Chapter 3

Innovation actors in Sweden

This chapter describes the main actors in the Swedish innovation system, their contribution to the system's dynamism and the main challenges they face. Businesses and universities are the main innovation actors. Sweden is home to highly innovative, export-oriented, internationalised firms operating at the technological frontier across a wide range of industries. Large firms dominate R&D expenditure in manufacturing industries, while smaller firms make a much larger contribution in the services sector. International comparisons suggest that the Swedish business sector has for the most part done well in the face of important global challenges. Sweden also possesses well-endowed and globally visible universities with a diverse range of strengths. However, universities currently face some long-term challenges. Compared to other world-leading countries there are signs of shortcomings in the impact of scientific research as evidenced in citations and commercial outcomes. In this context, the features of the funding system and of university governance are examined. Finally, human resources for science, technology and innovation are examined, highlighting the measureable decline in education quality.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

3.1. The business sector

3.1.1. Overall industry profile

Sweden has a high-performing business sector and is known for its innovative, export-oriented, internationalised firms. They operate in a wide range of industries: automobiles and components, telecommunications equipment, pulp and paper, chemicals and pharmaceuticals, packaging, and machinery end electrical goods. It also has a large services sector which contributes a comparatively large share of GDP. Each of the top ten firms – Volvo AB (engineering, trucks), Ericsson (telecommunications), SCA (pulp and paper), Electrolux (engineering, household appliances), Volvo Cars, Vattenfall and TeliaSonera (infrastructure), Skanska (construction), H&M (retail clothing) and ICA AB (retail) – had more than SEK 100 billion in turnover in 2010. A further group of large firms – Atlas Copco, Sandvik, Scania, SKF and companies in a range of service industries – has more than SEK 50 billion in annual turnover (GTAI, 2012). Large multinational enterprises (MNEs) such as ABB, TetraPak or AstraZeneca have important production and research facilities in Sweden. They have Swedish roots but, mainly owing to changes in ownership, their headquarters are located abroad.

The competitiveness of Sweden's industry is largely based on its strong R&D and broad innovation effort. The business sector as a whole spends approximately SEK 80 billion a year on R&D, of which around one-quarter is accounted for by the services sector.[1] R&D expenditures represent 2.9% of net sales in manufacturing and 0.6% in services (SCB, 2011b, pp. 14 *ff.*). As noted in Chapter 2, business expenditure on R&D (BERD) amounts to nearly 2.5% of GDP. BERD has traditionally been high, but has decreased from a peak of more than 3% around 2001. According to the Innovation Union Scoreboard (IUS), Sweden is the leading European country in the category "firm investments", which covers both R&D and non-R&D innovation expenditure (IUS, 2011). It has good to moderate, albeit recently declining, performance for in-house innovation by small and medium-sized enterprises (SMEs) and the introduction of new products and processes by SMEs. The same holds true for the collaboration intensity of innovative SMEs. Sweden leads among European countries in PCT patent applications per billion GDP.

In a sample of advanced countries, Sweden stands among the leaders. However, there are some indications of decline (Table 3.1). In 2006 Sweden had the second highest BERD in this sample (and the highest in Europe), but in 2010 it ranked fourth (and second in Europe). In addition, Austria, Denmark, Germany and Switzerland have narrowed the gap owing to higher growth of BERD.

Table 3.1. Business enterprise expenditure on R&D (BERD) as a percentage of GDP

	2000	2005	2006	2007	2008	2009	2010
Austria	..	1.72	1.72	1.77	1.85	1.85	1.88
Canada	1.15	1.14	1.14	1.09	0.98	0.99	0.91
China	0.54	0.91	0.99	1.01	1.08	1.25	..
Denmark	..	1.68	1.66	1.80	1.99	2.08	2.08
Finland	2.37	2.46	2.48	2.51	2.75	2.80	2.69
France	1.34	1.31	1.33	1.31	1.33	1.39	1.38
Germany	1.74	1.74	1.78	1.77	1.86	1.91	1.90
Israel	3.28	3.43	3.51	3.90	3.80	3.55	3.51
Italy	0.52	0.55	0.55	0.61	0.65	0.67	0.67
Japan	2.16	2.54	2.63	2.68	2.70	2.54	..
Korea	1.70	2.15	2.32	2.45	2.53	2.64	2.80
Netherlands	1.07	1.01	1.01	0.96	0.89	0.86	0.87
Norway	..	0.81	0.79	0.84	0.84	0.92	0.87
Sweden	..	2.59	2.75	2.47	2.74	2.54	2.35
Switzerland	1.87	..	..	..	2.20	..	..
United Kingdom	1.18	1.06	1.08	1.11	1.10	1.12	1.08
United States	2.02	1.80	1.86	1.93	2.04	2.04	..
Total OECD	**1.53**	**1.51**	**1.55**	**1.58**	**1.63**	**1.62**	**..**
EU27	1.11	1.09	1.11	1.12	1.15	1.17	1.16

Source: OECD Main Science and Technology Indicators, February 2012.

In nearly all industrialised countries, large enterprises account for most of R&D expenditure. This is true of Sweden, with its relatively large number of MNEs. The last few years reveal some interesting dynamics (Table 3.2). While aggregate expenditure remained more or less stable, R&D expenditures of foreign-owned enterprises, which account for a large fraction of Swedish BERD, have declined. (Their high share is largely the result of mergers or acquisitions of previously Swedish-owned firms, notably in research-intensive industries such as pharmaceuticals and the automotive industry.) At the other end of the spectrum, R&D expenditures of very small firms have declined significantly.

Table 3.2. R&D expenditure (BERD) by size class and ownership, 2009
SEK millions

	2005	2007	2009	Relative change 2005-09
10-49	7 014	5 594	5 080	0.72
50-249	9 848	10 090	9 495	0.96
250-	62 189	65 540	64 056	1.03
Manufacturing	57 224	56 903	59 557	1.05
Services	21 827	24 320	19 073	0.87
R&D in Sweden in Swedish-owned enterprises	41 556	47 548	50 092	1.21
R&D in Sweden in foreign-owned enterprises	37 495	33 675	28 538	0.76

Source: Growth Analysis (2011), p. 70.

The strong presence of large firms may give the impression that the R&D-performing SME population only makes a small contribution, but this is not the case. With BERD spending by SMEs at 0.48% of GDP, Sweden ranks sixth in Europe. Switzerland leads with 0.64%, followed by Denmark (0.56%) and Finland (0.52%). However, Sweden is nearly on a par with Austria and Belgium (both at 0.49%) and the EU average is only 0.25% (European Commission, 2011, p. 314). R&D expenditures differ across size classes and sectors. Large firms dominate in manufacturing industries, while smaller firms make a much larger contribution to overall expenditure in the services sector (Table 3.3).

Table 3.3. BERD by sectors and size classes, 2009

SEK millions

	10-49	50-249	250+	Total
All goods and services	**5 080**	**9 495**	**64 065**	**78 630**
Goods	3 154	6 027	56 948	66 130
Services	1 925	3 468	7 108	12 501
Metal, data- and electronic goods, optics, machinery	1 022	2 293	32 023	35 337
Cars and vehicles	495	420	11 855	12 770
Pharmaceutical	565	973	6 703	8 241
Chemistry	339	434	461	1 234
Other goods	358	582	2 827	3 767
Transport services	21	6	2 695	2 722
R&D providers	471	781	679	1 931
Other services	181	404	902	1 486

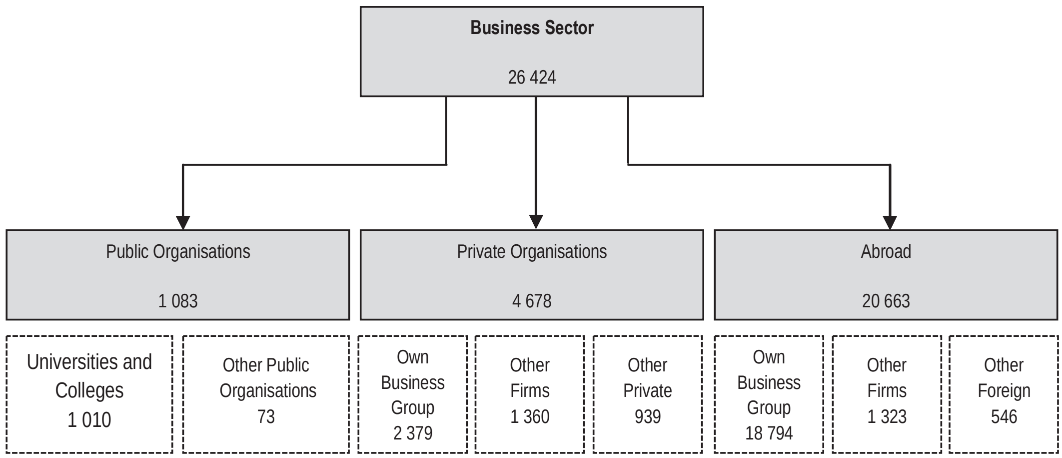
Source: SCB (2011a), p. 35.

As discussed in Chapter 1, a number of Swedish firms became important players on international markets during the 20th century. In recent years, the previously dominant model of domestic ownership, domestic production and domestic R&D is being replaced by firms that are often part of international conglomerates with global value chains and research and innovation networks. As a result of mergers and acquisitions some headquarters have moved abroad, and production and research facilities are increasingly distributed globally, although large Swedish firms have retained important R&D facilities in Sweden.

