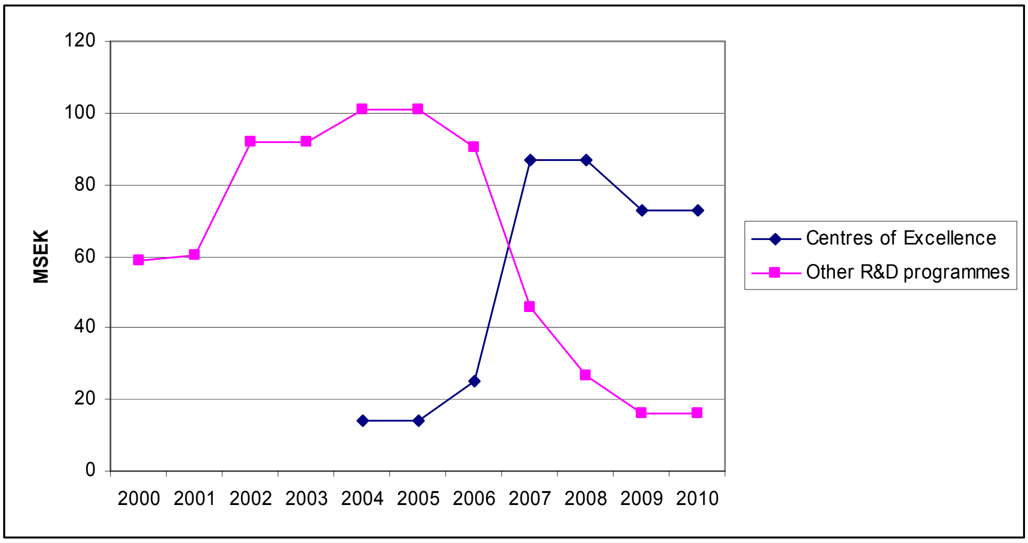
Part of the long-term programme investments of Swedish Research Council, the Swedish Research Council Formas and the Swedish Foundation for Strategic Research is currently taking place in the context of so-called Centres of Excellence in research. Similarly, VINNOVA's programme investments relate to Centres of Excellence in research and innovation characterised by excellent research, industrial involvement and a high level of innovation activities. A total of 11 such nanotech Centre programmes were funded for SEK 680 million, three of them by VINNOVA for SEK 240 million (appendix 1).

These financiers and other agencies and foundations are funding a further 15 or so R&D programmes with funds for 2006 of just over SEK 150 million. Around one third of them are programmes with industrial involvement with the aim to demonstrate technological opportunities. There are also two R&D programmes for companies concentrating on the verification of concepts/technologies (appendix 1).

Figure 5.2.12 shows the annual state funding of nanoresearch between 2000 and 2010 divided into Centre of excellence programmes and other R&D programmes.[108] From this, it is apparent that Centre programmes are a relatively new phenomenon, but that their funding volume is not currently as large as that in the other type of R&D programme. The figure shows that more R&D programmes need to be started if the total volume of state funding is not to reduce in the years up to 2010.

[108] Direct state grants are not included in the figure. For definitions see chapter 4.

Figure 5.2.12 Volume (MSEK) of state-funded nano R&D 2000 – 2010 distributed by type of programmes



Source: appendix 1

Proposals were made for future nanoresearch in Sweden in the nanoresearch strategy presented by IVA in December 2006.[109] Henceforth, the proposals with relevance for state-funded research are described.

The volume of Swedish nanoresearch is relatively small in an international perspective, but the international competitiveness of Swedish research measured in terms of the number of articles and citation rate, is relatively strong. Swedish research groups are also at the forefront of research within certain niches of nanotechnology. However, state R&D funding is fragmented and needs to be concentrated. Also, the funding volume should be increased.

The connection between university research and corporate activities should also be intensified. University research should be driven by industrial needs (problems and opportunities) to a higher degree than it currently is. State-funded R&D programmes which demand collaboration between companies and research groups at universities and/or institutes relating to industrial needs are an instrument which can stimulate the application of nanotechnology in corporate products and processes. This type of programme currently accounts for a smaller portion of state R&D funding.

Collaboration between research groups at universities can also be improved. This is critical, since nanotechnology has strong interdisciplinary characteristics and it is anticipated that many of the future applications will

[109] Strategy for a Swedish Nanosystem in Europe, IVA 2006.

be generated at the interface between different scientific disciplines. State R&D funding can promote this form of collaboration through programmes which support interdisciplinary research projects, e.g. at the interface between nanotechnology and biotechnology.

There seems to be a positive correlation between the number of spin-offs and international competitiveness in nanoresearch. Those universities which are identified as the most pre-eminent, Lund University and Chalmers, also showed the most spin-offs.

For newly formed enterprises based on research, verification and reproducibility of the new nanotechnology is important in the commercialisation process. Hence, the state should increase funding of R&D programmes aimed at verification and reproducibility.

5.3 ICT industry

Information and Communication Technology - ICT - is defined here as *technology to electronically gather, store, receive, process, analyse and send information*.[110] Currently, practically all sectors in the Swedish economy and other OECD countries are dependent upon ICT. For instance, the automotive industry requires embedded systems to increase safety in cars, the defence industry requires sensor technology to improve weapons systems, the pharmaceutical industry requires software to develop diagnostic tools and the process industry requires robots in order to automate manufacturing processes.

The ICT industry consists of an inner core and an outer circle of companies.[111] The core comprises companies which produce and sell ICT products (goods and services). The outer circle comprises companies which produce ICT for their own use. Accordingly, the ICT industry is defined here as the inner core, which can be divided into six sectors (see appendix 2 for a more comprehensive description):

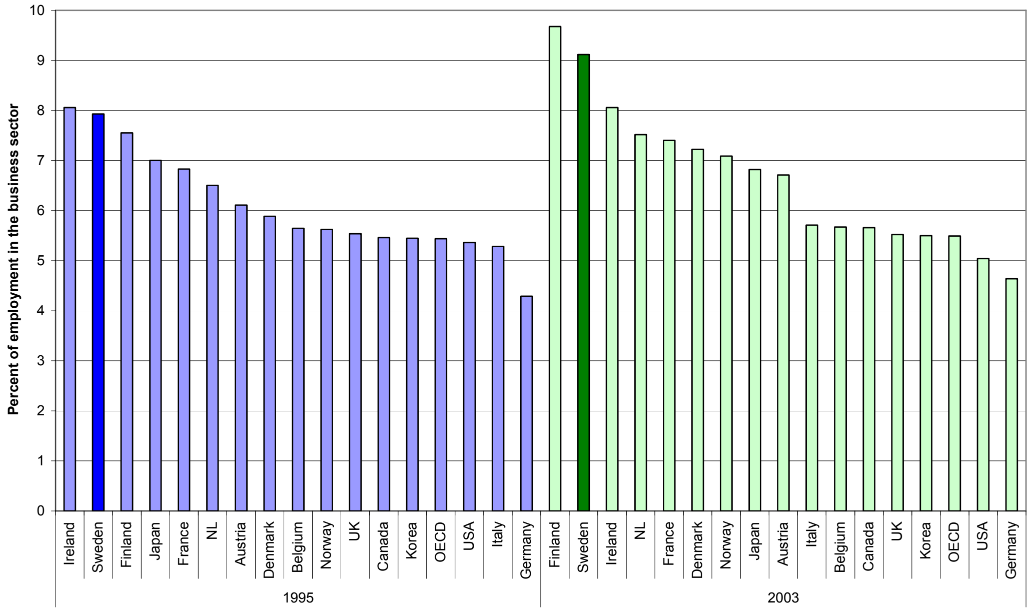
- Manufacturers of electronics and electronic components (hardware)
- Manufacturers of IT equipment including computers (hardware)
- Manufacturers of communication equipment and communication systems (hardware)
- Software developers
- Producers of IT services
- Teleoperators

[110] The definition is linked to the one underlying the international statistical nomenclature. OECD, 2005, Working Party on Indicators for the Information Society.
[111] Lindmark. S. and Gunnarsson S. 2007.

The ICT industry grew rapidly during the 1990s. For the OECD countries, the annual growth rate in turn over was between 20% and 30%. After the year 2000, this reduced to around 4% per year.[112] Telecommunication products currently dominate, with almost 50% of sales. Measured by growth rate since the year 2000 however, software and IT services are showing the highest levels (appendix 4, figure 4).

The ICT industry increased its employment share in Sweden between 1995 and 2003 from just under 8% to just over 9%. In an international comparison, this is a high proportion (figure 5.3.1).

Figure 5.3.1 Employment in the ICT industry as a percentage of total employment 1995 and 2003



OECD, "ICT Outlook", 2006. Modified by VINNOVA, 2006

In 2004, the ICT industry in Sweden had just over 107,000 employees of which 45% were within IT services, 40% within manufacturing companies and 15% within operator activities. In the goods producing sector of the ICT industry (hardware), there were some 2,200 companies and in the service producing (software and IT services), around 7,500 companies. The Swedish ICT industry is primarily composed of small enterprises. Around 80% of the almost 10,000 companies were small or medium-sized. Many of the smaller enterprises are subcontractors to large companies. However, almost 50% of those employed work in large companies with more than 500 employees. [113]

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[112] Based on forecast data for 2006. OECD, "ICT Outlook", 2006.
[113] ITPS, 2006

The flagship of the Swedish ICT industry is Ericsson which currently operates in 18 sites and employs around 21,000 people in Sweden, equivalent to 30% of the total number of employees in the company (appendix 4, figure 5). An additional 73,000 jobs in subcontracting companies are dependent on Ericsson. According to Statistics Sweden's calculations, the company accounts for approx. 7% of Sweden's exports.

5.3.1 Investment in R&D

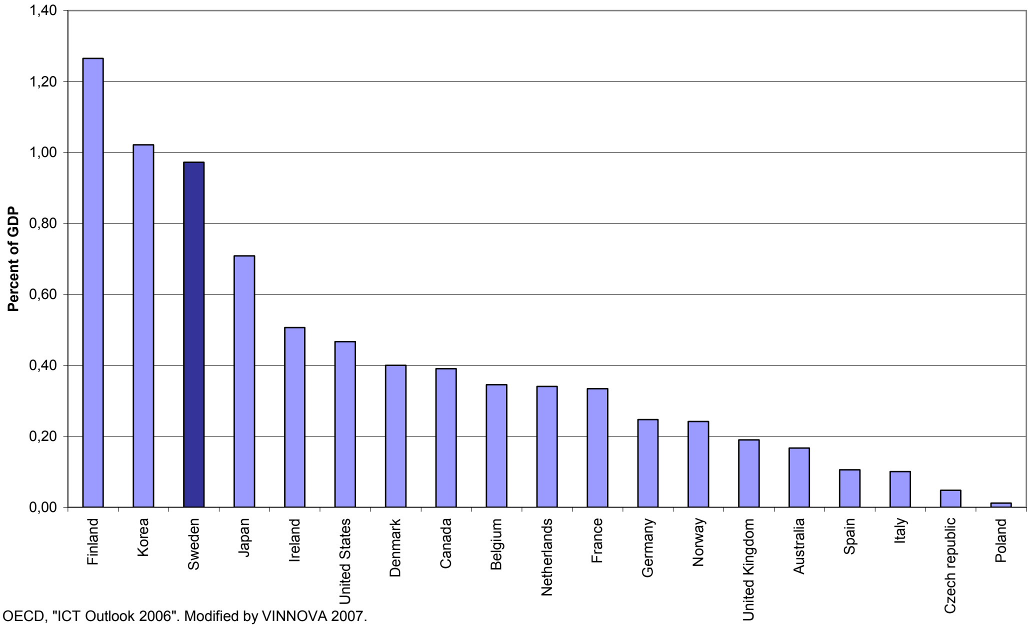
Technical development is proceeding quickly. Indicators of this include the fact that the price per gigabyte of stored digital information has fallen from approx. SEK 92,000 in 1998 to less than SEK 10. Also, since 1965, the processor power in computers has doubled every 18 months. The result is that the number of transistors per microprocessor has increased by over 95 million.[114] For ICT companies, the rapid technological development sets high standards for continuously being able to develop new and improved goods and services and thereby investing in R&D.[115]

The ICT industry's R&D investments in relation to GDP increased during the 1990s within OECD. In 2002, the Finnish ICT industry had the highest proportion with just under 1.3%, whilst the Swedish ICT industry's proportion was just under 1% (figure 5.3.2).

[114] Brown, James, "The Social Life of Information", Harvard Business School Press, Boston, 2000, Moore, Gordon, "Cramming more components onto integrated circuits", [ftp://download.intel.com/research/silicon/moorespaper.pdf] 2006-04-01 samt NSF, "Science & Engineering Indicators Database 2002", [http://www.nsf.gov/sbe/srs/seind02/] 2006-04-05

[115] Ericsson CEO and Group Chief Executive Carl-Henric Svanberg has highlighted technical innovations as a critical resource for the survival of the company and especially emphasised the fact that: " Yesterday's successes... do not mean much if we cannot also managed to create the best technology today and tomorrow.", AB Ericsson, Annual Report 2003.

Figure 5.3.2 R&D investments in the ICT industry as a proportion of GDP in 2002.

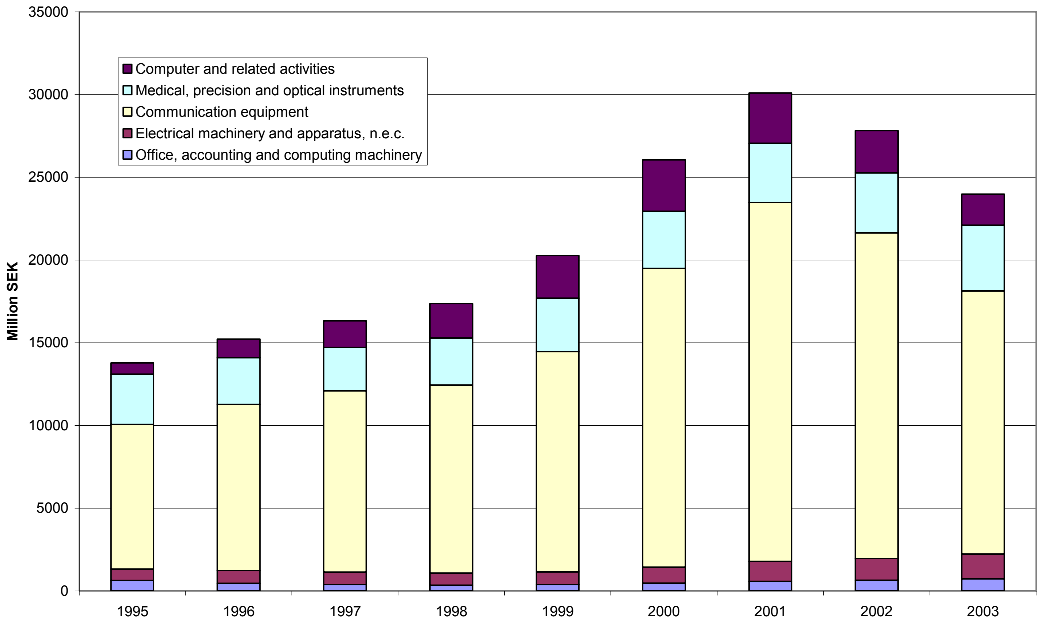


OECD, "ICT Outlook 2006". Modified by VINNOVA 2007.

The ICT industry's R&D investments in Sweden were just below SEK 28 billion in 2005, equivalent to around 36% of the whole of Swedish business financed R&D.[116] In 2003, telecom equipment accounted for the largest proportion of R&D investment; just over 60%. Its share has diminished somewhat since 1995. The computer consultants' share (IT services) has been small since 1995, but increased from 5% to 8% during the period 1995-2003 (figure 5.3.3).

[116] This does not include telecom operators.

Figure 5.3.3 R&D investments (current prices) in Sweden by the ICT industry 1995-2003 distributed by product group



Source: OECD, MSTI 2006, modified by VINNOVA.

In 2005, Ericsson accounted for 45% of the ICT industry's R&D investments in Sweden. The company's R&D investments in Sweden amounted to SEK 12.5 billion, equivalent to around 16% of turnover. During the 1990s, the company continuously expanded its R&D which reached a peak in 2001 at approx. SEK 40 billion, equivalent to around 20% of the company's turnover. Of the SEK 40 billion approx. half was invested in Sweden (appendix 4, figure 6).[117]

5.3.2 Innovations

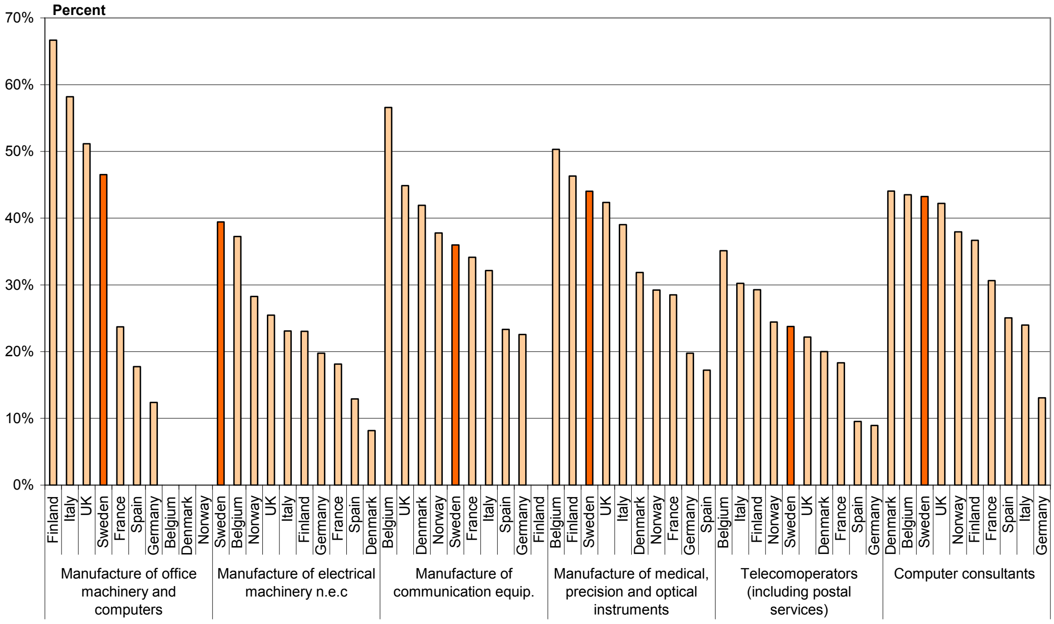
Information on innovations in European industry is collected by Eurostat within the Community Innovation Survey (CIS).[118] The latest survey shows that the proportion of ICT companies in Sweden conducting innovation activity is not particularly large in a European comparison (appendix 4, figure 7).

The proportion of innovative ICT companies in Sweden which launched new products onto the market between 2002 and 2004 varies depending on product fields from around 25% for telecom operators to approx. 45% for producers of computers and office machinery as well as manufactures of

[117] Sigurdsson, Jon 2003, and Ericsson AB "Annual Report 2003".
[118] See section 1.1.

telecom equipment. The ICT industry in Sweden shows a comparatively high proportion within all product groups (figure 5.3.4).

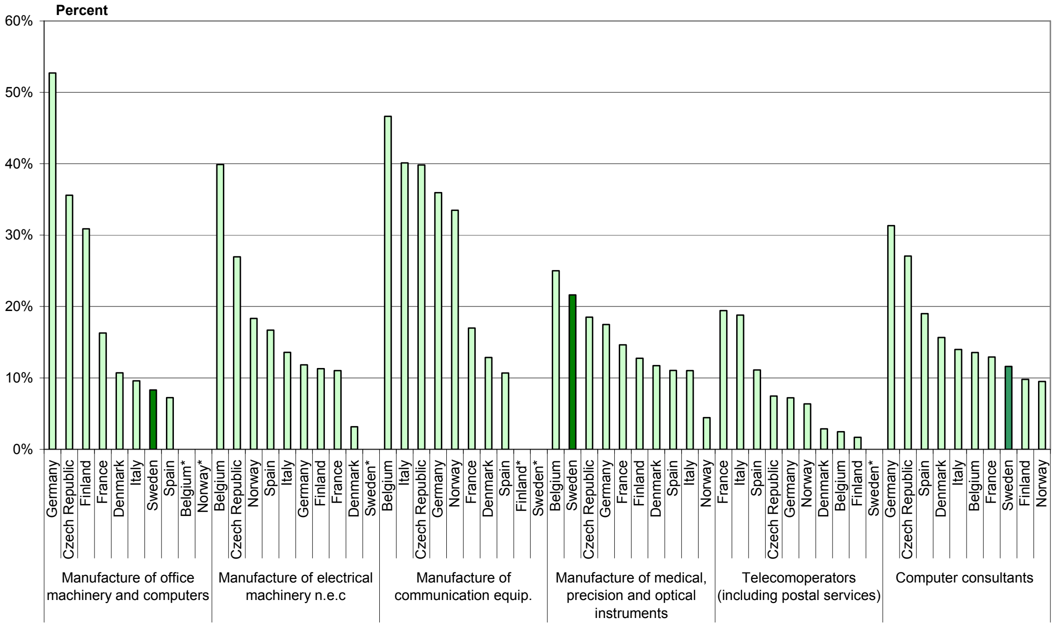
Figure 5.3.4 Proportion of innovative ICT companies in six product groups that launched new products onto the market during 2002-2004



Eurostat, NewCronos, 2006. Modified by VINNOVA, 2006

The CIS study also presents information on how large a proportion of turnover for 2004 is for products new to the market and launched between 2002 and 2004. Figure 5.3.5 shows that the proportion for turnover in a European context is comparatively high for Swedish producers of optical instruments etc. On the other hand, the same proportion for computer consultants and producers of computers and office machinery is relatively low.

Figure 5.3.5 Proportion of turn over in 2004 from products new to the market in innovative ICT companies distributed by product groups

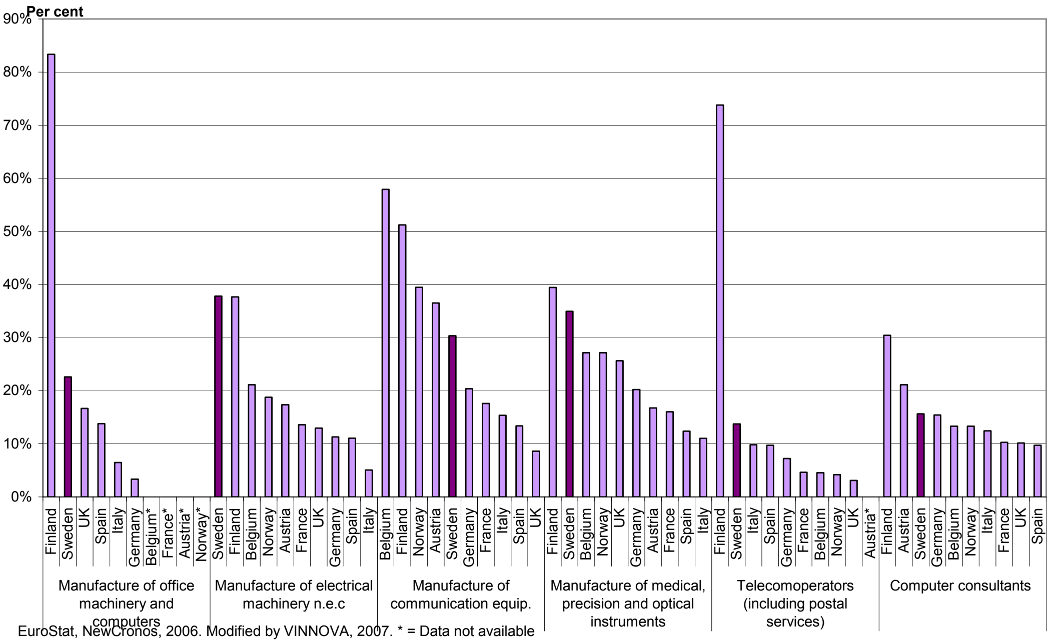


EuroStat, NewCronos, 2006. Modified by VINNOVA, 2007. * = Data not available

Utilisation of research by industry

CIS data shows that the proportion of innovative ICT companies in Sweden collaborating with universities for the purpose of generating innovations varies between product groups. In a European comparison, the Swedish proportions are relatively high (figure 5.3.6).

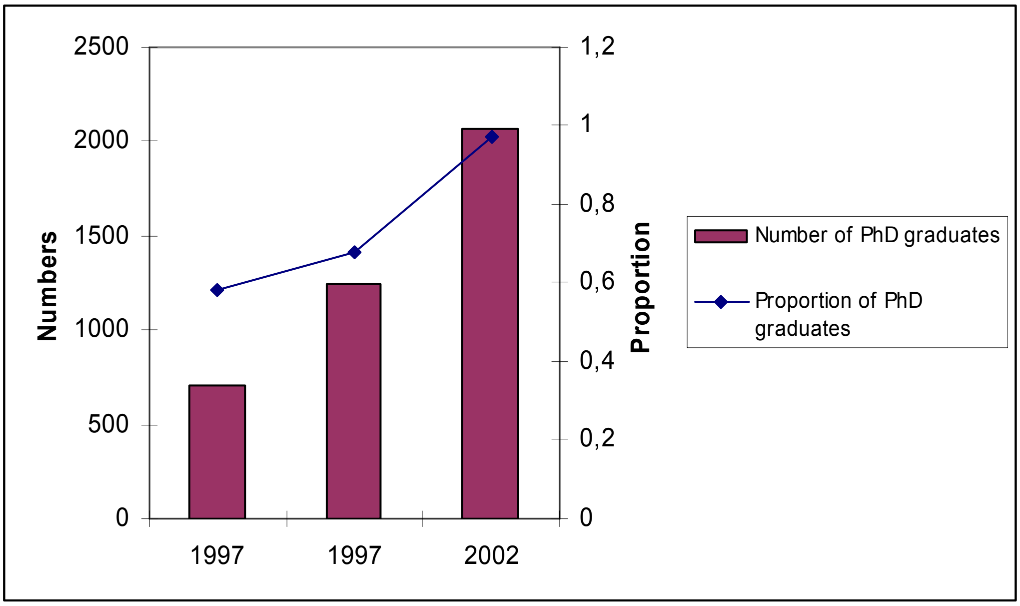
Figure 5.3.6 Proportion of innovative companies that collaborated with universities in order to generate innovations 2002-2004 distributed by product groups



EuroStat, NewCronos, 2006. Modified by VINNOVA, 2007. * = Data not available

One way for the ICT industry to utilise research at universities and institutes is to employ researchers. One indicator that such researcher recruitment has taken place is a change in the number and proportion of researchers in companies. However, an increase in the number of researchers across two years is not only due to recruitment from universities. Researchers may also have been recruited from other industries and sectors of the national economy. Figure 5.3.7 shows that both the number of researchers and their proportion of all employees in the ICT industry roughly trebled between 1993 and 2002.[119]

Figure 5.3.7 Number and proportion of researchers (PhD graduates) employed in Swedish ICT industry 1993, 1997 and 2002.



Source: SCB/VINNOVA

Within the ICT industry's product groups in 2002, most researchers were in Computer Consultants (just over 800) and Radio and Telecom Equipment (just under 500). These also increased the number of researchers most since 1993. The highest proportion of researchers in 2002 was within Instruments with just under 2% and Radio and Telecom Equipment with just over 1.7% (appendix 4, figures 8 and 9).

5.3.3 ICT research at universities and research institutes

In 2003 at some 20 Swedish universities, ICT research was carried out worth approx. SEK 1.5 billion.[120] In 1995, the corresponding figure was just

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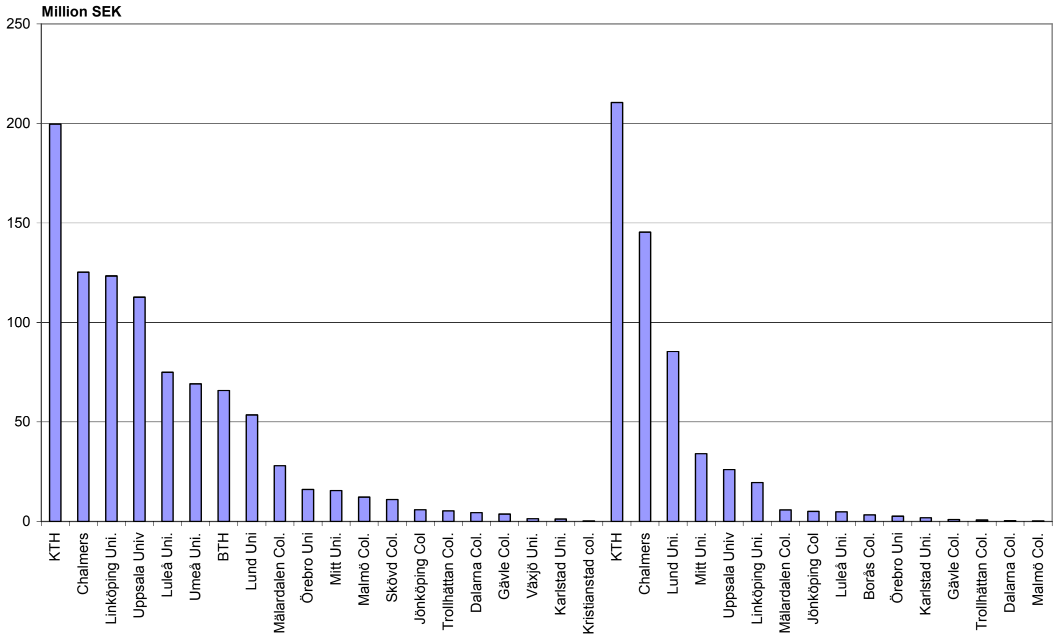
[119] By researcher is here meant PhD graduate.

[120] ICT research means research into the subjects of information technology, electronics, electrotechnology and photonics.

over SEK 0.8 billion. There have been no major displacements between subsidiary fields between 1995 and 2003. Around 60% of the research during the entire period related to information technology, whilst the remaining 40% related to electronics, electrotechnology and photonics (appendix 4, figure 10).[121]

In 2003, a very large section of the information technology research was carried out at KTH, Chalmers and Linköping University. The first two of these also carried out a large section of the electronics research, in conjunction with Lund University (figure 5.3.8)

Figure 5.3.8 ICT research (MSEK) at Swedish universities in 2003



Source: VINNOVA

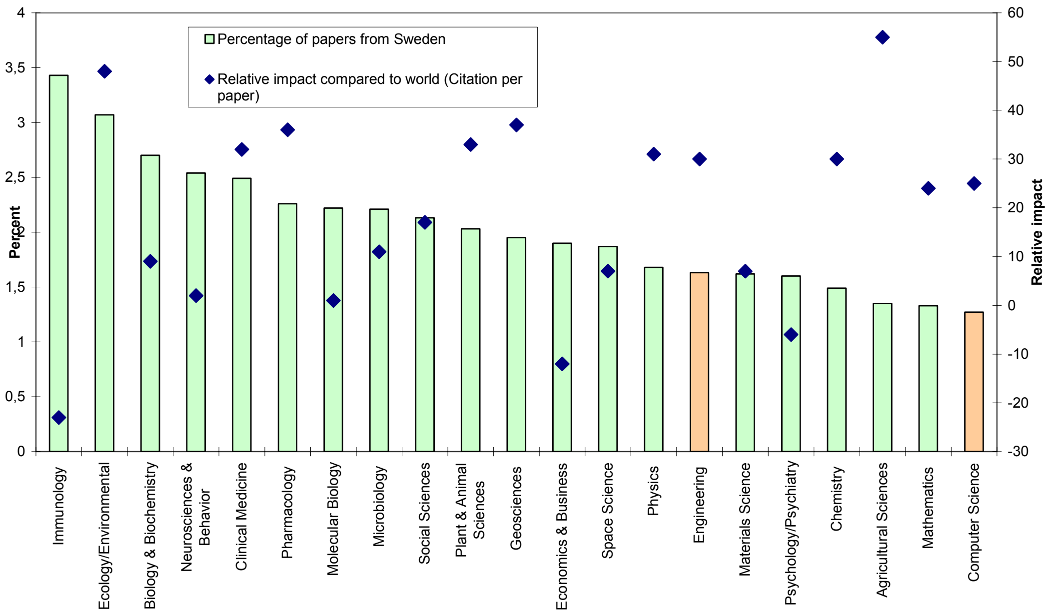
ICT research is also carried out at the institutes within Swedish ICT Research AB (Acreo, Interactive Institute, SICS, Santa Anna, Viktoria Institute and IVF). The research is broad and covers both hardware and software. The total research initiatives in 2005 are estimated at SEK 250 million.[122] In addition, there is comprehensive defence-related ICT research at the Swedish Defence Research Agency which, amongst other things, develops sensor technology.