Figure 3.1 provides an overview of the flow of R&D funding emanating from Sweden's business sector in 2009. It does not cover "intramural" business expenditures on R&D (spent on R&D within the enterprise), the most important form of R&D funding, but traces flows to different types of "external" organisations. Overall, SEK 26.5 billion is spent outside the funding organisation. SEK 20.7 billion (78%) goes to foreign units, of which SEK 18.8 billion to entities belonging to the same business group. Therefore, the most important "external" recipients by far are foreign affiliates of Swedish MNEs. Private organisations receive around SEK 4.7 billion, of which roughly half stays within the business group. Only SEK 1 billion (4.1%) is directed towards public organisations (almost all of which funds research by universities and colleges).

Figure 3.1. External R&D funding by the business sector

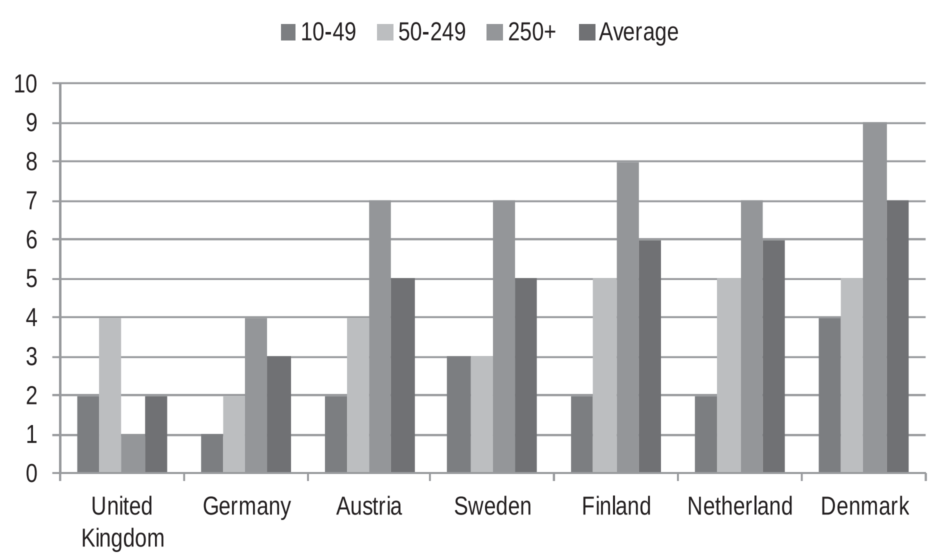
SEK billions



Source: SCB (2011a), p. 28 (own translation). Updated 24 November 2011.

Because of past successful innovation, Sweden has a large surplus in the technology balance of payments, with receipts (2010) on a par with those of Switzerland (OECD Main Science and Technology Indicators 2012/1). A number of other indicators also place Sweden among the top European countries, as would be expected for an innovation leader. However, firms in a number of comparator countries – Switzerland, Denmark, the Netherlands and Finland – seem more successful in bringing innovations to the market and generating revenues, while Austria is on a par with Sweden (Figure 3.2).

Figure 3.2. The share of revenue from products and services that are new to the market in total revenue, 2008



Source: Growth Analysis (2011), p. 75, based on Eurostat.

Overall, innovation expenditures of Swedish firms are among the highest in the world and have a leading place among comparator countries across Europe. This reflects the overall good position, the strong role and the high R&D expenditures of large firms.

3.1.2. Major industrial sectors

Sweden has a diversified industrial landscape, including when compared to other Nordic countries. Often seen as specialised in high technology, it also has a strong base in a number of medium-technology sectors which rank among the top performers worldwide in their respective fields. The most important of these sectors are described below.

Cars and car components are an important part of Swedish industry. The region of Västra Götaland specialises in this sector. Volvo AB (trucks, components, aero, engineering) is the largest Swedish firm, with Volvo cars, Scania, the now ailing carmaker SAAB, and second-tier firms such as Autoliv or Haldex as other major actors. The car industry has the second highest R&D expenditures in Swedish industry: approximately SEK 16 billion in 2009 and nearly 8% of turnover. Nearly 10 000 full-time equivalent (FTE) R&D personnel constitute 12.5% of the total (SCB, 2011b). The Volvo group alone claims to have 13 000 R&D staff worldwide, of whom 60% are in Sweden.

Aerospace is another research-intensive, but smaller, industrial sector, with actors such as SAAB or Volvo Aero. For a small country aerospace has a strong industrial presence, built on a strong past and some current military effort, notably by the SAAB group. The legacy also includes strong public-private partnerships. The industry has diversified into propulsion, components for civil aviation and space equipment. In 2007 around USD 290 million were spent for R&D.

Machinery and electro/electronics, including *optical industries* and *telecommunication equipment suppliers* constitute Sweden's main research-intensive industry sector. It has a range of actors and a variety of competencies. Global players such as Ericsson, Alfa Laval, Sandvik, SKF or the Swedish ABB form traditionally strong industrial cores. The machinery industry had about SEK 200 billion in turnover in 2010, and Ericsson alone accounted for another SEK 200 billion. It is Sweden's biggest export company, with 8.8% of total exports in 2010, down from a peak of 19.7% in 2001 (Erixon, 2011, p. 72). Ericsson can also be viewed as a key transmitter of foreign knowledge to the Swedish innovation system. Over more than two decades, it successfully transformed itself from a hardware producer to a broad ICT production *and* service company, with the help of government technology policy (see Arnold *et al.*, 2008; Erixon, 2011, pp. 71 *ff.*). All sub-sectors taken together spent around SEK 27 billion on R&D in 2009, and its 17 000 R&D personnel accounted for 9.4% of the sector's total workforce. Much of the S&T output, including patents, can be attributed to this large sector. Science, technology and innovation policy provides support through science-industry co-operation initiatives. The VINNOVA Vinn programme operates five competence centres in ICT and another five in materials (VINNOVA, 2009a).

The *pulp and paper industry* had a turnover of approximately SEK 200 billion in 2009. The industry employs around 1 800 R&D personnel (5.7% of all employees). R&D expenditures amounted to more than SEK 3 billion in 2009 (SCB, 2011b). In an international comparison, the Swedish (like the Finnish) pulp and paper industry is characterised by a high degree of concentration and modern mills, with important actors such as SCA and the Swedish-Finnish Stora Enso. The industry invested early in process and environmental technologies, owing in part to government environmental regulations in Sweden and abroad, notably in Germany, its main export market, and also to societal pressure and considerations of industrial risk. R&D investments have been higher than in other main producer countries over a longer period of time (Foster *et al*., 2006, pp. 122–40).

Chemistry, including *pharmaceuticals*, is also a large industry sector. It has an annual turnover of SEK 180 billion and around 35 000 employees (2008) (GTAI, 2012). In the pharmaceutical industry alone, R&D personnel account for nearly 35% of all personnel (4 700). The chemicals industry has 1 700 R&D personnel (9.4%) (SCB, 2011b). In 2009, the pharmaceutical industry spent more than SEK 6 billion on R&D (9% of sector turnover but a considerable decline from 2007; SCB, 2011b). Apart from some basic and specialised branches, such as chemicals for the pulp and paper industries, the pharmaceutical industry is still the most important segment in this sector. It can rely on a strong scientific base in Sweden. The industry was affected by the withdrawal of Pharmacia's (now Pfizer's) capacities from Sweden, and lately also from reorganisations and relocations at AstraZeneca, the most important of the firms. Pharmacia and Astra have become parts of larger MNEs since the 1990s. However, the history of Pharmacia shows that much of the sector's know-how and research capacity has survived and even grown through buy-outs and other processes. The recently announced closure of AstraZeneca's large Södertälje laboratories has drawn much attention. Many firms are located in the Stockholm and Skane regions, and science and technology policies strongly support the pharmaceutical industry through various instruments.

Medical technologies benefit from the highly developed Swedish health system and from a number of new establishments such as the Nya Karolinska university hospital in Stockholm. The industry has an annual turnover of about SEK 23 billion and is dominated by a few large firms such as Getinge, Gambro (formerly part of ABB) and Mölnycke, which are clustered in the Stockholm, Gothenburg and Malmö areas. On the broader life science industry in Sweden, see Box 3.1.

Box 3.1. The life science industry in Sweden: Strengths and challenges

The life science industry in Sweden is composed of three segments, biotechnology, pharmaceuticals and medical technology. All have both small and large actors. A recent publication (Sandström *et al*., 2011, p. 5) provides the following overview: Former big players have reduced their presence in Sweden over the last decade, notably U.S.-based Pfizer which, after the takeover of Pharmacia, had been very strong in Sweden. AstraZeneca, with headquarters in London, is also closing facilities in Sweden. A large part of the smaller firms belongs to the biotech segment, including a number of university spin-offs. Traditionally this sector, notably the pharmaceutical producers, makes a positive contribution to Sweden's trade balance. Taken together the sector had over 700 companies and around 32 000 employees in 2009. This is a considerable industrial strength, however Denmark, a much smaller country, has an even larger industrial sector in the Life Sciences. [1]

In more detail the sector is structured as follows, excluding sales and marketing companies. In 2009, AstraZeneca still accounted for a quarter of all employees, followed by only three firms with more than 1 000 employees each. The number of micro-sized companies (1-10 employees) grew more than threefold from 130 in 1997 to 430 in 2009. The number of small (11-50) and medium-sized firms (51-250) also grew during this period. Overall employment increased by 38% in the period between 1997 and 2009 but decreased by some 7% between 2006 and 2009. The main cutbacks were in the largest firms, with an overall reduction of more than 4 400 employees between 2005 and 2009. A new difficult period started with the recent closures of large AstraZeneca research facilities in Lund, and the 2012 announcement of the dismantling of the Södertälje labs will lead to a loss of another 1 200 jobs, mainly in R&D. This is seen as a serious setback to Sweden as a research location, as "a vital share of overall industrial research is now disappearing"[2] and weakening its competitive advantage in international trade. The Swedish government works together with academia and industry to retain competencies and plans to establish co-operative research structures. Restructuring in the pharmaceutical industry is not necessarily bad: the Pharmacia story shows that Pfizer is now small in Sweden but a similar number of about 5 000 employees work in a dozen spin-off or sold-off companies (Sandström *et al*., 2011, p. 32).