[121] We do not know whether the volume is large or small in an international perspective, since it has not been possible to find comparable information.
[122] Oral information from Swedish ICT Research AB. Operating costs for software-related R&D is excluded since there is no comprehensive information.

International competitiveness of research

In order to measure the quality and thereby the competitiveness of research, it is a common procedure to use publication frequency in scientific journals combined with citations per published article (known as the Impact Factor). The subject fields which can be anticipated to be most relevant to the ICT field are in engineering and computer science. During the period 2001-2005 Swedish articles comprised around 1.6% of world production for engineering and 1.3% for computer science. The citation level for Swedish articles was high. Swedish articles within engineering have a 30% higher citation rate compared with the world average, whilst the corresponding level for computer science is 25% higher (figure 5.3.9).

Figure 5.3.9 Swedish proportion of all articles and citation per Swedish article distributed by scientific fields 2001-2005



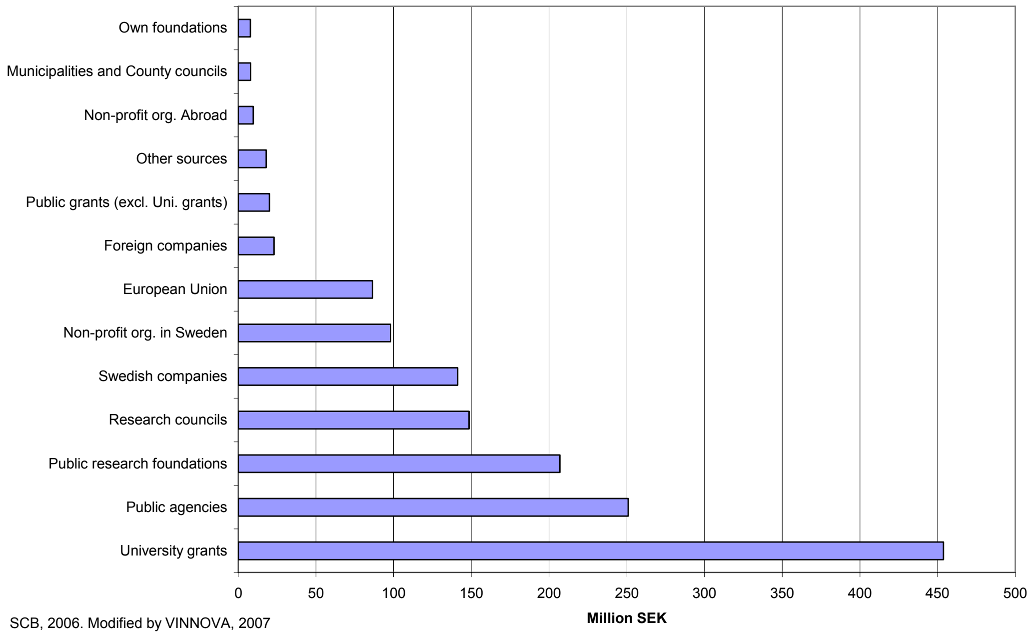
Thomson Scientific, 2006. Modified by VINNOVA, 2007

Statistics Sweden has conducted citation analyses based on the Thomson Scientific Inc. grouping of journals. They show that, in regard to Impact Factor, Swedish ICT research, having been 56% above the world average at the end of the 1980s was 32% above that average in 2004 (appendix 4, figure 11). This indicates that Swedish ICT research is maintaining good quality and international competitiveness even if there are signs of its competitiveness weakening in recent years.

5.3.4 State-funded R&D programmes

A large number of organisations fund ICT research at Swedish universities. University grants in combination with research funding from state agencies, research foundations and research councils account for a major section of the funding (figure 5.3.10).

Figure 5.3.10 ICT research at Swedish universities in 2003 distributed by type of funding organisation



SCB, 2006. Modified by VINNOVA, 2007

In terms of its history in the ICT field, Sweden has become internationally renowned through major, successful research initiatives. Part of the state-funded ICT research in Sweden has been run under a programme in which research collaboration between industry and universities was a vital component.[123]

The Swedish Board for Technological Development (STU) made one of the first investments in electronics research in Sweden. The **N**ational **M**ikroelectronics **P**rogramme, NMP was launched in 1984 and consisted of four programme blocks[124]. Its aim was to *"strengthen Sweden's capacity to construct and manufacture microelectronic components"*.[125] In 1987, NMP became the **I**nformation **T**echnology **P**rogramme (ITP). Compared with NMP, this programme had a broader approach. Microelectronics research was still included as an important component, but was augmented by comprehensive investment in industrial development, plus basic research into information technology. ITP was replaced by the IT-2000 programme

[123] There is also a variety of smaller-scale programme investments.
[124] NMP 1; Basic research, NMP 2; Applied research, NMP 3; Support for development projects, NMP 4; Support for industrial development.
[125] Bill 1983/84:8. The programme was funded by STU, FMV, Ericsson and the Swedish Telecommunications Administration. The companies invested SEK 291 million.

with similar aims and during the periods 1992-1995 and 1997-2001 a range of targeted collaboration projects were carried out in such fields as microelectronics.[126] As a result of the financial crash in IT at the turn of the millennium, research financiers lowered their ambitions in the ICT field generally and the electronics field in particular.

Major public programme investments are currently taking place in Centre programmes, known as Centres of Excellence in research, funded by the Swedish Research Council FORMAS, the Knowledge Foundation, the Swedish Foundation for Strategic Research and the Swedish Research Council. VINNOVA (Swedish Governmental Agency for Innovation Systems) is also funding Centre programmes or so-called research and innovation environments which, in addition to excellent research, are also intended to be characterised by industrial involvement and a high level of innovation activity. In Sweden, there are currently some 30 Centre programmes concentrating on ICT. The total state funding to Centre programmes will run to approx. SEK 1,735 million over a 5-10 year period, of which VINNOVA's programmes will account for approx. SEK 900 million. Of these environments, 23 are located at universities, four at institutes and three are regional so-called PPP clusters (figure 5.3.11).[127]

A number of investigations have highlighted the need to increase the type of state R&D programme with industrial involvement in programme design and research projects. One example is the Royal Swedish Academy of Engineering Sciences' (IVA) report, "IT without frontiers" presented in 2006.[128] It concentrated on the challenges brought about by increased international competition resulting from globalisation. Its main message was that Sweden's future competitiveness is dependent upon increased industrial and public use of ICT products. A pre-requisite for that is an increased volume of research in Sweden into materials, components and systems. The report proposes that new state-funded R&D programmes with industrial involvement be started within the fields of mobility and mobile communication, with the emphasis upon the integration of various access technologies to enable the development of mobile payments, secure content management, e-identification and similar services. A similar R&D programme was also proposed for software-intensive systems.

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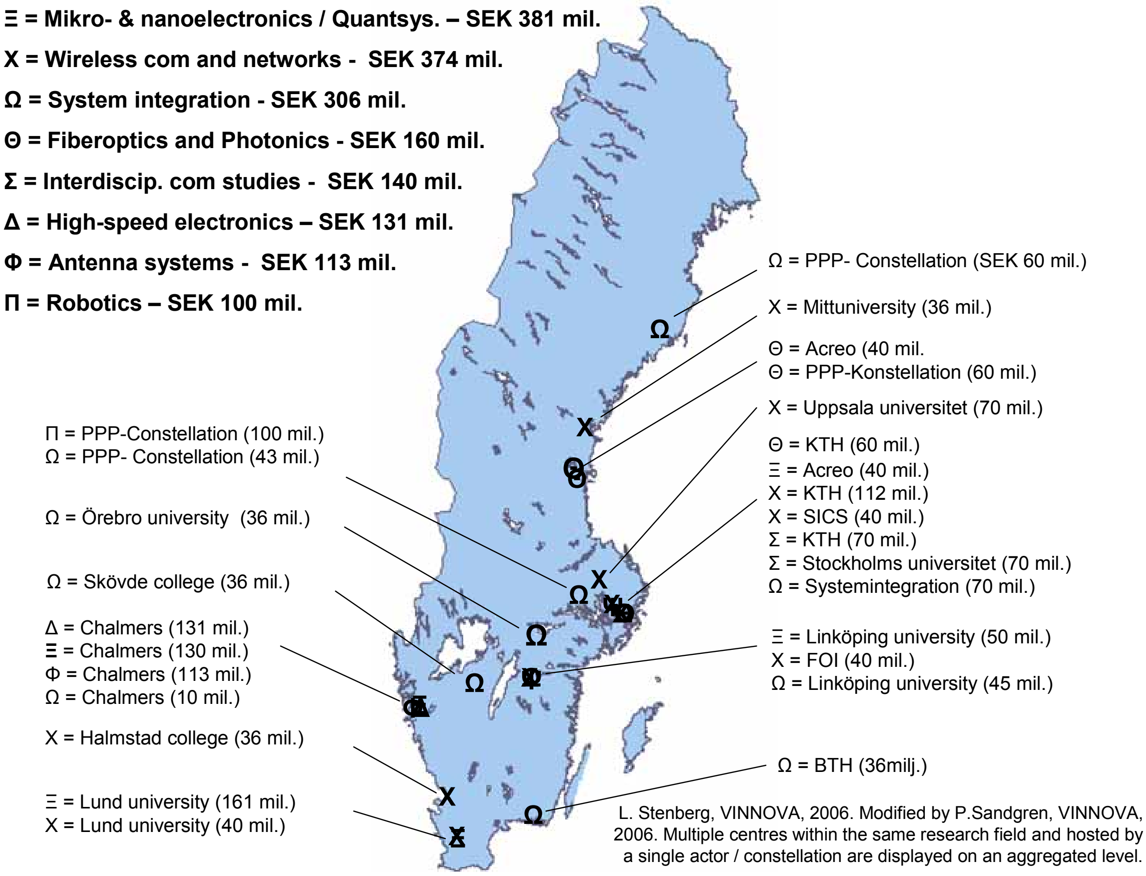
[126] The first collaborative programmes begun as early as 1993. Nilsson, O, 2001.

[127] PPP is an abbreviation for Public-Private Partnership. In the figure, these clusters are comprised of VINNOVA's VINNVÄXT winners, e.g. Robotic Valley (Västerås-Örebro-Eskilstuna), Fiber Optic Valley (Hudiksvall-Gävle-Sundsvall) and Process IT Innovations (Umeå, Norrbotten/Västerbotten Region)

[128] IVA, 2006. "IT without frontiers".

Figure 5.3.11 Centres of Excellence in ICT, financed by VINNOVA, the Knowledge Foundation, the Swedish Foundation for Strategic Research and the Swedish Research Council



Source: VINNOVA[129]

The proposal in the IVA report is consistent with proposals for R&D programmes with industrial involvement previously presented by such bodies as the Ministry of Enterprise Energy and Communications and VINNOVA.[130] Some fields which have been highlighted are:[131]

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[129] The classification is based on a survey at VINNOVA and includes Linné Centres (VR, FORMAS), Institute Excellence Centers (VINNOVA), the Swedish Foundation for Strategic Research (SSF), VINN Excellent Center (VINNOVA) and VINNVÄXT-1 (VINNOVA), VINNVÄXT-2 (VINNOVA). The survey has been supplemented by data from the Knowledge Foundation's so-called research profiles plus investment in a vehicle safety centre (SAFER) at Chalmers. The data shown is preliminary and the direction of the environments often means they fit into several categories.

[130] See for example: VINNOVA, " Research strategy for the electronics field", 2006, Ministry of Enterprise, Energy and Communications & Ministry of Education and Research, "The IT and Telecom Industry - Part of Innovative Sweden", 2005 and Ministry of Enterprise, Energy and Communications, "Policy for the IT Society", 2006.

[131] In the light of this, it is probable that future state R&D programmes will concentrate on the use of ICT in products and processes. However, there is a risk that ambitions in the field will be compelled to diminish. For example, the Swedish Foundation for Strategic Research

- convergence of communication and service infrastructure which may subsequently replace the Internet and mobile, fixed and audiovisual networks
- development of more robust, context-aware and easy-to-use ICT systems which can also adapt and improve according to the circumstances
- development towards smaller, cheaper, reliable and energy-saving electronic components and systems which form the basis for innovation in all important products and services.

Microelectronics is a generic technology with major and substantially increasing importance in a number of industries.[132] Microelectronics is often associated with traditional semiconductor research (CMOS), but includes a range of different fields including silicon carbide research.[133] The link to the materials field is important since this is a strong Swedish industrial field with major innovation and market potential. The microelectronics research strategy presented by VINNOVA in 2006 emphasised the importance of research being commercialised by companies participating in the programme, or through newly formed enterprise. However, in the latter case, the programme would need opportunities to fund verification of new technology.

Interdisciplinary research programmes was also highlighted in the IVA-report as important for future investment. In these, ICT should be combined with other technologies such as biotechnology, nanotechnology and environmental engineering. This has the potential to create collaborative clusters between research players and companies with no prior research collaboration. This in turn will create better conditions for innovation based on technical combinations.

(SSF), which since the mid-1990s has been one of the most important financiers of ICT research, has declared that it does not intend to continue investments in the electronics field.

[132] A clear example is the automotive industry. For more information, see: The Economist, "Strap in and boot up – Cars are now sold on their electronics, not just their mechanics", 26/8/06.

[133] Research into new materials, specifically silicon carbide, was included as a focus area in "Collaboration Project in Microelectronics" in the 1990s. Silicon carbide is more tolerant of high temperatures than normal silicon, which is a standard material for most electronics manufacture. It is forecast that silicon carbide will be used in such things as vehicles, power electronics and on base stations for mobile networks. For more information, see: Ryberg, Jonas, "Ready for silicon carbide factory in Norrköping", [http://www.nyteknik.se/art/38977] 2/11/06.

5.4 Automotive industry

From an international perspective, it is unique for a small country in terms of population like Sweden to have two of the world's leading truck manufacturers (AB Volvo and Scania) and two large car manufacturers (Volvo Car and Saab Automobile). Sweden is also one of the two countries in the world most dependent upon its automotive industry; Sweden has the highest number of people employed within the automotive industry relative to the whole of industry. The greater proportion of production is exported (cars 85% and trucks 95%). In 2004, the automotive industry was the largest Swedish export sector.[134]

The number of car manufacturers in the world has diminished. Several makes have disappeared in recent decades and new producers in Asia and Eastern Europe have arrived. The truck industry has been more stable over time although there have also been mergers there. The global automotive industry is currently dominated by a small number of companies, with the 10 largest companies accounting for 80% of the world market. In the next decade, it is estimated that the automotive market will grow by 3% per year. An important trend is that automotive companies are concentrating increasingly on marketing, brand value, financing, spare parts, service and insurance at the same time as component suppliers are taking over a greater portion of manufacture and product development.

In terms of employment, the largest automotive industrial countries in Europe are Germany, France, Great Britain, Italy, Spain, Sweden, Belgium and the Czech Republic. However, only four of these - France, Italy, Sweden and Germany - still operate both development and production of vehicles.

Industrial structure

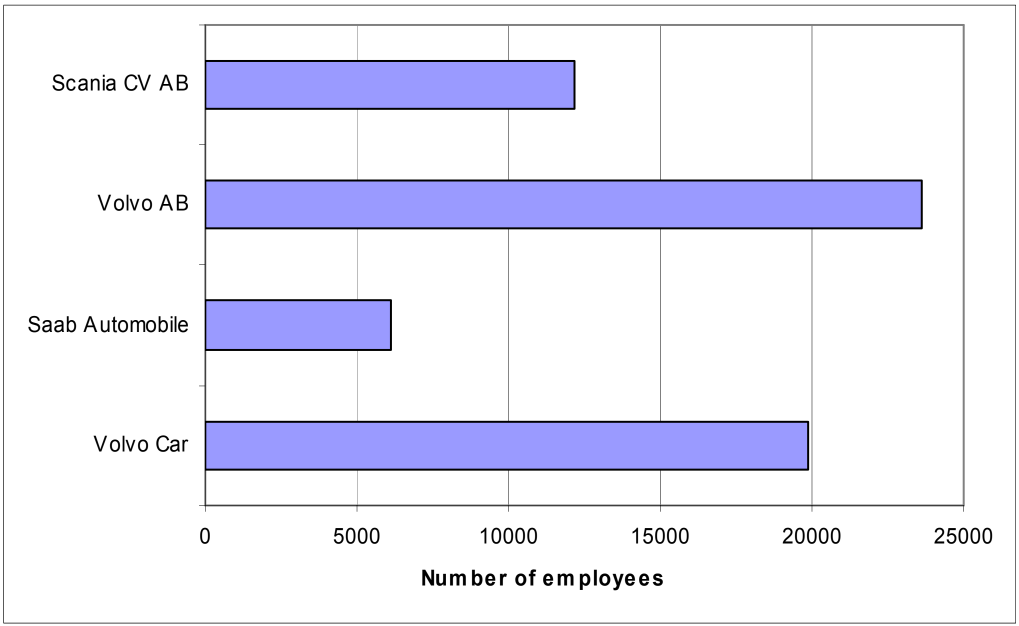
In round numbers, the automotive industry in Sweden currently employs 140,000 people. Of these, just over 67,000 work for *vehicle manufacturers* and just over 72,000 in *component supplier companies.* In total, motoring (including garages, haulage contractors etc.) employs almost 400,000 people which is roughly equivalent to every tenth working person in the country. The automotive industry thus comprises a significant part of Sweden's industry.

At the end of 2005, the four major automotive manufacturers, Scania CV AB, AB Volvo, Volvo Car (Ford Group) and Saab Automobile (GM Group), employed just over 61,000 people in Sweden, which was almost

[134] VINNOVA, VA 2007:05. A report on the automotive industry in Sweden. Unless otherwise stated, information on this chapter is taken from there.

half those employed in the automotive industry (5.4.1). Companies are highly export-intensive and have comprehensive research and development. Volvo Car, Scania CV AB and Volvo AB have development responsibility for entire vehicles, whilst SAAB Automobile has development responsibility for some special fields within the GM Group. In their production plants, the four companies have world-leading production technology. They are also leading in the development of computerised working methods, including construction and simulation as well as project control and working organisation.

Figure 5.4.1 Number of employees in Sweden in the four big vehicle manufacturers in 2005.



Source: Bil Sweden

In addition to the big four, there are some 20 other automotive manufacturers with just over 8,000 employees (table 5.4.1). The majority of these develops and manufactures working vehicles such as contract and forestry machines, military vehicles, wheel loaders, highway machines, fire tenders and ambulances.

Table 5.4.1 Number of companies and employees in other vehicle manufacturers than the big four in 2005.

Vehicle type	No. companies	No. employees
Light vehicles (< 3.5 tonne)	2	675
Heavy vehicles (> 3.5 tonne)	5	401
Working vehicles	14	7515

The big four automotive manufacturers are dependent upon component suppliers. The input goods' proportion of sale value is higher than in most industries and approx. 30% of the purchase volume goes to suppliers in

Sweden. Component suppliers in Sweden are a heterogeneous group of smaller companies, but amongst them are some relatively large ones. They supply goods and services to automotive manufacturers in Sweden and other countries. However, dependence upon the Swedish automotive manufacturers is great amongst many of them. Some of the companies have developed specialist knowledge, e.g. within the field of safety and are successfully competing on international markets.

Component companies may be categorised according to their principal activity into one of the fields: Bodywork & Chassis, Propulsion, Fittings, Electronics/IT, Parts & Materials and Engineering Consultants (see appendix for a description of the fields).[135] The majority of companies are within Bodywork & Chassis and Parts & Materials (table 5.4.2). Measured by employees, just over 50% are in both these fields of activity.

Table 5.4.2 Number of companies and employees in component companies in 2005 distributed by fields of activity

Field of activity	No. companies	No. employees
Bodywork & Chassis	106	25652
Propulsion	51	18677
Fittings	38	11233
Electronics/IT	22	1546
Parts & Materials	106	13821
Engineering Consultants	28	4583

Component companies are specialised in either light vehicles, heavy vehicles or working vehicles. But a relatively large proportion of them supply both light and heavy vehicles. Table 5.4.3 shows that heavy vehicles are the “client” to roughly the same number of component companies as light vehicles.

Table 5.4.3 Number of component companies and employees in 2005 distributed by vehicle type

Vehicle type	No. companies	No. employees
Light vehicles	83	25177
Heavy vehicles	99	23470
Light & Heavy	140	23311
Working vehicles	29	3554

Location of the automotive industry

Western Sweden has 35% of the companies and 49% of the employees.[136] Three out of four major automotive manufacturers are here. Just over 40%

[135] Over and above component companies, there are a number of companies important to the automotive industry. This applies to companies such as those in production engineering, tools, logistics, business systems, packaging materials, production equipment and staffing companies and management consultants.
[136] Counties of Västra Götaland Värmland

of companies in the region are subcontractors to the four major automotive manufacturers.[137]

Southern Sweden has 29% of companies and 19% of employees.[138] Just under 60% of companies are subcontractors to the four major automotive manufacturers.principally in subcontract production. The region has a number of manufacturers of working vehicles.

Eastern Sweden has 28% of the companies and 24% of the employees in the automotive industry.[139] The major proportion of Scania's activity is here as are a number of manufacturers of working vehicles. Around 45% of companies are subcontractors to the four major automotive manufacturers, principally operating in sheet metal and cutting work.

Northern Sweden has 8% of both companies and employees.[140] Manufacturers of trucks have units in the region. There is also a manufacture of working vehicles here. Just under 50% of companies are subcontractors to the four major automotive manufacturers.

Strategic areas of expertise

Automotive manufacturers and component suppliers build their competitiveness on the fact that vehicles and components have unique properties of functions. In addition, production technology is also of major significance. Companies' capacity to develop vehicles and vehicle components is based on them having expertise in vital automotive fields.

One such field of expertise is **vehicle safety**. Safety work is aimed both at preventing accidents and at preventing injuries. Driving characteristics, steering, suspension, brakes, driver environment and various forms of information and support systems are important in order to prevent accidents. Crash safety, safety bodies with various types of protection, shock-absorbing interiors, safety belts and air bags are significant in reducing and minimising any injuries. Warning systems with sensors and software are built-in to create proactive safety.

Another field of expertise is **environment and energy**. Emissions from vehicles contribute to many environmental problems. Technical measures

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[137] Just over 55 per cent of the component companies are subcontractors to the four major automotive manufacturers

[138] Counties of Jönköping, Kronoberg, Kalmar, Blekinge, Halland and Skåne.

[139] Counties of Stockholm, Södermanland, Västmanland, Örebro, Östergötland and Uppsala.

[140] Counties of Norrbotten, Västerbotten, Jämtland, Västernorrland, Gävleborg and Kopparberg.

can reduce emissions of air pollutants and noise as well as increasing energy efficiency in road vehicles. Car weight is also significant.

Vehicle electronics, vehicle IT and telematics are a third strategic field of expertise. Electronics and telematics equipment account for an increasing proportion of vehicles' added value. Within the field of electronics, vehicle manufacturers have built up their knowledge whilst Sweden is leading within telecommunication. This means that automotive electronics, automotive IT and automotive telematics have particular potential for development in Sweden.

A fourth area of expertise is **vehicle design** which is gaining increasing importance in product development work within the automotive industry.

Materials, metallurgy and chemistry are also strategic fields of expertise, since steel qualities and process technologies such as rolling, casting, forging and processing are important for the competitiveness of automotive manufacturers.

Production engineering is a further field of expertise important to companies' competitiveness. Efficient production engineering increases industry's opportunities to operate production in Sweden in a competitive fashion. Demands for quicker production, customer order control, flexibility and turnover, more product variants on the same production lines, new materials requiring new manufacturing processes and increased environmental awareness associated with the manufacturing process.

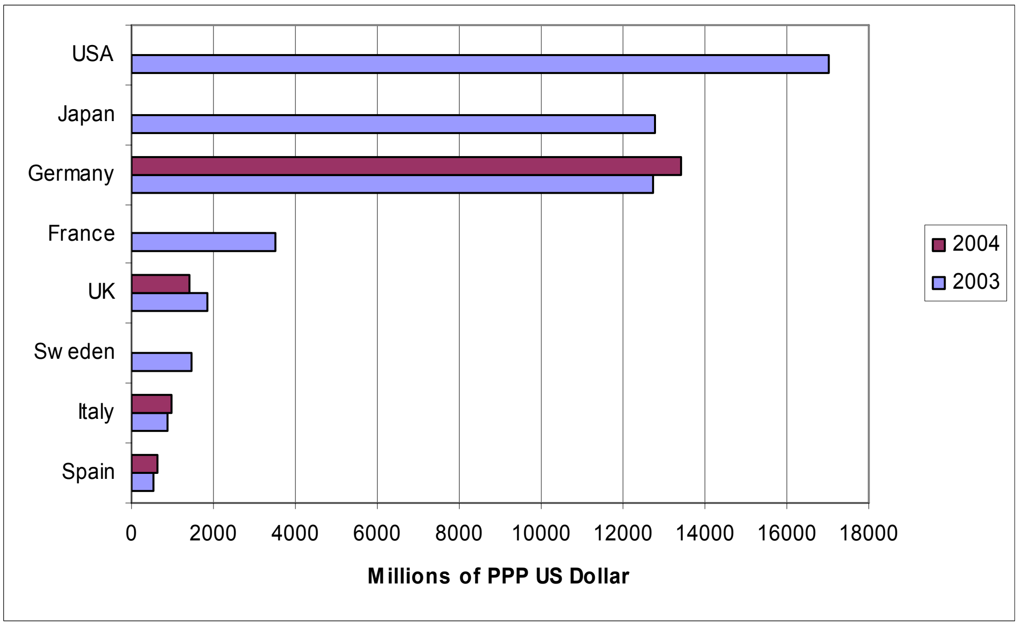
The big four manufacturers of light and heavy vehicles master all fields of expertise. Other vehicle manufacturers have fewer strategic skills, e.g. two light and five heavy vehicle manufacturers primarily base their competitiveness on expertise within the fields of vehicle design and production engineering. The manufacturers of working vehicles generally base their competitiveness on expertise in production engineering, design and materials etc. (appendix 4, figure 12).

The majority of component suppliers base their competitiveness on expertise within production engineering and materials technology. For engineering consultants and Electronics/IT, automotive electronics is also an important field of expertise for competitiveness (appendix 4, figure 13).

5.4.1 Investments in R&D

Research and development (R&D) is required in order to improve vehicle and component properties and functions. In an international perspective, the automotive industry in Sweden invests fairly minor resources in research and development (figure 5.4.2). The US, Japan and Germany account for the majority of R&D investments in the global automotive industry.

Figure 5.4.2 R&D investments (millions of PPP USD) in the automotive industry in 2003 and 2004.



Source: OECD

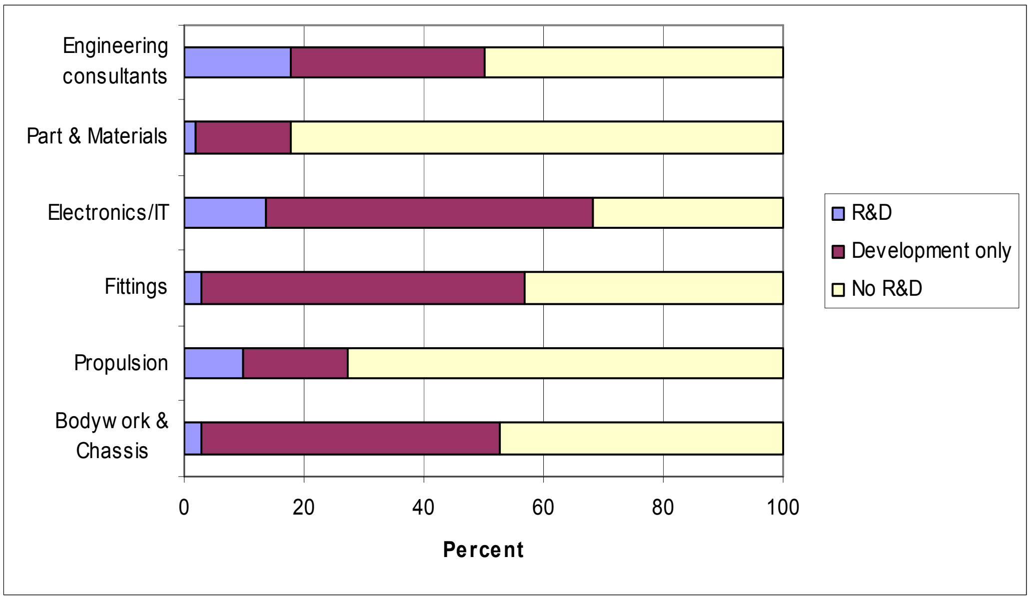
The big four vehicle manufacturers all operate research and development. Amongst the other automotive manufacturers there are only a few carrying out research, but all except one company operate product development.

Table 5.4.4 Number of vehicle manufacturers with R&D in 2005, distributed by vehicle type.

Vehicle type	R&D	Development only	No R&D
Light vehicles	2	1	1
Heavy vehicles	2	5	0
Working vehicles	2	12	0

Amongst the component manufacturers, it is uncommon to run R&D. Just over 60% of them do not. Only 5% operate research (and development), whilst just over 34% have only development activity. The highest proportion of component companies which carry out research are amongst Engineering Consultants and Electronics/IT companies. The lowest proportion of companies with research and/or development are in the fields of Fittings and Propulsion, where just over 80% and 70% respectively of companies do not operate any research and or development (figure 5.4.3).