…/…

Box 3.1. The life science industry in Sweden: strengths and challenges *(continued)*

In 2009, more than 10 000 employees worked in drug discovery and development, still the largest part of the Swedish life science industries, although it has become much smaller since 2006. AstraZeneca and the remaining Pfizer companies concentrate on drug discovery and development and less on drug production. A number of smaller segments (each with 1 000-2 000 employees) cover drug production, medical biotechnology, biotechnology tools and various sub-segments of medical technologies (Sandström *et al*., 2011, p. 14), followed by a large number of small, specialised industrial segments. Regional concentration is highest in the Stockholm/Uppsala region with more than 50% of all employees, followed by the Skane region with nearly 20%. The three sub-sectors are of nearly equal size (see Sandström et al., 2011, pp. 17 *ff.*) and all have a considerable to dominant share of foreign ownership:

- Pharmaceutical companies have nearly 15 000 employees and are dominated by drug discovery and development (and still by AstraZeneca). There are limited pharmaceutical production facilities, which are in some cases former Pharmacia or Astra facilities taken over by other producers.
- Biotechnology companies have over 16 000 employees in a larger number of firms. Although drug development also dominates, the portfolio of activities is broader. Some companies are quite large and include spin-offs from former Pharmacia.
- Medical technology companies employ some 15 000 people in a broad range of activities performed by companies of all size classes. This industry has a strong "Mittelstand".

Overall the Swedish life sciences industry has considerable strengths, including many university spin-offs, a balanced industrial portfolio, high value added and a strong research base. Collaborative funding and good framework conditions for clinical trials are further strengths, as are research-friendly regulatory frameworks. On the downside, core industrial actors are reducing their research capacities and other strengths seem to be eroding as the following example of clinical research shows. This development is of special importance as flexible and generous framework conditions for clinical research are seen as important for the life sciences industry in Sweden.

Sweden is renowned for its clinical research in academic institutions such as the Karolinska Institutet but also in hospitals close to academic research with a long tradition in clinical studies, supported by career tracks, research-friendly regulation and available funds. Sweden, along with Switzerland, is a world leader in medical publications, with nearly 700 publications a year million inhabitants, followed by Denmark, Finland, Israel and the Netherlands (Academy of Finland and Vetenskapsrådet, 2009, p. 21; Karlsson and Persson, 2012). This represents 1.5% of world biomedical research publications and a good but stagnant, and in some respects deteriorating, position as a research location (Karlsson and Persson, 2012). For academic actors, outputs and impacts see the section on universities.

Over time clinical research careers have become less attractive for young MDs, while other career paths have become more so. Numbers of publications have not increased over the last years and technology transfer is not fully developed. A recent evaluation (Academy of Finland and Vetenskapsrådet, 2009, p. 9) covering Sweden and Finland proposed reforms in education and career paths to allow for double track careers. Research-active MDs are too old when they finally become independent (or even enter a real position); there is not enough time for research when compared to standard medical care; and this career path does not offer high-paying jobs, so many talented young people go elsewhere. Numbers of combined MD-PhDs have declined. More research money should allow for longer studies and be more strongly based on merit. Other recommendations include a boost in internationalisation and attention to regulatory matters; overall the evaluation sees an "alarming" signal. The bibliometric analysis reveals that Sweden's previous pre-eminence and research output are declining. More importantly, the evaluation panel found a widespread perception that the previously favourable circumstances for clinical research are rapidly eroding (Academy of Finland and Vetenskapsrådet, 2009, p. 9).

1. Sandström *et al*. (2011), p. 41, count more than 37 000 employees, of whom more than 25% in drug discovery and development.

2. VINNOVA press release, 16 February 2012: *www.vinnova.se/en/misc/menues-functions/News/2012/120216-VINNOVA-Director-General-proposes-Life-Science-partnership/*

Source: Sandström *et al*. (2011); Academy of Finland and Vetenskapsrådet (2009).

The *services industries* spend around SEK 20 billion on R&D, a quarter in ICT services, but more than 40% in special "R&D institutions". Although services account for only a quarter of overall R&D expenditure, over 70% of R&D performed by very small firms (10-49 employees) is in the services sector and over 60% in firms with 50-249 employees (SCB, 2011a, p. 17). Sweden's highly developed logistics sector ranked third worldwide after Germany and Singapore in the World Bank Logistics Performance Index 2010 but dropped to thirteenth place in 2012) (World Bank, 2010). Sweden's strong sea and land transport infrastructure supports the innovative, export-oriented producing sectors. Moreover, the increasingly blurred borderline between manufacturing and services is exemplified in the trend towards "servitisation" of manufacturing, which is already quite advanced in Swedish industry (Box 1.2).

So far Swedish companies have succeeded in specialising at the high end of global value chains (GVCs). They have also been able to deal with the shifting and increasingly blurred borderline between manufacturing and services. The share of manufacturing in employment and – to a lesser extent – in value added, has declined and the relative weight of services is increasing (*e.g.* Ericsson). Yet, in contrast to other OECD economies that have undergone marked deindustrialisation, manufacturing is still a very important part of the Swedish economy. At the same time market services – in many cases related to manufacturing activity – make up an increasing and dynamic part of the economy. More broadly, innovation in services, which is often not based on R&D, has become an increasingly important factor in driving overall productivity growth. Maintaining an edge in technology, and more broadly in innovation, is critical for companies in high-income countries if they are to achieve productivity growth and maintain their international competitiveness in the longer term.

Box 3.2. The servitisation of Swedish manufacturing

Swedish manufacturing is becoming "servitised", as manufacturing now both buys more services and produces more services in-house and also sells and exports more services. Manufacturing firms' purchases of services (Kommerskollegium, 2010) more than doubled between 1975 and 2005 as a share of production value. However, costs are increasingly dominated by services produced in-house, especially by qualified services production. [An increasing number of employees in manufacturing are in service-related occupations. In 2006, almost half of manufacturing employees worked in service-related occupations if employees in subsidiaries are included.

Industrial companies also develop more and increasingly complex industrial service offerings. Swedish manufacturing firms sell and export more services than they did a decade ago. The share of services sales in total turnover has risen by 25% if subsidiaries are included. This indicates that the industry's sales have broadened (diversified). Furthermore, sales of services – as a share of total turnover – are almost 60% higher than indicated in official statistics when all manufacturing subsidiaries are included.

Swedish-based manufacturing firms state that an important reason for their move towards servitisation is to avoid exposure to price competition from low-cost countries. Another reason is the fact that new services can open new revenue streams that will help to mitigate effects of shifting demand in production and products owing to business cycle fluctuations (VINNOVA, 2009b).

Source: Kommerskollegium (2010); VINNOVA, (2009b).

Sweden boasts many clusters, but only a few are large. In an international comparison, only the information technologies cluster in Stockholm and the automotive cluster in Västra Götaland can be seen as fully "three star clusters" (Ketels, 2009, pp. 36 *ff.*).[2] Sweden's relative specialisation in thematic clusters is lower than in comparable European countries. Most are in more traditional fields of economic activity, and only a few new (and high-technology) clusters are developing (Ketels, 2009, p. 33).

Overall and across sectors, the Swedish economy appears to benefit from a high degree of innovativeness, based on considerable investments in R&D. Nevertheless there are recurrent concerns about the efficiency of R&D investment, the impact of globalisation, and issues relative to SMEs and entrepreneurship. There are three main issues. The first is the relation between input-output, commonly known as the "Swedish R&D paradox" (Box 3.3). Second, there are concerns about Sweden as a future research location, as businesses that were once firmly rooted in Sweden are now increasingly globalised MNEs. The third concerns the number of innovative SMEs, their growth (potential), levels of entrepreneurship and the potential for new growth sectors to emerge.

Box 3.3. The "Swedish (R&D) paradox"

Discussion of the Swedish R&D "paradox" can be traced back to the early 1990s and placed against the backdrop of the search for an explanation of Sweden's unsatisfactory economic performance at the time. While the paradox is expressed in various ways, it postulates that Sweden's high level of R&D input (*i.e.* R&D expenditures, researchers and other innovation expenditures) does not translate into a proportionately high level of output (*i.e.* patents, licensing income or economic growth). Over the past two decades, the literature on the Swedish national innovation system has debated the precise form, magnitude and possible explanations for the purported paradox (Edquist and McKelvey, 1998; Bitard *et al*., 2008; Ejermo *et al*., 2011; Ejermo and Kander, 2011).

Evidence of the existence or persistence of the paradox is mixed. To some extent, the long-term evidence challenges certain aspects of the "paradox": In an analysis based on long technological waves and patenting trends, Ejermo and Kander (2011) observe that many mature industrialised countries are in a comparable situation as regards productivity of R&D inputs in high-technology sectors. In any case, the trend in Sweden from 1985 to 2002 appears to be positive. Nevertheless, there are reasons for concern. First, the performance of services over time is uneven. Second, research productivity has grown especially in low- and medium-technology manufacturing, such as transport and chemicals. Ejermo *et a*l. (2011) find that the paradox holds for fast-growing sectors, an apparent indication of diminishing returns rather than a substantive system failure.