Figure 5.4.3 Proportion of component companies with R&D in 2005 distributed by fields of activity



5.4.2 Innovations

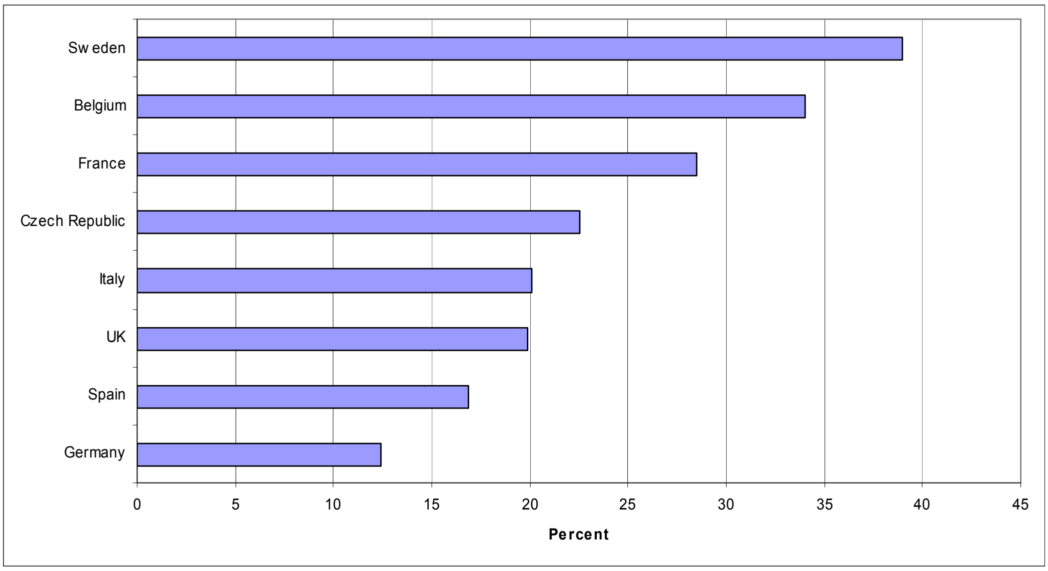
Customer requirements for increased comfort, safety and environmental friendliness are placing the automotive industry under great pressure to innovate and it is expected to undergo rapid technological changes in the next 10 years. Even now, these requirements have resulted in such things as electrical systems, electronics and software increasing in vehicles (the automotive industry has become an important source of demand for innovations from the IT and telecommunications industry) and an increasing number of car models are being launched which run on alternative fuels. Competition from low-cost countries is leading to a demand to make production more efficient and reduce manufacturing costs.[141]

The automotive industry in Sweden is showing a large proportion in a European perspective, or around 2/3, of innovative companies (appendix 4, figure 14). In this sense, only the automotive industry in Germany is more innovative than that in Sweden.[142] However, the proportion of companies running innovation activity is a very rough measurement of innovativity. An additional and better measurement is the proportion of innovative companies which have launched new products. Using this measurement, the

[141] Government Offices of Sweden, 2005 " The automotive industry - part of Innovative Sweden".
[142] It is important to note that the automotive industry in the CIS study (see chapter 1.1) probably does not include all component suppliers, since the automotive industry in it is the same as SNI 34.

automotive industry in Sweden is the most innovative in a European perspective (figure 5.4.4).

Figure 5.4.4 Proportion of innovative automotive companies that launched new products 2002-2004.

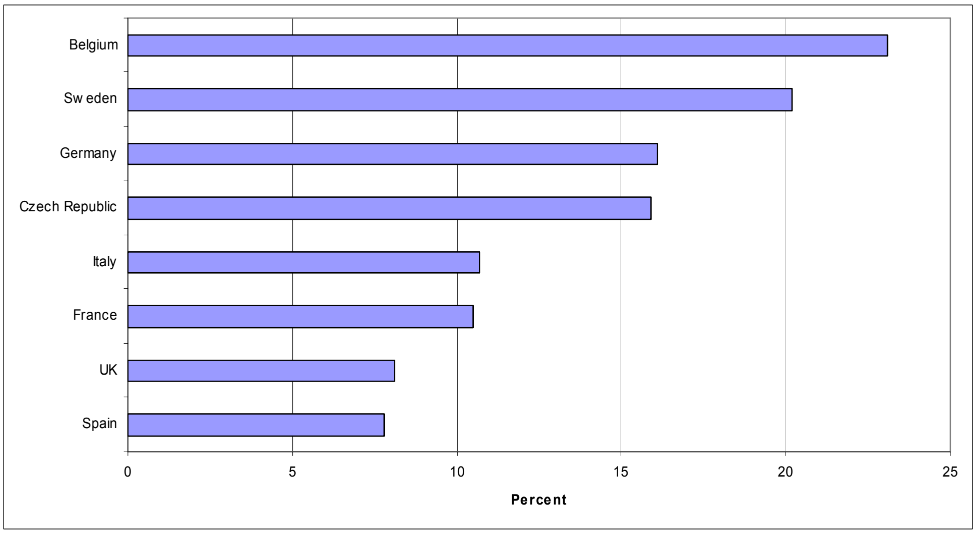


Source: Eurostat http://ec.europa.eu/eurostat/. *Modified by VINNOVA 2006*

Automotive industry's utilisation of research

One indicator that a company is utilising university research is their collaboration with universities in order to generate innovations. In a European perspective, a major proportion of innovative automotive companies in Sweden are running such research collaboration (figure 5.4.5).

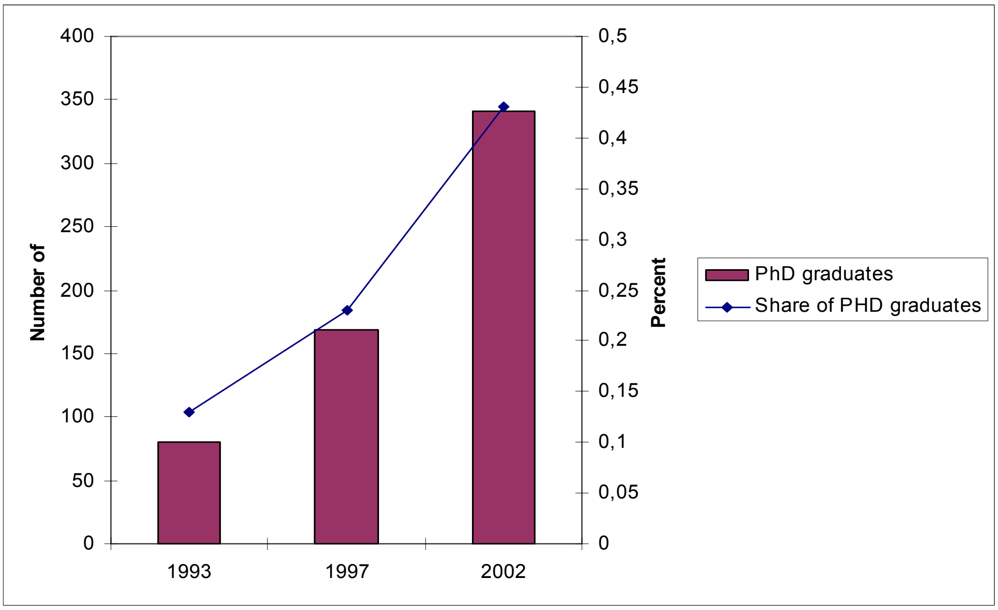
Figure 5.4.5 Proportion of innovative automotive companies that collaborate with universities with the aim to generate innovations 2002-2004.



Source: Eurostat, http://ec.europa.eu/eurostat/ *Modified by VINNOVA 2006*

Another way in which industry can accrue knowledge and expertise from universities is to recruit researchers.[143] The fact that researcher recruitment is an important method of knowledge transfer to the automotive industry is indicated by the fact that the number and proportion of researchers (PhD graduates) in the automotive industry has increased between 1993 and 2002 (figure 5.4.6).

Figure 5.4.6 Number and share of researchers (PhD graduates) in Swedish automotive industry, 1993, 1997 and 2002.



Source: VINNOVA

5.4.3 State-funded R&D programmes

In 1994, a clear structure was established for state automotive R&D funding. In the light of the automotive industry's wish for bigger and stronger research environments and a stronger recruitment base, the government appointed an inquiry in 1993 to investigate suitable ways of organising automotive research. The result was the Council for Vehicle Research (PFF). In this, the government, through the agencies and industry, wrote an agreement for an automotive engineering research programme comprising SEK 30 million per year each from industry and the state for three years; a total of SEK 180 million.

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143 It is clear from the next section that one of the main reasons for the automotive engineering research programme being initiated in 1993 was that the industry had expressed a need for a better recruitment base for qualified researchers. In the two major programmes administered by VINNOVA, the automotive research and Green Vehicle programmes, approx. 83 doctorates and 114 licentiate degrees had been obtained up to the end of 2006.

In conjunction with preparations for the collaborative Green Vehicle programme the structure of PFF was changed to achieve a structure to manage a number of different R&D programmes. PFF currently comprises four different programmes; the two already mentioned plus the Swedish Emission Research Programme and Intelligent Vehicle Safety Systems. All these are intended to cease in 2008 and an appointed inquiry will make proposals as to how things should continue after that.[144] Further sectorial industry R&D programmes, such as MERA and V-ICT, have been added in recent years.

In parallel with sectorial industry R&D programmes, needs-driven research and research and development close to the automotive industry has been funded by a number of other research financiers such as VINNOVA, the Swedish Energy Agency, Swedish Road Administration and MISTRA. This research has been conducted in traditional programmes and lately, to an increasing extent, as Centre initiatives.

Of major automotive industrial interests, but also connected to other industrial and public interests, is the issue of fuel. The investments consist mainly, in terms of pure finance a least, of pilot facilities in which various types of raw materials and industrial processes are developed and tested in order to produce tomorrow’s fuels.

In addition to the above fields, research is described within a number of other fields of major relevance to the automotive industry, for example in new materials and information and communications technology. However, the volume of this research is difficult to estimate.

Table 5.4.7 summarises a number of research initiatives for the automotive industry. The following apply to the various types of research programme:

- **Centre programme** relates to long-term, often 10-year, research initiatives in which agencies, industry and universities normally contribute around the same amount each.
- **Industry programme** relates to research and development activities largely initiated and controlled by industry.
- **Research programme** relates to research in which agencies, academia and industry normally jointly influence direction and project selection.
- **Fuel programme** relates to investments in alternative fuels, i.e. alternatives to today’s petrol and diesel.

[144] The results of the inquiry were published in spring 2007.

Table 5.4.7 Automotive related R&D programmes

Type	Name	Volume [MSEK/year] Total	Governm. Share	Other sources	Period Start	End
Centre	Competence Centre for Combustion Engine Technologies	21,0	7,0	14,0	1995	2016
Centre	Competence Centre for Combustion Processes	21,0	7,0	14,0	1995	2016
Centre	Competence Centre for Catalysis	21,0	7,0	14,0	1995	2016
Centre	Hybrid Technologies Centre	30,0	10,0	20,0	2007	2017
Centre	Competence Centre CICERO	21,0	7,0	14,0	2006	2014
Centre	Graduate Research School CECOST	24,0	12,0	12,0	2006	2009
Centre	Centre for ECO2 Vehicle Design	21,0	7,0	14,0	2005	2015
Centre	Traffic Safety SAFER	30,0	10,0	20,0	2006	2016
Centre	Test Site Sweden	11,4	6,4	5,0	2006	2009
Industry	Vehicle Research Program (ffp)	60,0	30,0	30,0	2006	2008
Industry	Swedish 'Green Car' Initiative 1 (GB1)	227,0	68,1	158,9	2000	2007
Industry	Swedish 'Green Car' Initiative 2 (GB 2)	268,0	94,0	174,0	2006	2008
Industry	Emissions Research Program (EMFO)	30,0	20,0	10,0	2002	2008
Industry	Intelligent Vehicle Safety Systems (IVSS)	80,0	46,3	33,8	2003	2010
Industry	Vehicle ICT Program (V-ICT)	62,5	31,3	31,3	2005	2008
Industry	Production Technologies (MERA)	152,5	76,3	76,3	2005	2008
Industry	Volvo DME	24,8	12,4	12,4	2006	2010
Industry	Hybrid Wheel Loader	8,0	2,7	5,3	2006	2008
R&D programme	Fuel cells in a sustainable society	16,0	9,5	6,5	1997	2006
R&D programme	Energy Efficient Aftertreatment Systems for Combustion Engines	8,5	6,5	2,0	2006	2009
R&D programme	Energy Systems for Road Vehicles	22,6	20,5	2,1	2007	2010
R&D programme	Innovative Vehicles, Vessels and Systems	20,0	10,0	10,0	2002	2006
R&D programme	Light Materials and Lightweight Design	21,7	10,8	10,8	2003	2008
Fuels	Synthesis Gas from Black Liquour	50,0	50,0	?		
Fuels	Fuels from Biomass	60,0	60,0	?		
Fuels	Ethanol from Cellulose	35,0	35,0	?		
	SUM	**1347,0**	**656,7**	**690,3**		

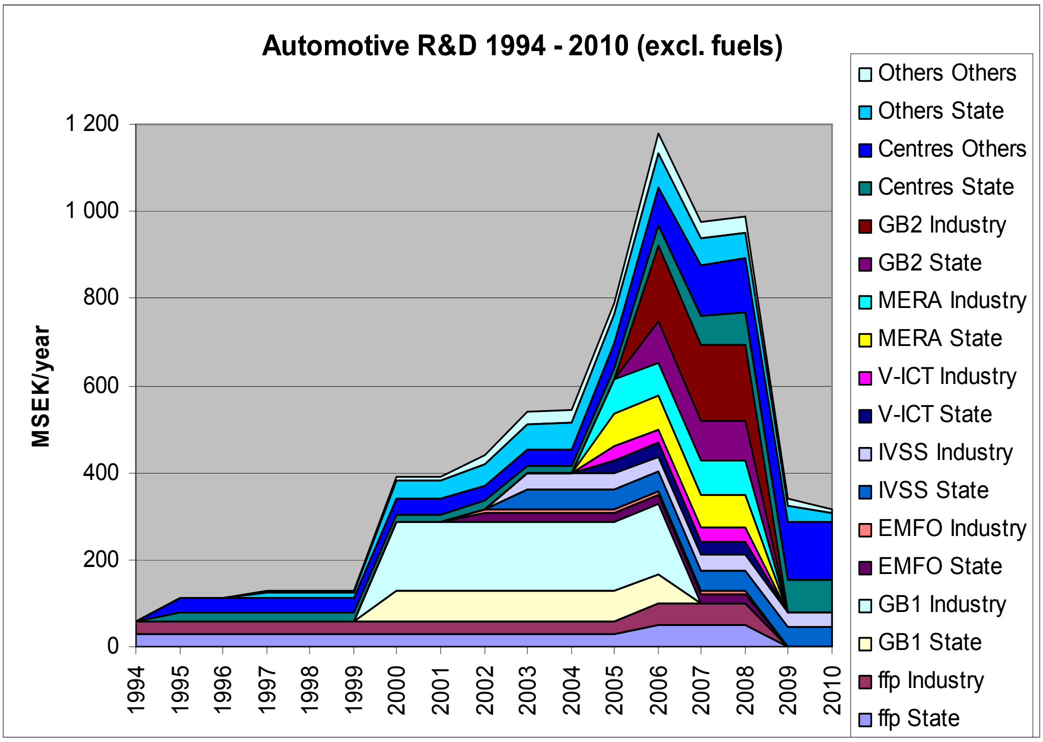
Source: VINNOVA

The table provides a snapshot of the situation in 2006. The development over time is shown in figure 5.4.8 (excluding fuel, which "by tradition" is not seen as automotive research). However, some investments have been found with relevance to the automotive industry in the period 1994-2001. For example, with assistance from state quarters, a number of demonstration vehicles were produced with advanced hybrid technology. Thus, the growth in state funding is not in reality as strong. Around half the research investments are funded by industry in all types of programme, except Centre programmes where industry funds 1/3.[145] Appendix 4, figure 15 shows the

[145] The state is responsible for 1/3 and universities for 1/3.

funding divided into State and Other sections, with the other section chiefly composed of industrial funds.

Figure 5.4.8 Volume of automotive R&D programmes (excl. fuels) in million SEK (current prices) 1994-2010.



Source: VINNOVA

The decline from 2008 and onwards can be explained by the fact that the current agreements for industry programmes cease then. It is as yet unclear what form the funding will take after that. If industry programmes are studied separately, this can be seen even more clearly (appendix 4, figure 16).

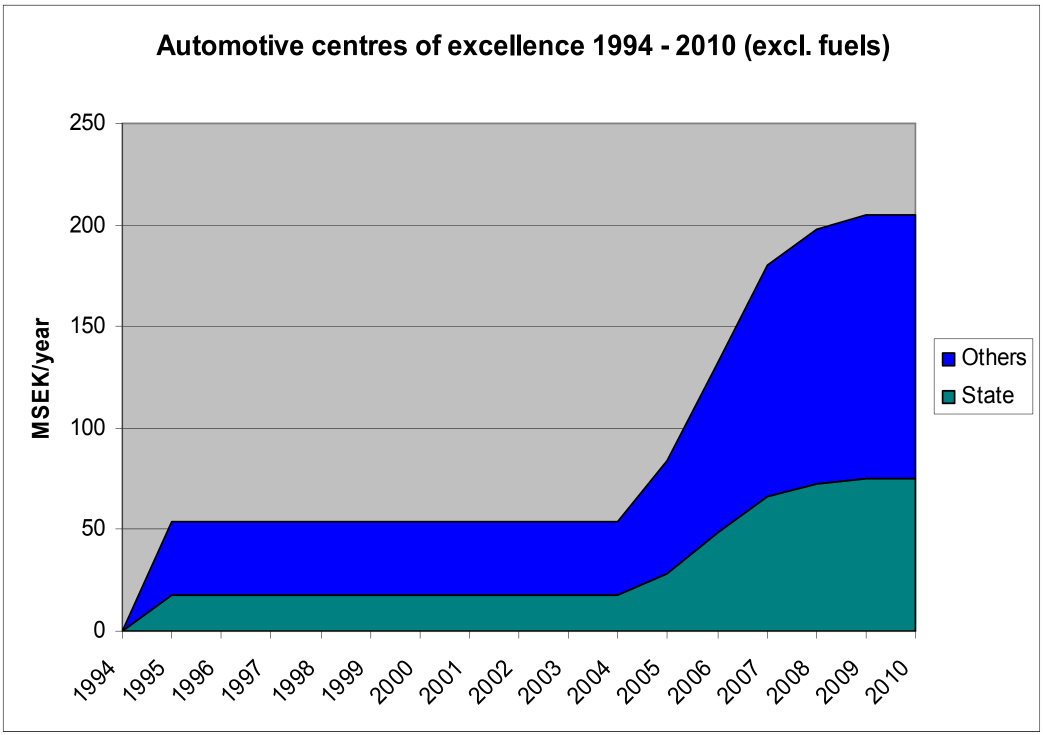
Industry programmes involve universities to a varying extent, from virtually all projects being implemented jointly with academia to only a small proportion having such connection. Correspondingly, the degree to which state funds go to universities varies greatly. The working model within industry programmes is that industry drafts problems and appoints an industrial project manager who guarantees industrial relevance in the research.

One aspect which has consistently been brought up in the assessments so far carried out by the PFF programmes is that there has been little subcontractor participation in the programmes. In many studies of the automotive industry, it has been emphasised that subcontractors' capacity for renewal must be increased, as must their capacity to broaden their customer base to also include overseas customers. Increased participation by subcontractors in industry R&D programmes can be an instrument to increase their renewal capacity.[146]

In research programmes, the automotive industry is represented in the programme boards, which to a great extent determine the direction of research and project choice. Research is carried out in universities. Industrial co-financing in projects is often a requirement. This is a guarantee that programmes will correspond with industrial needs.

There have been many Centre investments recently (figure 5.4.9) and since all Centre investments were decided upon during 2005 or 2006, they will operate for a long time to come. According to plan, in the majority of cases they will continue until 2016. Collaboration between industry and academia is one of the cornerstones of Centre investments.

Figure 5.4.9 Volume of centre programmes in million SEK distributed by state funding and other funding 1994-2010



Source: VINNOVA

For universities and institutes, it is important to achieve world-class research expertise within fields relevant to “Swedish” automotive industry. For research groups to achieve and maintain internationally renowned expertise

[146] Given that over half of subcontractors do not operate R&D activity, it may be difficult to realise.

requires strong connections with academic and industrial players within and outside of Sweden. Centre programmes will be in a position to contribute to the development of such environments. In many contexts, the SAFER safety investment at Chalmers is held up as an example. This centre has a pronounced ambition to be the best in the world, to operate both in the EU and in other bodies vital to the automotive industry, to assemble in one place personnel resources with a broad spectrum of expertise from both academia and industry, and not least of all to grow to a size which makes it comparable with other automotive industrial clusters in the world.

Appendices

1. Nanotechnology research programmes

I. Centres of Excellence

Name	University	Period	Contri-bution MSEK	Type of centre and funding organisation
NANOWIRES for Fundamental Materials Science and Quantum Physics and for Applications in Electronics, Photonics and in Life-sciences	LU	2006-2010	22	The Swedish Research Council's initiative to foster strong research environments
Nanowires for emerging nanoelectronics and life-science applications	LU	2006-2010	34	Strategic Research Centre, The Swedish Foundation for Strategic Research
Strategic Research Centre for Nano Science	LU	2004-2008	40	SRC in Microelectronics, The Swedish Foundation for Strategic Research
Nanoscience and Quantum Engineering	LU	2007-2016	87	Linné support[147]
Strategic Research Centre for Nanodevices and Quantum Computing (NANODEV)	CTH	2004-2008	30	SRC in Microelectronics, The Swedish Foundation for Strategic Research
Engineered quantum systems	CTH	2007-2016	100	Linné support
Functional Nanoscale Materials	LiU	2007-2016	70	VINN Excellence Centre, VINNOVA[148]
Materials Science for Advanced Surface Engineering, MS²E	LiU	2007-2010	45	Strategic Research Centre, The Swedish Foundation for Strategic Research
Linköping Linnaeus Initiative for Novel Functional Materials (LiLi-NFM)	LiU	2007-2016	80	Linné support
Hierarchic Engineering of Industrial Materials	KTH	2007-2016	70	VINN Excellence Centre, VINNOVA
Uppsala Berzelii Centre for Basic and Applied Research in BioNanoTechnology	UU	2007-2016	100	The Swedish Research Council and VINNOVA

Source: VINNOVA, VA 2007:01

[147] The Swedish Research Council and The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
[148] The Swedish Governmental Agency for Innovation Systems

II. Other research programmes

Name	Period	Contri-bution MSEK	Funding organisation
BioNanoIT: Research, development and demonstration linking biotechnology, nanotechnology and IT	2002-2007	T.o.m 2006 45,6	VINNOVA
Micro- and nanosystem: Research, development and demonstration	2002-2005[149]	90	VINNOVA
Designed materials incl. nanomaterials	2006-2007	20	VINNOVA
Multidiciplinary BIO: collaboration between Swedish and Japanese researchers	2004-2008	24	VINNOVA and FORMAS[150]
Nano-X: postdoctoral program in applied nanoscience and nanotechnology	2006-2010	80	SSF[151]
22 nanotechnology related projects, like Nanochemistry KTH, CARAMEL CTH etc	1996-2006	>400	SSF
minST, Micro- and nanosystem technology: programme for smaller companies	2004-2006	15	The Knowledge Foundation
7, research and doctoral programmes	2001-	11,6	The Knowledge Foundation
Grätzel solar cells	2006-2008	17	The Swedish Energy Agency
The ÅSC programme: Ångström solar energy centre	1998-2005	150	The Swedish Energy Agency and MISTRA[152]
Fundamental research in nanoscience	ongoing	10/år	The Swedish Research Council
Postdoctoral research in micro- and nanoscience	2004-	50	The Knut and Alice Wallenberg Foundation
Research and infrastructure in nanotecnology	2004-2005	195	The Knut and Alice Wallenberg Foundation
Nanoscience centre in Lund	2003	10	The Knut and Alice Wallenberg Foundation
Neuronanoscience centre in Lund	2005-2010	40	The Knut and Alice Wallenberg Foundation
Defence research programme in nanotechnology	2003-2008	100	FOI[153]

Source: VINNOVA, VA 2007:1

[149] A new program is under development and in 2004, VINNOVA was provided 100 MSEK dedicated for applied industry research in nano- and microelectronics in the IT/Telecom area.
[150] The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
[151] The Swedish Foundation for Strategic Research
[152] The Foundation for Strategic Environmental Research
[153] Swedish Defence Research Agency

2. ICT-industry distributed by market segment and dominating companies

Market segment	***Description***	***Exemplification of companies in the specific market segment***
Manufacture of electronics and components	Market dominated by companies serving the consumer electronics market	Siemens, Hitachi, Matsushita, Sony, Philips, Samsung, Intel and Canon
Manufacture of IT equipment (including computers)	Market dominated by computer manufacturers and manufactures of affiliated hardware	Dell, HP, Toshiba, Dell, NEC, Fujitsu, Apple and Sun Microsystems.
Producers of IT services (Consultants)	Market dominated by consultants providing IT-sollutions and management of IT-systems	EDS, Tech Data, Accenture, CSC, First data ADP, Capgemini, IAC/Interactive and SAIC
Software developers	Market dominated by software developers providing operating systems (OS), business systems, digital entertainment and special purpose software applications.	Microsoft, Oracle, SAP, Softbank, CA, Electronic Arts, Symantec/Veritas and Adobe.
Teleoperators	Market dominated by old national telcom monopolies and new mobile communication operators	NTT, Verizon, Deutsche Telekom, France Telecom, Vodafone and Telefonica.
Manufacture of communication equipment and communication systems	Market dominated by manufactures of network infrastructure for datacom and telecom.	Nokia, Motorola, Cisco, Ericsson, Alcatel/ Lucent, L-3 and Qualcomm

Source: OECD,"ICT Outlook", 2006. Modified by VINNOVA, 2007

3. Fields of activity, automotive component companies

Bodywork & Chassis

Companies produce bodywork, doors, windows, tanks, wheels, wheel suspension, brakes, hydraulics etc. this group includes activities, often technologically intensive, working with bodywork, doors, windows, tanks, wheels, wheel suspension, brakes, hydraulics etc. Some companies specialise in steel and aluminium products, whilst others specialise in plastic. The field also spans from forging and casting of metal, welding and pressing of sheet to injection moulding and pressing of plastic. As a rule, the chassis consists of metal with wheel suspension and brakes, whilst the bodywork may contain plastic-based materials.

Propulsion
Companies produce engines, engine management, transmission, exhaust systems, cooling systems, catalysers, hybrid technologies etc. This group also includes activities working with engines and components included in the driveline, engine management, transmission, exhaust systems, cooling systems, catalysers, hybrid technologies etc.

Fittings
Companies manufacture seats, upholstery, panels, foam and materials, safety belts, air bags etc. This group includes activities working with seats, upholstery, panels, safety belts, air bags etc. as well as foam and materials for fittings.

Electronics/IT
Companies manufacture electrical systems, communications, lamps, batteries, climate control, telematics etc. This group includes activities which develop and manufacture electrical systems, communications systems, lamps, batteries, climate control, telematics etc.

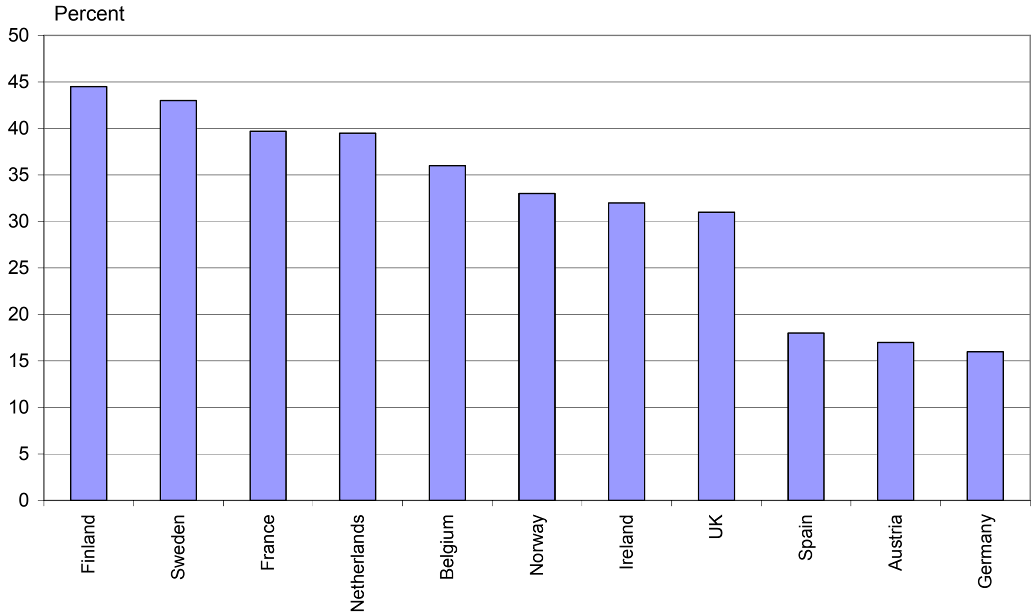
Parts & Materials
Companies work with raw materials and processed components of steel, aluminium, composites etc (not textiles). Companies manufacture parts which may be included in many different parts of the car, such as in propulsion, bodywork, fittings. Companies also often manufacture components for other industries, e.g. the telecom industry. Many are typical subcontract companies.

Engineering Consultants
Companies provide services in automotive and product development methodology etc. This group includes companies working as consultants and service operations in automotive and product development methodology. Some of the companies are specialist consultants, whilst other consulting companies operate in several fields. The major part of the activity is directed towards car companies in Sweden.