Even in areas in which the "paradox" may persist, the policy implications (if any) are not clear. It is difficult to evaluate the extent to which it is due to substantive efficiency problems (*e.g.* related to framework conditions or to the governance of innovations) or merely a reflection of industrial/sectoral specialisation patterns and the associated R&D productivity (conditioned among others by the novelty of the knowledge domain), or even the international outlook of Swedish business and the resulting propensity to register output outside of Sweden.

3.1.3. Challenges and opportunities of globalisation for large firms

Sweden embraced internationalisation early, and over the course of time has derived significant benefits from this move. Today Sweden is a very open economy. This means that it is better prepared than many other countries to operate in changing international environments and seize emerging opportunities (Rae and Sollie, 2007). However, it also means that the profound ongoing changes in the global economy and the rise of emerging economies, most prominently in Asia, will have a major impact on Swedish businesses and the Swedish economy at large. Competitive pressures are increasing in many areas as emerging economies strengthen and upgrade their capabilities. China, in particular, is investing heavily in its skills and knowledge base in R&D and ICT. Companies from emerging economies have already become, or are on the way to becoming, competitors of global leaders, e.g. in communications technology. In areas such as telecommunications equipment, Chinese firms now compete in global markets. Competition for hosting research centres, and not just production sites, has increased. Accordingly, the risk of production and research activities moving offshore has increased. It may become harder to retain and to attract economic activities to Sweden.

Globalisation has profoundly transformed large Swedish enterprises. Foreign ownership has increased, particularly since the 1990s. Swedish-based MNEs – irrespective of their ownership structure and including firms like AstraZeneca – now have many more employees abroad than in Sweden. In 1987 these firms had 750 000 employees in Sweden and another 500 000 worldwide. In 1998 they had 650 000 employees both in Sweden and abroad, but by 2009 they had slightly over 400 000 employees in Sweden and more than 1.1 million worldwide (Andersson *et al*., 2012, pp. 12 *ff*.)

In a series of mergers and acquisitions the two passenger car firms and the two big pharmaceutical companies became parts of larger multinational enterprises (on the pharmaceutical industry see Box 3.1.). In the car industry persistent attempts by local management and public authorities to rescue companies with brands in high-quality niches failed to offset fully certain disadvantages, notably their small scale, in a competitive global market. In one case this led to a new takeover, in the second operations temporarily ceased. In the area of energy technology and mechanical engineering, one of the largest Swedish actors became a bigger actor through a European merger of equals. Sweden's largest telecommunications equipment provider successfully embraced digitisation but underwent a severe restructuring in the first half of the 2000s, having transformed itself from a global hardware provider into a global service company. Finally large infrastructure providers became international players.

Irrespective of ownership, however, large enterprises – both domestic and foreign-owned – are guided by their global corporate strategies. Activities and related resources are reallocated within global corporate structures. New, more open, models of innovation and the emergence of new global centres of R&D are driving an ongoing process of reallocation, including of corporate R&D resources. R&D staff is still strong in Sweden in the largest companies: The top ten industrial actors still account for more than 30 000 R&D staff (ranging from over 9 000 to 1 000 employees). However there is a downward trend, with some firms considerably downsizing (Andersson et al., 2012, pp. 38 f.).

As indicated, much inward foreign direct investment (FDI) in R&D in Sweden has taken place through mergers and acquisitions. By contrast, very prominent examples of R&D-related (re)locations of foreign research or R&D-intensive production units to Sweden seem to be scarce. Large-scale inward (re)locations have been recorded by other high-income countries such as Switzerland and the United States owing to the quality of their research infrastructure or more liberal regulatory frameworks. Prominent examples are the establishment by European, including Swiss, "Big Pharma" of research facilities in the Boston area in the United States or, in the other direction, the establishment of IBM's research laboratory in Rüschlikon near Zurich, a city that has also attracted Google and Disney Research.

3.1.4. How innovative are Swedish SMEs?

The size distribution of firms is a function of a country's industrial specialisation, integration into international markets and macroeconomic conditions (*e.g.* availability of finance for investment), microeconomic environment (shaped by long-term industrial and competition policy) and institutional framework conditions (especially enforcement of contracts and the impact on transaction costs). Whereas large firms command scale advantages that are central to economic efficiency (and ultimately to global competitiveness), smaller firms can be the source of much innovative dynamism. Smaller firms often generate novelty in sectoral and technological niches that may be otherwise neglected. SMEs may act as a vehicle for the commercialisation of radical, or at least unconventional, innovations, such as new business processes. A large and dynamic pool of SMEs may therefore help to shift technological change more rapidly towards emerging sectors. Less directly, a vibrant pool of SMEs can indicate the absence of barriers to entry and more generally of competitive pressure, a key determinant of innovation.

Sweden has the same number of SMEs relative to the total population of firms as the EU27 average (Table 3.4). Within this overall picture there are of course differences. The share of large firms in employment is higher (36.3% compared to the EU average of 32.6%) and their share of value added is also larger. Within the SME sector Sweden has more micro-enterprises than the EU average but fewer small firms (4.8% *vs*. 6.9%) and medium-sized ones (0.8% *vs*. 1.1%). In total Sweden's 550 000 SMEs employ more than 1.7 million people and contributed more than 55% of the economy's value added.[3] While there are differences overall, they are not very large (Table 3.5).

Table 3.4. SMEs in Sweden: Enterprises, employment, value added

	Enterprises			Employment			Value added		
	Sweden		EU27	Sweden		EU27	Sweden		EU27
	Number	Share	Share	Number	Share	Share	EUR billion	Share	Share
Micro	523 126	94.2%	91.8%	685 631	24.7%	29.7%	37	20.2%	21.0%
Small	26 486	4.8%	6.9%	578 795	20.%	20.7%	32	17.2%	18.9%
Medium-sized	4 661	0.8%	1.1%	501 667	18.1%	17.0%	33	18.0%	18.0%
SMEs	554 273	99.8%	99.8%	1 766 093	63.7%	67.4%	101	55.8%	57.9%
Large	968	0.2%	0.2%	1 005 178	36.3%	32.6%	80	44.2%	42.1%
Total	555 241	100.0%	100.0%	2 771 271	100.0%	100.0%	181	100.0%	100.0%

Source: Hytti and Pulkkanen (2010), p. 14, Table 6; European Commission (2009).

The lack of "visibility" of Swedish SMEs, together with more general concerns about a lack of entrepreneurial spirit, is a subject of debate in Swedish innovation policy discussions. As mentioned, this is linked to the dominant role of large firms as regards investments in R&D, absorption of talent and agenda setting (the latter together with the leading universities). These views are seen by some as related problems: a lack of successful small firms may hinder the development of new industrial dynamics, but large firms, which may be weakened by the some effects of globalisation, consume most of the resource (attention, talent, public support). While regional innovation policy actors show an intense interest in existing SMEs, the important "middle layer" of firms that are larger than SMEs but considerably smaller than the globalised industrial giants seems to receive much less attention.

An important question (related to the Swedish "paradox" referred to above) is whether Swedish SMEs are less active in R&D (and in innovation more broadly) than their peers in other advanced countries. Table 3.5 does not show that R&D expenditures by Swedish SMEs are weak: Swedish firms of all size classes are at or near the top in terms of BERD as a percentage of GDP.

Table 3.5. Business expenditures on R&D by firm size classes, 2007

Percentages

	10-49 in relation to GDP	50-249 in relation to GDP	250+ in relation to GDP	250+ as % of all R&D	Share of five largest R&D performers
Germany	0.05	0.13	1.58	89.8	57
United Kingdom	0.04	0.14	0.94	83.9	26
Finland	0.18	0.26	2.01	82.0	88
Sweden	0.17	0.31	2.17	81.9	74
Switzerland (2004)	0.15	0.27	1.70	80.2	80
Netherlands	0.07	0.15	0.75	77.3	76
Austria	0.13	0.32	1.21	72.9	58
Denmark	0.15	0.3	1.21	72.9	--

Source: Growth Analysis (2011, p. 68), based on Entreprenörskapsforum (2010), p. 111.

In 2007, firms with more than 250 employees accounted for over 80% of Swedish BERD (Table 3.5). This is not exceptional. In Finland, Switzerland and the Netherlands the share of BERD accounted for by firms with more than 250 employees is also around 80%, and it is even higher in the United Kingdom and especially in Germany (nearly 90%). In a group of comparator countries, only Austria and Denmark have a lower share (73%). One could argue that a handful of very large firms is a specific feature of Sweden (*e.g.* IVA, 2011). This is in many respects valid, of course. Yet, in Finland, Switzerland and the Netherlands the five largest R&D-performing firms account for a higher share of BERD than in Sweden (Growth Analysis, 2011, p. 68). On this account, and among comparator countries, Sweden has a high concentration of BERD but is not an outlier. This observation is confirmed for more finely grained size bands: firms with 10-49 employees account for 6% of BERD, those with 50-99 employees for 5%, those with 100-249 employees for 7% (together 19%), those with 250-499 employees for 10%, those with 500-999 employees for 6% and those with more than 1 000 employees for 66% (SCB, 2011a, p. 18). This overall distribution is broadly comparable to Austria's where firms with fewer than 50 employees account for 11% of BERD, those with 50-249 employees for 18% and those with more 250 employees for 71% (Federal Ministry of Science and Research, 2012, p. 39).