4. Figures

Chapter 1.1

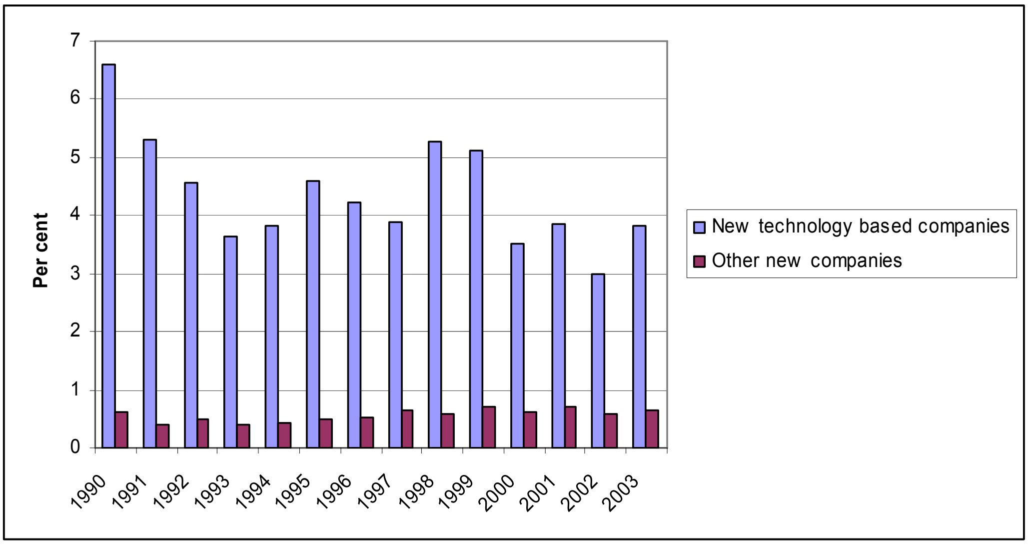
Figure 1 Proportion of innovative companies that collaborated in innovative activities, 2002-2004



Source: Eurostat, http://ec.europa.eu/eurostat/

Chapter 1.2

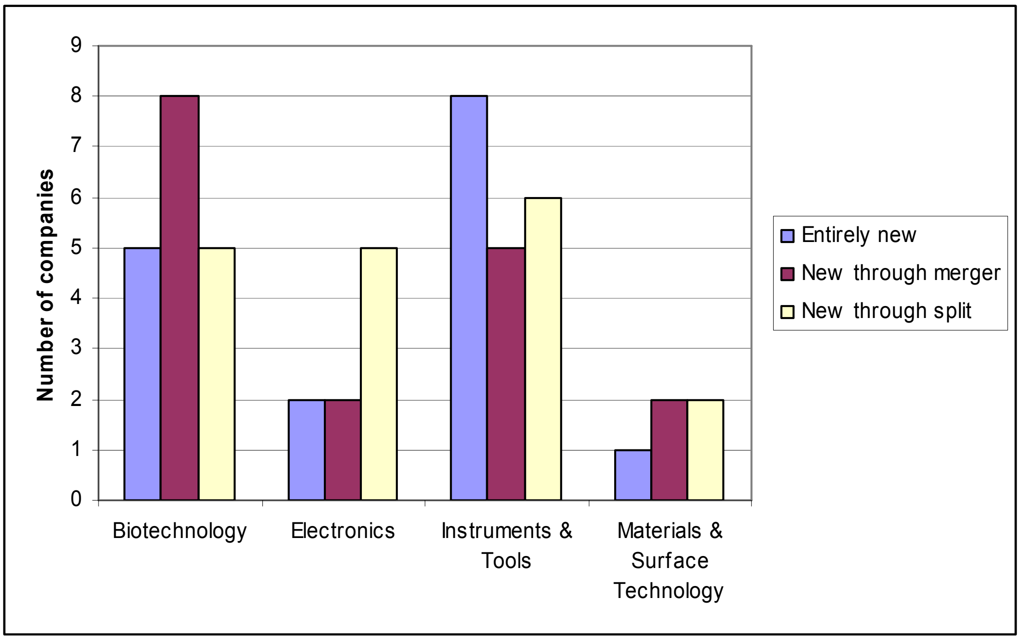
Figure 2 New firms, NTBFs and others, with personnel roots in universities as a proportion of all new companies in each category, 1990-2003



Source: VINNOVA

Chapter 5.2

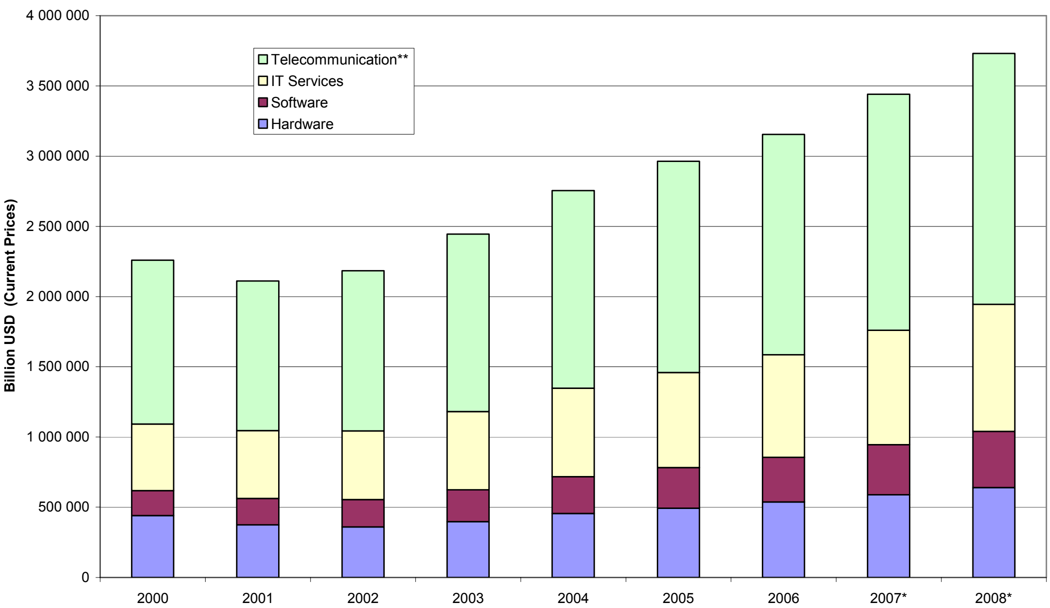
Figure 3 Number of nanocompanies established between 1990-2004 distributed by fields of application and manners of origin.



Source: VINNOVA/SCB

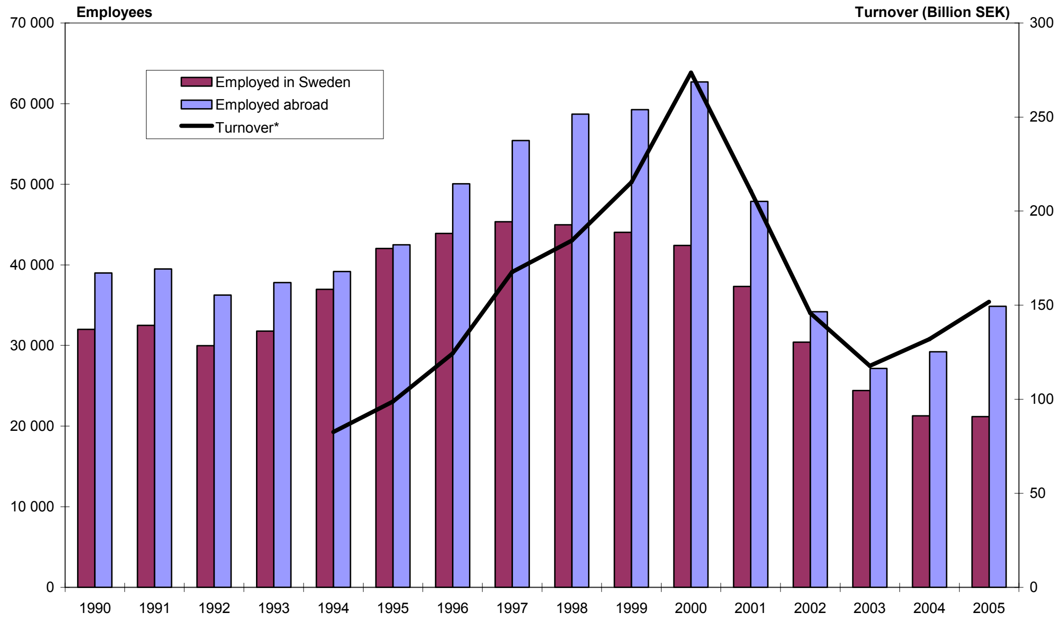
Chapter 5.3

Figure 4 Sales of ICT products (billion USD, current prices) distributed by product groups.



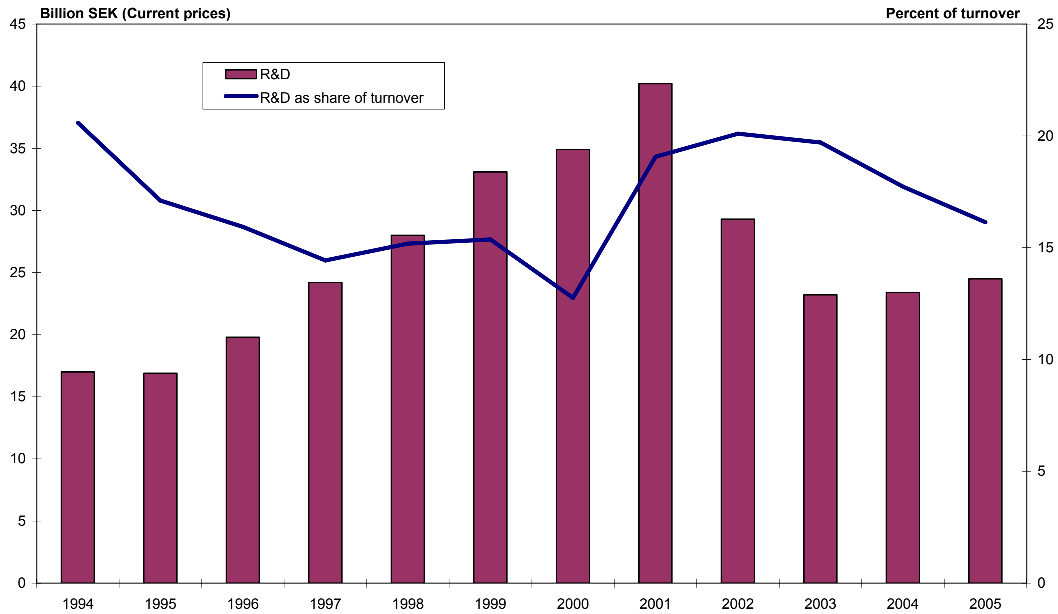
OECD, "ICT Outlook", 2006. Modified by VINNOVA 2007. * = Estimation ** = Including both operators and equipment

Figure 5 Ericssons number of employees in Sweden and abroad and turn over, 1990-2005



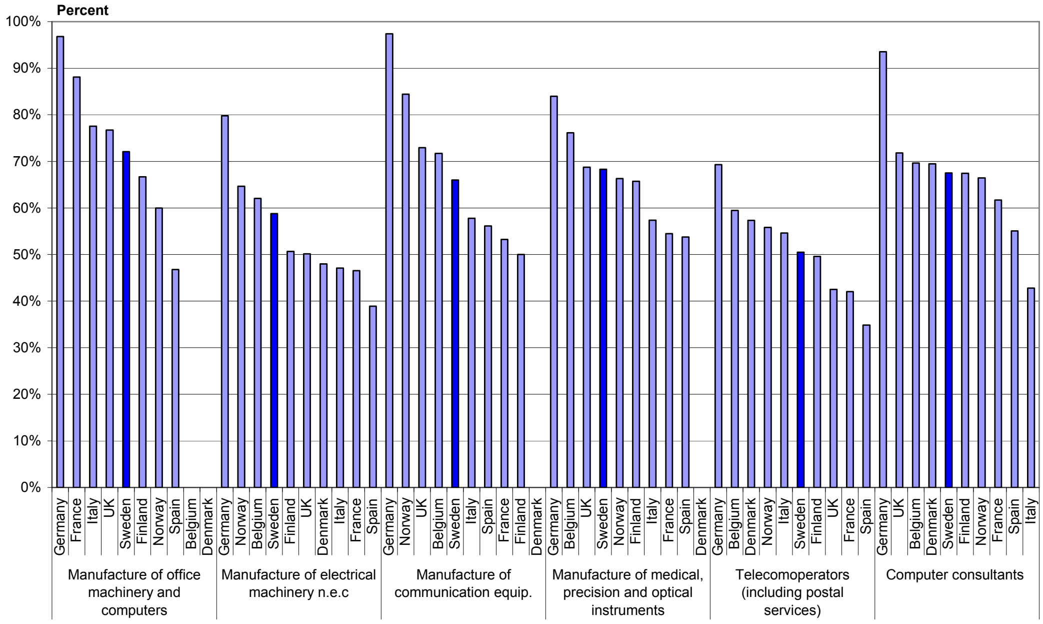
Ericsson, 2006. Modified by VINNOVA 2007. * = SonyEricsson excluded

Figure 6 Ericssons R&D investments (current prices) and its share of turn over, 1990-2005



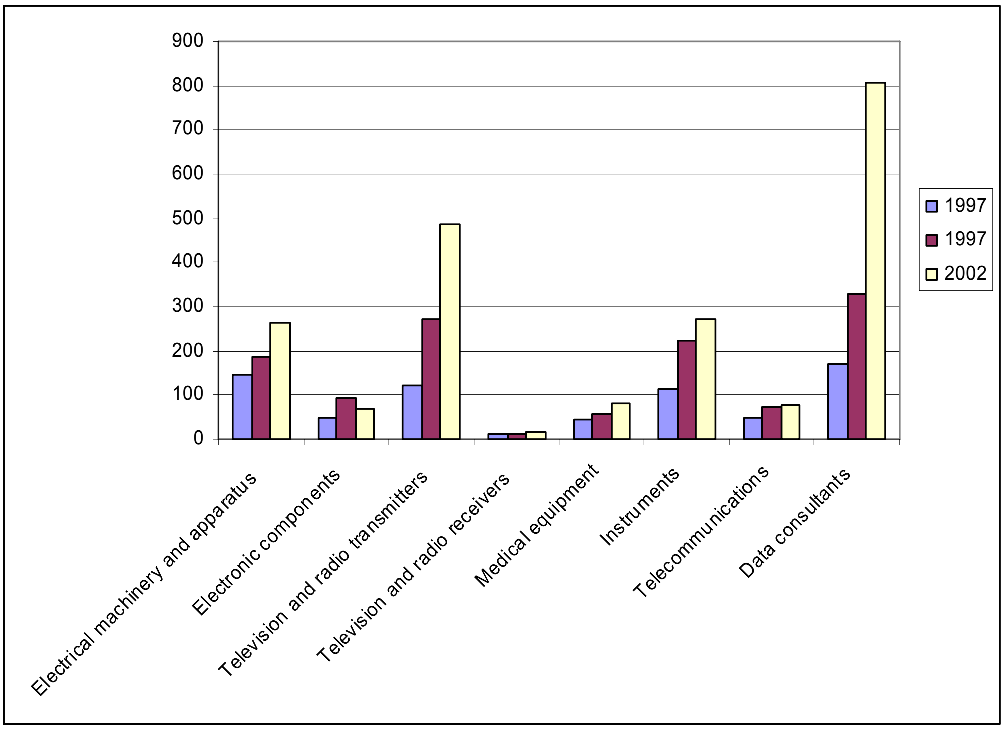
Ericsson, 2006. Modified by VINNOVA 2007. * = SonyEricsson excluded

Figure 7 Proportion of innovative ICT companies distributed by product groups 2002-2004



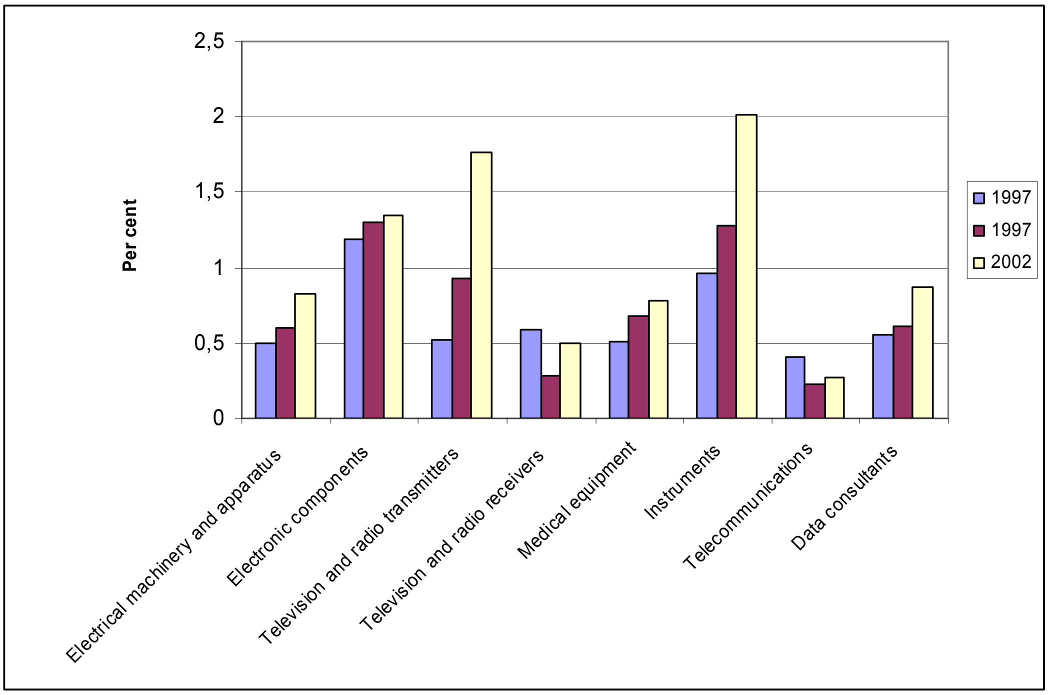
Eurostat, NewCronos, 2006. Bearbetad av VINNOVA, 2007

Figure 8 Number of science and engineering PhD graduates in the ICT industry, 1993, 1997 and 2002.



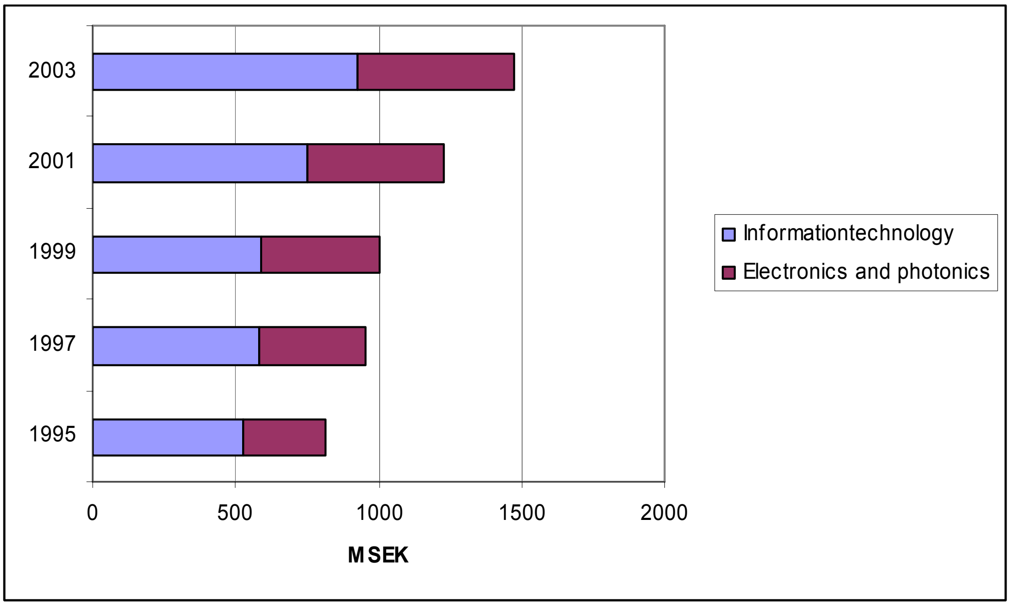
Source: SCB

Figure 9 Share of science and engineering PhD graduates in the ICT industry, 1993, 1997 and 2002.



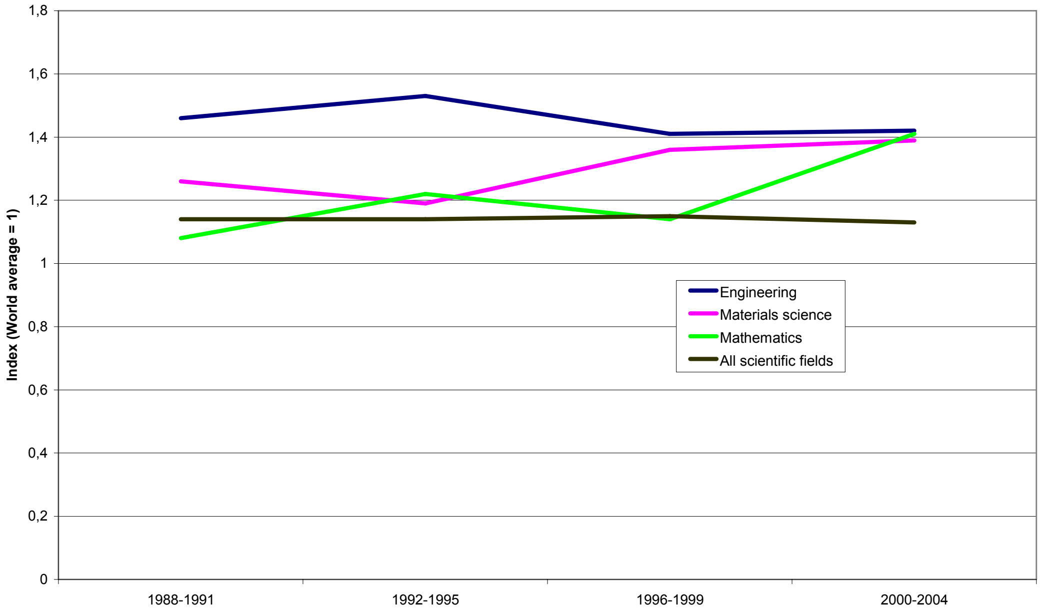
Source: SCB

Figure 10 Informationtechnology and electronic & photonic research at Swedish universities, 1995-2003 (MSEK current prices)



Source: SCB, modified by VINNOVA

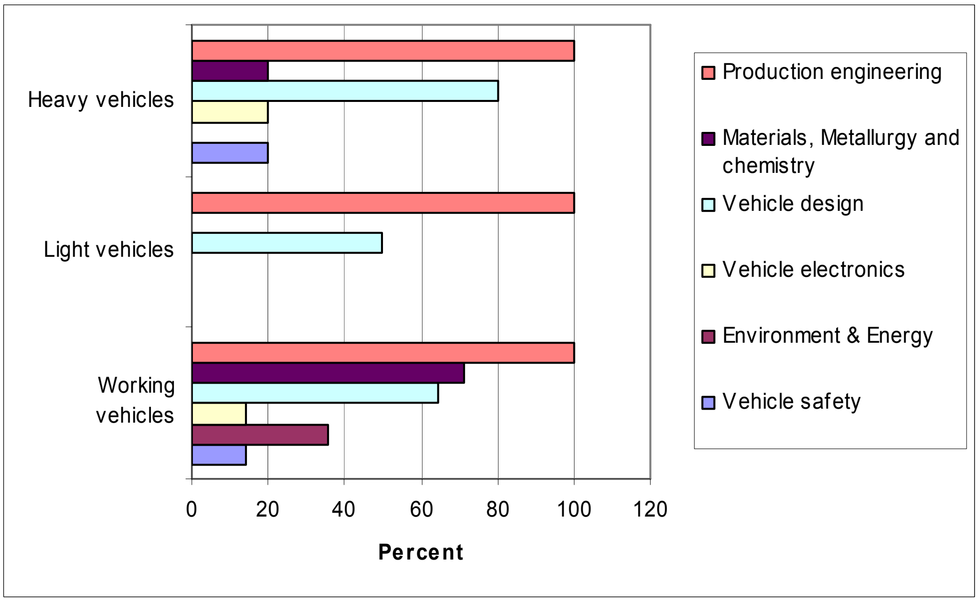
Figure 11 Scientific quality of Swedish research in four scientific fields, 1998-2004.



SCB, 2006. Modified by VINNOVA, 2007

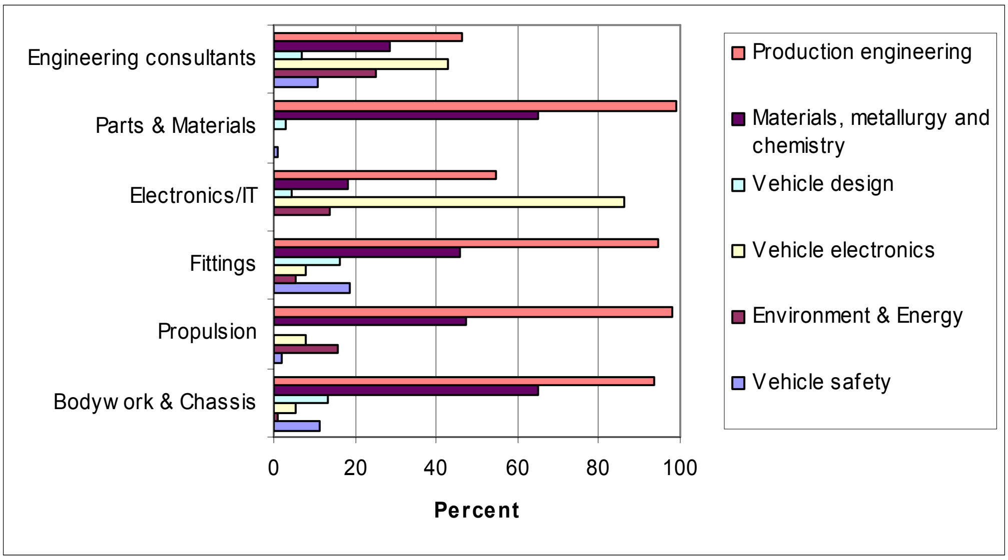
Chapter 5.4

Figure 12 Proportion of vehicle manufacturers, other than the big four, distributed by strategic areas of expertise



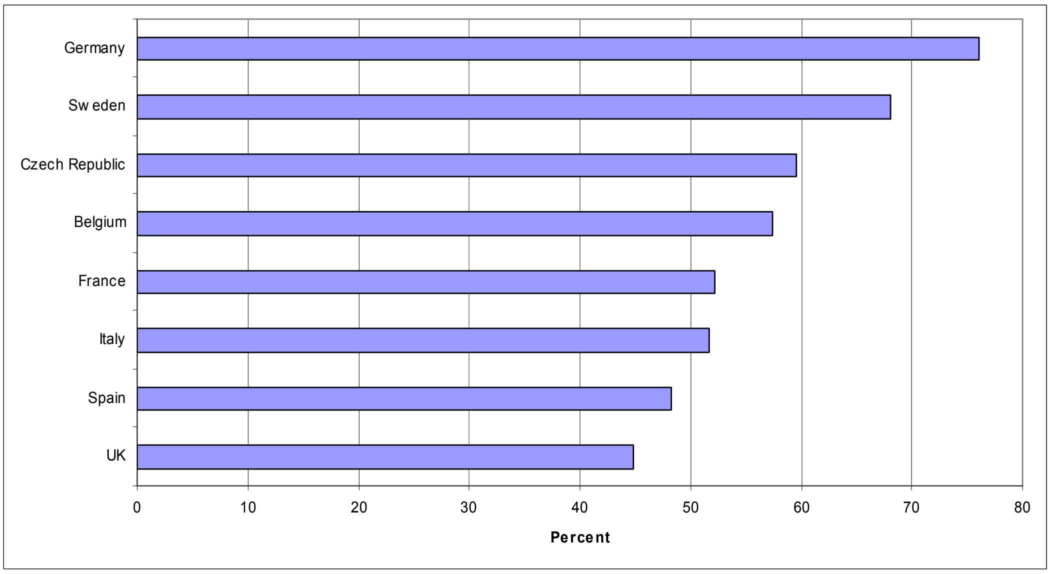
Source: VINNOVA

Figure 13 Proportion of component companies distributed by strategic areas of expertise and fields of activity



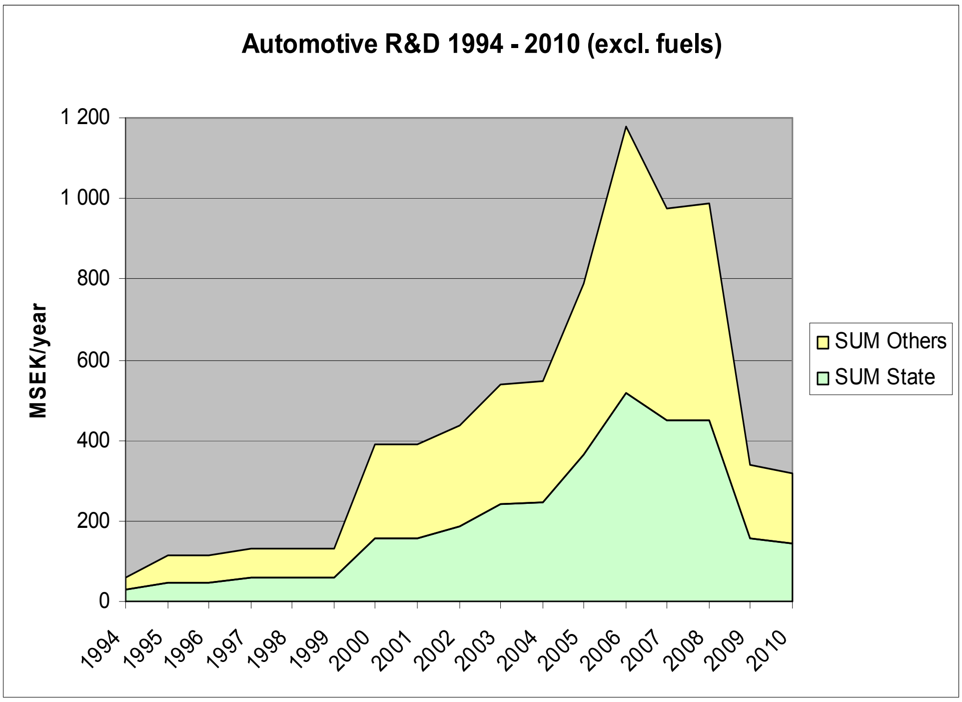
Source: VINNOVA

Figure 14 Proportion of automotive companies with innovative activity in 2002-2004



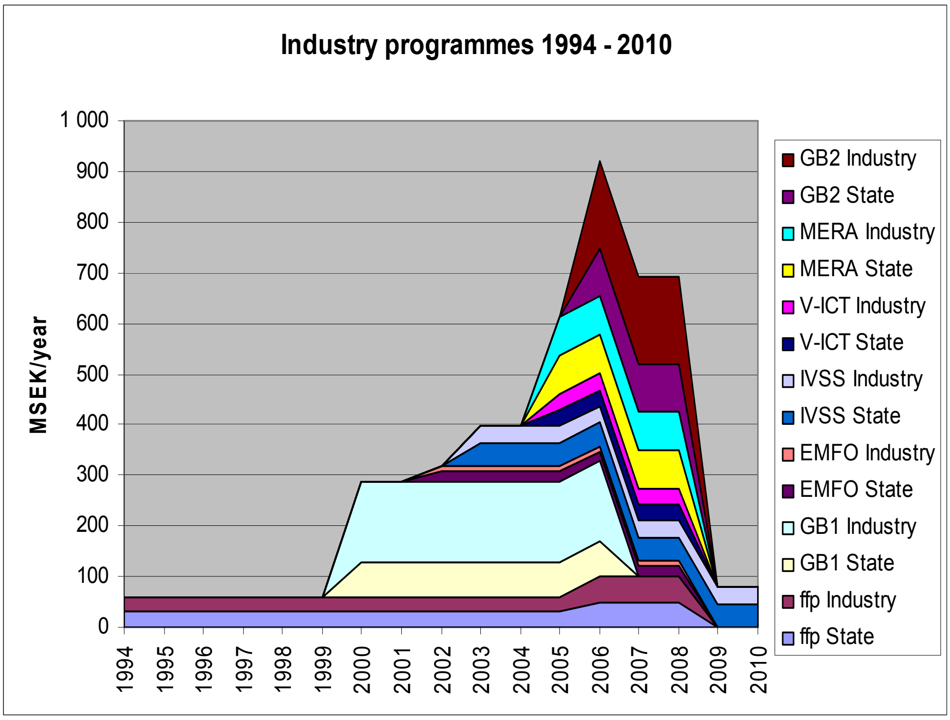
Source: Eurostat, http://ec.europa.eu/eurostat/

Figure 15 Volume of R&D programmes (excl. fuels) in million SEK (current prices) 1994-2010, distributed by state and other funding



Source: VINNOVA

Figure 16 Industry R&D programmes in million SEK (current prices) 1994-2010, distributed by state and industry funding



Source: VINNOVA

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VINNOVA´s mission is to promote sustainable growth
by funding needs-driven research
and developing effective innovation systems

VERKET FÖR INNOVATIONSSYSTEM – SWEDISH GOVERNMENTAL AGENCY FOR INNOVATION SYSTEMS

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