SMEs accounted for around SEK 15 billion in R&D expenditure in 2009, a figure again comparable to that of Austria.[4] Firms with 50-249 employees had annual R&D budgets of about SEK 10 billion over the last years, growing during 2005-07 and then falling in 2009 to the level of 2005. R&D expenditures among firms with fewer than 50 employees shrank from SEK 7 billion in 2005 to SEK 5 billion in 2009, with a sharp decrease even before the financial crisis of 2008 (Growth Analysis, 2011, p. 70). The reason for this decrease should be further explored. At the same time, SMEs accounted for 13% of FP7 co-operation funding received by Sweden in 2007-12 compared to an EU average of 16%.[5]

Table 3.6 notes the shares of innovative firms per size class and main sector. Sweden possesses large shares of innovation actors among SMEs in both the manufacturing and services sectors.

Table 3.6. Share of innovative firms (%) per branch and size class, 2004-06

No. of employees	All	Industry (10-37)	Manufacturing (15-37)	Services (51-74)	Financial services (65-67)
< 10	44	51	52	39	51
10-49	40	46	46	37	44
50-249	55	64	64	47	55
> 250	72	81	81	61	87

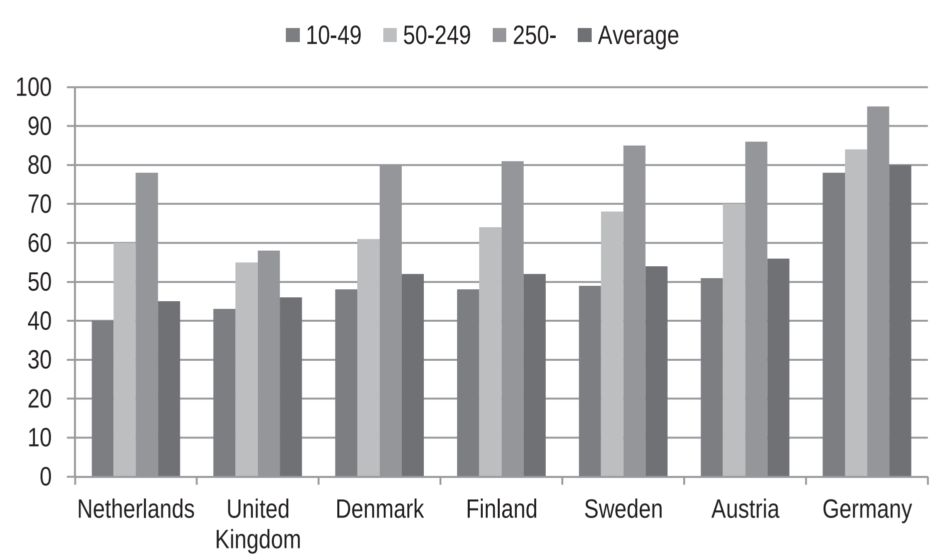
Source: Hytti and Pulkkanen (2010), p. 16, Table 8, data from SBA.

A 2007 national survey cited in Hytti and Pulkkanen (2010, p. 16) reports that 22% of a sample of SMEs were active in R&D, 31% were engaged in innovation activities and 37% performed either R&D or innovation. The majority of firms use their own resources for financing innovative activities and report lack of time and resources as the strongest obstacles. Though many firms claim a strong interest in doing so, few SMEs co-operated with universities or research institutes. Swedish SMEs rarely file for patents.

Further evidence of the innovativeness of Swedish SMEs is provided by an EU-wide comparison across firm size bands (Figure 3.3). Compared to a number of other countries, both the 50-249 and 10-49 segments have considerably high shares of firms with innovation activities. Sweden is ahead of Finland, Denmark, the United Kingdom and the Netherlands and nearly on a par with Austria (Growth Analysis, 2011, pp. 74 *ff.*; see also Figures 3.3-3.5). Smaller firms in Sweden do not appear to be at a disadvantage compared to other countries of similar size and/or R&D intensity.

Figure 3.3. Share of enterprises with innovation activity, 2008

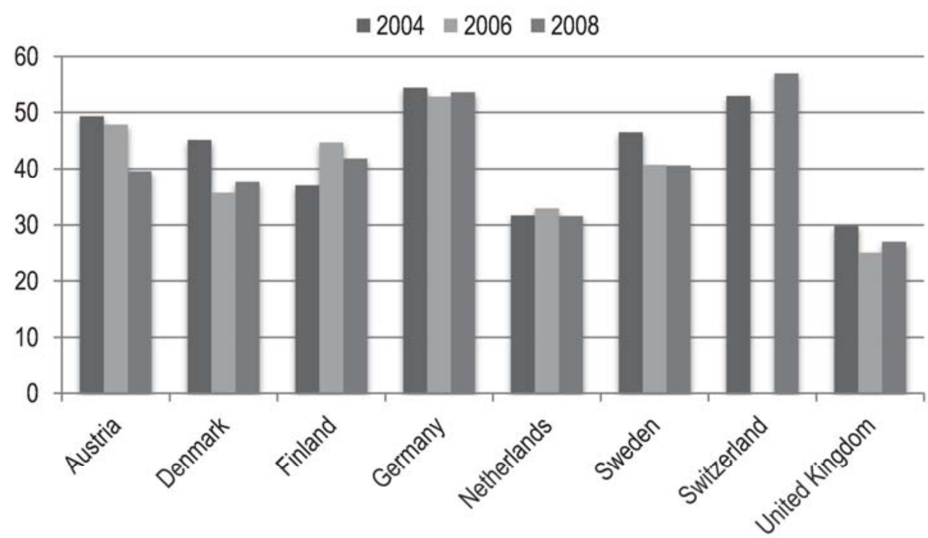
Average and distribution by employment size



Source: Growth Analysis (2011), p. 74, based on Eurostat Community Innovation Survey (CIS) 2006-2008.

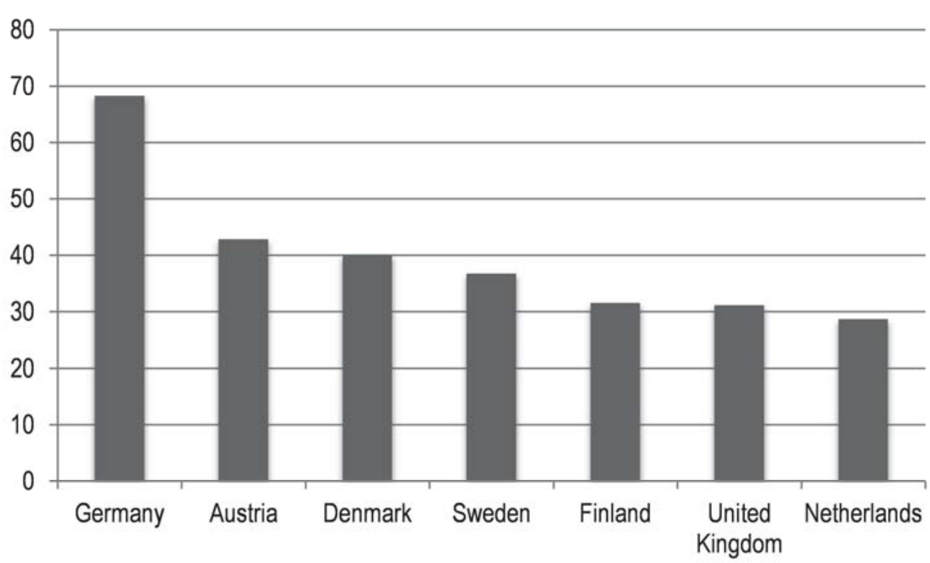
EU Innovation Union Scoreboard data show that Swedish SMEs seem quite competitive as introducers of new products and processes. They do not belong to the top tier in a comparison of leading European comparator countries, but they have a strong middle position (Figure 3.4). A similar pattern can be observed for market or organisational innovations (Figure 3.5).

Figure 3.4. SMEs introducing product or process innovations as a percentage of all SMEs



Source: Growth Analysis (2011), p. 39, based on ProInno Metrics IUS database 2010.

Figure 3.5. SMEs introducing market or organisational innovations as a percentage of all SMEs



Source: Growth Analysis (2011), p. 39, based on ProInno Metrics IUS database 2010.

With respect to other innovation indicators by SMEs, international comparisons are somewhat less favourable to Sweden. In the four SME-related indicators provided in the Innovation Union Scoreboard (IUS), Sweden is nowhere in the lead, ranking fourth in three categories. The category “sales of new to market/new to firm innovations” includes all firm sizes and Sweden ranks very low. However, it ranks first in EU-wide comparison for the share of innovative firms that bring new or significantly improved products to market, as opposed to innovative firms that are “only” design or marketing innovators (European Commission, 2011, p. 321). Sweden’s middling position on a number of indicators of innovation in SMEs contrasts with its leading overall position in the EU, and second only to Switzerland in Europe.

While the imperfect nature of international survey data calls for caution in drawing conclusions,[6] the data in Table 3.7 highlight differences between Sweden and similar countries that are pronounced enough to raise the possibility of systemic issues. This applies less to changes over time (annual average growth, in brackets) as these are influenced by macroeconomic developments and possible sampling differences in the various iterations of the Community Innovation Survey (CIS) and its successor, the IUS. The relative position of Sweden is compared to the EU average in a sample of six comparable countries in terms of size and/or innovation performance. Sweden ranks fourth for in-house innovation, second for the share of innovative SMEs collaborating with others, third for SMEs introducing product and process innovations, and fourth (in a five country comparison) for marketing or organisational innovations. The apparent weakness of Swedish firms with respect to marketing and organisational innovations should be taken seriously as these forms of innovation are important for the services sector.

Table 3.7. Innovation in SMEs: Relative position and change, 2006-10

EU average = 100 (annual average growth in brackets)

	Sweden	Finland	Denmark	Austria	Germany	Switzerland
SME innovating in-house	122 (- 3%)	127 (+ 3.3%)	135 (0%)	113 (- 5.1%)	152 (- 0.1%)	93 (- 4.8%)
Innovative SME collaborating	148 (- 4.7%)	137 (- 3%)	199 (+ 1.7%)	132 (- 5%)	80 (+ 1%)	84 (- 6.1%)
SME introducing product/ process innovations	119 (- 3.3%)	122 (+ 3.1%)	110 (- 4.4%)	116 (- 5.4%)	157 (- 0.3%)	159 (0.7%)
SME introducing marketing/ org. innovations	94 (0%)	81 (0%)	102 (- 10.6%)	109 (- 5.3%)	160 (+ 1.3%)	N/A

Source: Own compilation from European Commission (2012), pp. 53, 54, 68, 74, 75 and 81. For calculating average annual growth, see pp. 85 f.

In conclusion, the distribution of R&D expenditures across firms of various sizes is broadly comparable to other technologically advanced countries. Sweden is not exceptional in terms of the concentration of business R&D among top performers. The propensity of Swedish SMEs in particular to innovate, though not in the lead internationally, appears to be broadly in keeping with SMEs in other technologically advanced countries. A decline in small business (fewer than 50 employees) R&D expenditures and perceptible shortcomings with respect to marketing and organisation innovations are areas that may require targeted policy interventions. Prior to this, however, Swedish innovation policy might put some effort into deeper analysis of SMEs and “Mittelstand” (250+) enterprises and their innovation behaviour.

3.2. Higher education institutes

3.2.1. The university sector: actor setting and international positioning

In Sweden, aside from large private-sector corporations, universities are the main R&D actors. The vast majority of publicly funded research takes place at some 40 universities and university colleges. Several are well placed in international university rankings and dominate university-based R&D. Five universities (Karolinska Institutet, Uppsala University, Lund University, Stockholm University and the University of Gothenburg) receive almost 60% of total public R&D funds.

A variety of higher education institutes: strong traditional and upcoming actors

Some 50 higher education institutes (HEIs) provide a variety of higher education offerings, and about half grant PhDs. In 2011 there were 370 000 first- and second-cycle students (Bachelor's and Master's study programmes) and 18 000 PhD students in higher education and 63 500 degrees were granted. While the vast majority of Swedish universities, university colleges, academies or institutes are public (36 in 2012), there are about ten independent private or semi-private institutes, such as Chalmers University of Technology in Gothenburg (founded in 1829), the Stockholm School of Economics (founded in 1909), or Jönköping University Foundation (founded in 1977). The country that is responsible for establishing and awarding the Nobel Prizes regularly receives high scores on various university-related indicators and in international comparisons and devotes significant amounts of money to higher education. It clearly places high priority on university-based fundamental scientific research.

The Swedish university system dates from 1477 and the foundation of Uppsala University, the oldest university in the Nordic countries. Today it has an enrolment of 26 000[7] first- and second-cycle students, 1 800 PhD students and 4 000 full-time equivalent (FTE) teaching and research staff, of whom 600 full professors. In 2012 the university had nine faculties in three disciplinary areas: arts and social sciences with six faculties, medicine and pharmacy with two faculties, and science and technology with one faculty. It offers 60 Bachelor's and 50 Master's programmes and confers 4 800 degrees a year.

Lund University was founded in 1666. It has eight faculties and many institutes and research centres. It has 32 000 first- and second-cycle students, 2 500 PhD students and 5 000 FTE teaching and research staff, and offers 75 educational programmes at the Bachelor level and about 210 at the Master level. About half of the courses at the Master's level are taught in English. It grants 5 200 degrees a year. Two of the largest research facilities in Sweden, the Max-Lab IV (Ljungberg *et al*., 2009) and the European Spallation Source (ESS), will be built in Lund to support top scientific research in materials and life sciences as well as industrial development. The Faculty of Engineering, Lunds Tekniska Högskola, was founded in 1961 as an independent institute but today belongs to Lund University and is one of Sweden's few complete engineering faculties with about 7 000 students and 1 400 employees.

While the two oldest Swedish higher education institutes are internationally well-regarded comprehensive universities, the Karolinska Institutet, founded in 1810 as an "academy for the training of skilled army surgeons" (Karolinska Institutet, 2012), is Sweden's top medical university. It enjoys a high reputation worldwide and accounts for over 40% of the medical research conducted at Swedish universities. It has 3 600 FTE teaching and research staff and educates 7 300 first- and second-cycle students enrolled in 15 programmes and 2 200 PhD students. It grants 2 500 degrees a year. Research at Karolinska

Institutet spans the entire medical field and is conducted in 22 departments, mostly situated adjacent to Stockholm's teaching hospitals. The Nobel Assembly at Karolinska Institutet is responsible for the selection of Nobel laureates in Physiology or Medicine.

Sweden's two major technical universities with a strong international reputation are the state-owned Royal Institute of Technology (Kungliga Tekniska Högskolan, KTH, founded in 1827) in Stockholm and the independent Chalmers University of Technology (Box 3.4). Chalmers has 17 departments on two campuses in Gothenburg, with a research and teaching staff of 1 800 FTE in 200 research groups, 9 500 first- and second-cycle students, and 1 100 PhD students. Chalmers offers 40 Master's programmes in various science and engineering fields and grants 2 300 degrees a year. It focuses on sustainability, innovation and education in basic and applied sciences. KTH has ten schools and 2 400 FTE teaching and research staff, and a third of Sweden's university-level technical research and engineering capacity. Around 15 000 first- and second-cycle students and about 1 800 PhD students are enrolled in one of nine Bachelor's of Science in Engineering and 16 Master's of Science in Engineering or in a variety of other shorter programmes. KTH grants 2 600 degrees a year ranging from Bachelor to Master to licentiate and doctorate.

Box 3.4. Chalmers University of Technology: An entrepreneurial university in Sweden

Chalmers University of Technology views itself as an *entrepreneurial university*. It is of special interest in the Swedish university system, since it started as a private industrial school in 1829 with a strong scientific orientation. In 1937, Chalmers was absorbed into the Swedish state-owned system but then opted out in 1994 to become a private foundation university but still received public university funding. To help jump-start structural changes, the Swedish government provided Chalmers with a loan that was instrumental in starting various spin-off activities.

Clark (2007) analyses the factors that led to this new autonomy for appointing and rewarding personnel, allocating resources, devising programmes and collaborating with business. Beginning in the late 1970s, the "academic heartland" (p. 88) and the central administration at Chalmers started activities to strengthen entrepreneurship and innovation with a Chair in Innovation Engineering and the Chalmers Innovation Centre around which an infrastructure for transfers from university to industry and *vice versa* evolved in the following decades. The "developmental periphery" (p. 88) ranges from incubators to spin-off companies, from commitment to innovative behaviour to special innovation courses, from industrial contact groups to a major science park adjacent to the campus. Chalmers was well prepared to receive NUTEK funding for 6 out of 30 Swedish competence centres with strong industry involvement at the beginning of the 1990s.

Two features that developed early and show more commitment to Chalmers than to other Swedish universities were its strong alumni relations and fundraising campaigns. The "Chalmers spirit" welcomed the 1991 Swedish government initiative to give state-controlled universities a "foundation" status. While all comprehensive universities opposed this idea, Chalmers succeeded in obtaining this status over the Royal Institute of Technology. Almost two decades later the change is still seen as a success (Jacob *et al*., 2003).

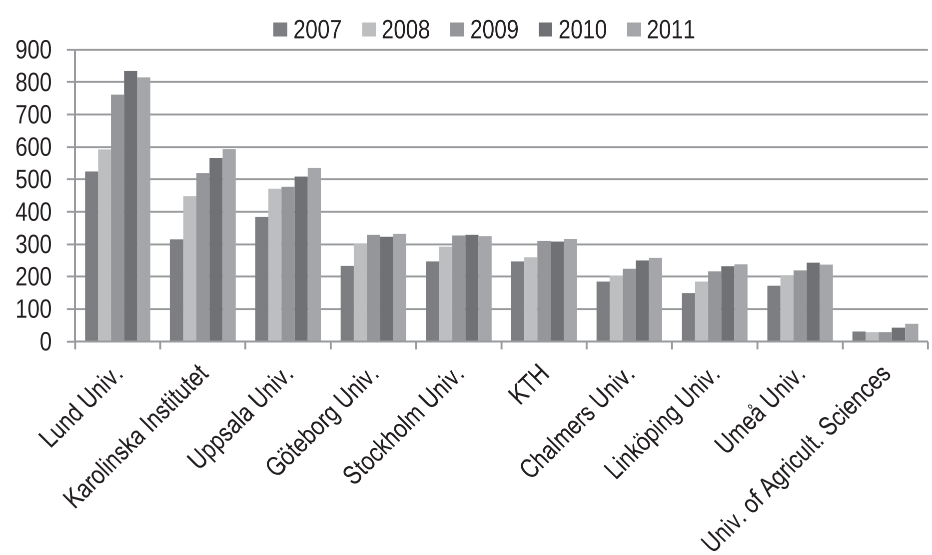
Lindholm Dahlstrand *et al*. (2010) reveal that 42% of the alumni of the Chalmers School of Entrepreneurship (started in 1997) start businesses. Åstebro *et al*. (2012) conclude that "transforming university goals and practices toward increasing start-ups led by faculty might not be the most effective way for universities to stimulate entrepreneurial economic development" but note that "the gross flow of start-ups by recently graduated students with an undergraduate degree in science or engineering is at least an order of magnitude larger than the spin-offs by their faculty, that a recent graduate is twice as likely as her Professor to start a business within three years of graduation, and that the graduates' spin-offs are not of low quality". Since the start of the Chalmers School of Entrepreneurship in 1997 – the first of its kind in Sweden – about 50 new companies have been created in which former students work as CEOs or hold other key positions. Åstebro *et al*. (2012) consider that the Chalmers approach shows that "to create a two-sided market for entrepreneurial talent and inventions and let students and university inventors match up to commercialize university inventions" might be a good alternative to traditional governance, when "the modal number of spin-offs from the top-100 U.S. research universities is zero", especially since "in a jurisdiction with the *Professor's Privilege*, such as in Sweden, the Chalmers arrangement poses no administrative difficulties".

Two other major research universities in Sweden are Stockholm University (founded in 1878) and the University of Gothenburg (founded in 1891). Stockholm University was founded as a university college and became a university in 1960. Today it is the largest Swedish university in terms of number of students, with more than 36 000 first- and second-cycle students and 1 500 PhD students. It has 3 400 FTE teaching and research staff, of whom 500 are full professors, and its four faculties – social sciences, humanities, law and science – are organised into 69 departments and centres. It offers 200 study programmes with roughly half of the Master's programmes offered in English. It awards 4 700 degrees a year. In 1889, Stockholm University appointed Sofia Kovalevskaya, the first woman to a hold full professorship in northern Europe, to a chair in mathematics. She was third female university professor in Europe.

The University of Gothenburg is located in Sweden's second largest city. With approximately 33 000 first- and second-cycle students, 1 600 PhD students, and a teaching and research staff of about 4 200 FTE of whom about 500 full professors, it is one of Sweden's large, wide-ranging universities. It awards 5 100 degrees a year. With 40 departments in nine faculty areas, it covers research and teaching in pharmacy, medicine, odontology and health care sciences; natural sciences; arts and humanities; fine, applied and performing arts; social sciences; business, economics and law; education; information technology; and teacher education.

Figure 3.6. Swedish Research Council support broken down by university

SEK millions



Source: Carlstedt *et al*. (2012), p. 17 and pp. 54 *ff*.

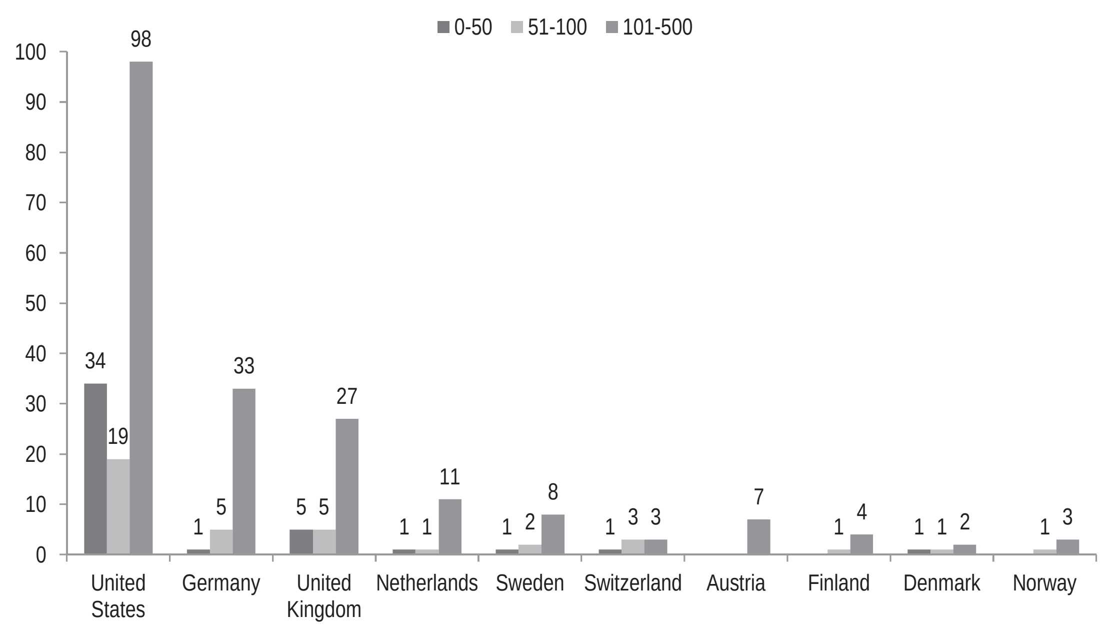
Box 3.5. Swedish university performance in various university rankings

In the *Times Higher Education World University Ranking 2011-2012*, Sweden has five universities among the top 200: Karolinska Institutet rank 32, Lund University rank 80, Uppsala University rank 87, Stockholm University rank 131, and the KTH Royal Institute of Technology rank 187. In comparison, Germany has twelve, Switzerland seven, France five, Denmark three, and Austria one. The ranking is dominated by universities in the United States and the United Kingdom with 75 and 32 universities, respectively, among the top 200. The United States has 30 universities among the top 50. The first non-US, non-UK university is ETH Zurich, rank 15.

In 2012, The *Times Higher Education Supplement* presented its first ranking of the top 100 universities under 50 years old (Times Higher Education, 2012). It includes three "young" Swedish universities: Umeå University rank 23, the Swedish University of Agricultural Sciences rank 27, and Linköping University rank 59. Switzerland has only EPFL (founded in 1968) as runner-up to Pohang University of Science and Technology (founded in 1986) in Korea, which takes first place. Germany has four universities among the top 50 and Austria one. France has four among the top 75 and Denmark two. The United Kingdom has an astonishing 20 universities and the United States nine. Among the top 20 universities under 50, eleven are in Europe, six are in East Asia (three among the top five), and three in the United States.

According to the Shanghai Jiao Tong ranking 2011, Sweden has 11 universities among the top 500, slightly less than 13 for the Netherlands but more than Switzerland with seven. All three countries only have one university each among the top 50 worldwide. In the Netherlands it is a comprehensive university, Utrecht University, rank 48, in Sweden it is a medical university, the Karolinska Institutet, in Switzerland it is a technical university, the Swiss Federal Institute of Technology in Zurich. The absolute numbers for Sweden show a strong university field (Figure 3.7). An interesting comparison is Shanghai performance as a percentage of US GDP per capita. Country performance compared to similar benchmark nations is excellent, with good representation in the top 50 group and very strong performance in the top-100, top-200 and top-500 tiers. However, Switzerland is in a class of its own (Aghion *et al*., 2008, p. 26).

Figure 3.7. Number of top universities in top 500 according to the Shanghai Jiao Tong ranking 2011



Source: *www.shanghairanking.com/ARWU2011.html*. Figure courtesy of Janger *et al*. (2012), p.43, Abb. 15.

The Swedish Research Council (VR, *Vetenskapsrådet*) is Sweden's largest financier of basic research on a competitive peer review basis with an annual budget of around SEK 4 billion (see Chapter 4). If success in receiving such funding is a measure of fundamental research capacity (Figure 3.6), the traditional universities described above dominate. However, Umeå University (founded in 1965), Linköping University (founded in 1969/75) and, to some extent, the Swedish University of Agricultural Sciences (founded in 1977) also have strengths in basic science. While the other public universities are under the Ministry of Education and Research, the University of Agricultural Sciences is the only university under the Ministry of Agriculture, Food and Consumer Affairs. The implicit stratification of the university system in terms of fundamental research capacity is apparent in the pattern of scientific publications. Ten Swedish universities listed among the top European research universities according to an EU survey account for 78% of all Swedish scientific publications, the highest concentration in Europe (European Commission, 2011, p. 165). Another indicator of stratification is provided by the various global rankings of universities (see Box 3.5) which regularly include a handful of Swedish institutes.

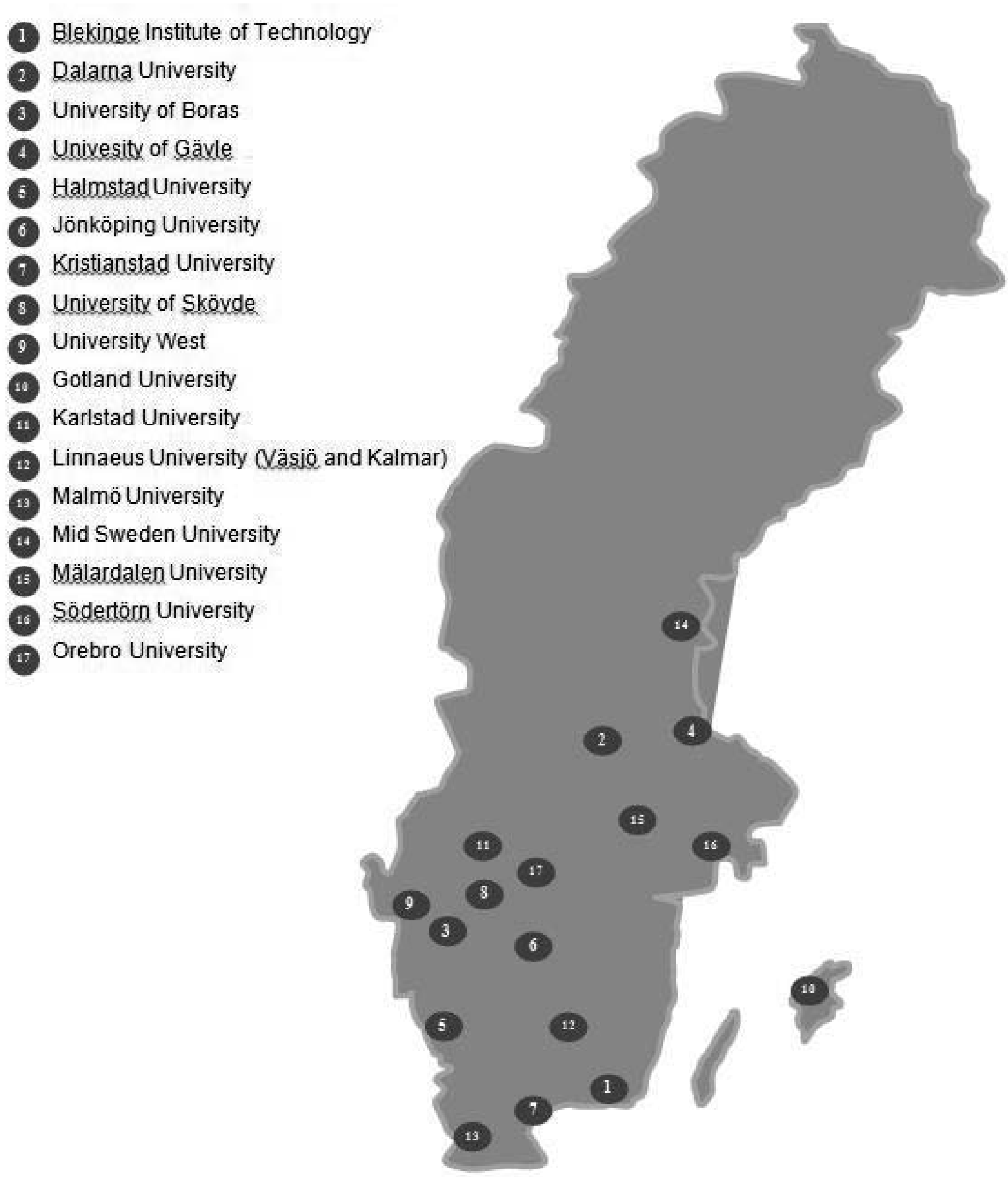
Variety continues: regionalisation of the Swedish higher education system

Sweden was one of the European forerunners in transforming higher education from elite to mass education, having started the process in the 1950s and 1960s. New institutes were founded and the number of students in higher education increased from about 143 000 in 1991 to 257 000 in 2000 (Fägerlind and Strömqvist, 2004, p. 218) and to 385 000 in 2011 (Inkinen, 2011, pp. 49-51). The term "mass education" should in some cases be taken literally, as one professor in many young universities has to deal with an enormous number of students (Ljungberg *et al*., 2009, p. 143).[8]

Since the mid-1970s, the Swedish higher education system has become more regionalised. New universities and university colleges were established, and today, in a country with a large area and a small population, most of the larger and medium-sized cities are home to a university and every county has at least a university college. The Swedish regionalisation process resulted in 17 "new" universities spread around the country (Figure 3.8). While initially their main focus was teaching, they were assigned a research role in the 1980s and in the last decades an increasing number have become universities. The Knowledge Foundation (KK-stiftelsen, KKS) finances research in regional universities to build up research capacity, with mutual benefits for academia and business, and to stimulate business growth through joint scientific-industrial R&D (see Chapter 4). With the support of the KKS, new universities can also gain the right to grant PhD degrees in fields in which they have demonstrated the ability to perform quality research. Nevertheless, many regional universities focus more on teaching and regional development than on scientific research. In recent years some regional universities in the south, west and east of Sweden have merged or are about to merge or to collaborate more closely with traditional universities. This is because some lack critical mass or may face problems as future student cohorts decline.

According to Kaiserfeld (2005), the regionalisation of knowledge raised regional production in Sweden but it has yet to be shown that it also raised regional productivity through knowledge transfer and exploitation. While from an education perspective regionalisation allowed Sweden to accommodate increasing student enrolments, the impact of the newer regional higher education institutions is less clear from an R&D perspective. As a result, the function of regional universities and university colleges as drivers of regional innovation systems is still somewhat unclear.

Figure 3.8. The 17 Swedish universities resulting from the regionalisation process



Source: Heldmark (2010), p. 8.

3.2.2. Inputs to the university system

Financing of universities

Research at Swedish universities is mainly financed by the state through non-competitive block grants. In 2011 the Ministry for Education and Research (MER) allocated SEK 14 billion in block grant funding for university research. The Research and Innovation Bill 2009-12 initiated a certain degree of performance-based funding to this allocation, although it applies to a small fraction of the total block grant funding for research (Box 3.6). Additional public funding for universities comes through the three research councils VR, Formas and FAS (described in Chapter 4) which distributed about

SEK 5.9 billion on a competitive basis in 2011, mostly to universities (Growth Analysis, 2011). In addition, universities receive funding from other agencies or foundations, such as SSF, VINNOVA and KKS. The universities have also been the main beneficiaries of direct grants made available for 24 strategic areas in which Swedish scientific research is of high quality and of high relevance for society and business.

Box 3.6. The introduction of performance based funding at Swedish universities and colleges

Until 2009, state research resources directly paid to universities and colleges as block grants were distributed according to historically established criteria among the 38 institutes. In 2008, the Brändström study proposed a new form of financing involving performance-based criteria (Jongbloed, 2009, p. 45). This was taken up in the 2009-12 Research and Innovation Bill (Swedish Government, 2008, p. 23 and pp. 51-67 for more details). Under the new arrangements, the Swedish government announced it would withdraw 10% of all university block grants for R&D and would distribute them together with an additional 10% based on quality indicators with a view to increasing the relevance and competitiveness of university research. The indicators include the fraction of third-party funding of R&D (weight factor of 50%), the number of publications (weight factor of 25%) and the number of citations (weight index 25%). Assessments are made on a yearly basis at the level of the university or university college. This new model for the assignment of research funds is supposed to create incentives for universities and colleges to favour the research areas in which excellent research is already being performed and in which they are able to compete internationally and create a clear and competitive research profile (Swedish Government, 2008, p. 23).

The United Kingdom introduced in 1986 the first such system, which was much more comprehensive, called the *Research Assessment Exercise* (RAE, to be replaced by REF, *Research Excellence Framework*, in 2014). Currently, countries such as Australia, New Zealand, Hong Kong (China) and Norway also assign research funds on the basis of universities' international performance (Flodström, 2010, p. 49ff).

The Swedish model is still under evaluation and remains somewhat controversial within the scientific community (Flodström, 2010, p. 26). The Swedish science funding agencies, as well as SULF, the Swedish Association of University Teachers, are also not (fully) satisfied with the implementation of this new system and the suggestions made in the report (Flodström, 2010).[1] It is therefore likely to undergo changes in the coming years. For instance, the issue of whether suggested peer-reviewed evaluation of selected research areas (Swedish Government 2008, p. 51 *ff*.) should be adopted still has to be discussed.

1. VINNOVA (2012); SULF (2012).

After a decade of stagnation and as a direct response to the financial crisis of 2008, the Swedish university budget has been increased considerably. Around one-third of the increase is allocated as a block grant without any conditions, another third for a number of areas of special interest to society and industry and a third for research infrastructure and industry-related research. Two recent major government investments in research infrastructure are the European Spallation Source (ESS) in Lund and the Science for Life Laboratory (SciLifeLab) in the Stockholm and Uppsala region.

In international comparison, Swedish higher education expenditure on R&D (HERD), at 0.9% of GDP, is around twice the OECD and the EU27 average. Only Denmark has similar levels of expenditure (Table 3.8). Comparator countries such as Austria, Finland, the Netherlands, and Switzerland average about 0.75% of GDP, while bigger nations such as Germany and the United Kingdom are well below that level at about 0.5% of GDP.

Table 3.8. Higher education expenditure on R&D (HERD) as a percentage of GDP

	2000	2005	2006	2007	2008	2009	2010
Austria	..	0.61	0.59	0.60	0.67	0.71	0.72
Canada	0.54	0.69	0.66	0.67	0.68	0.72	0.69
China	0.08	0.13	0.13	0.12	0.12	0.14	..
Denmark	0.45	0.60	0.64	0.68	0.77	0.90	0.90
Finland	0.60	0.66	0.65	0.65	0.64	0.74	0.79
France	0.40	0.40	0.40	0.41	0.43	0.47	0.48
Germany	0.40	0.41	0.41	0.41	0.45	0.50	0.51
Israel	0.65	0.64	0.65	0.61	0.64	0.59	0.58
Italy	0.32	0.33	0.34	0.35	0.37	0.38	0.36
Japan	0.44	0.45	0.43	0.43	0.40	0.45	..
Korea	0.26	0.28	0.30	0.34	0.37	0.39	0.40
Netherlands	0.62	0.66	0.64	0.63	0.67	0.73	0.75
Norway	..	0.46	0.45	0.51	0.51	0.57	0.55
Sweden	**..**	**0.78**	**0.76**	**0.75**	**0.79**	**0.91**	**0.90**
Switzerland	0.58	..	0.66	..	0.72	..	..
United Kingdom	0.37	0.44	0.46	0.46	0.47	0.52	0.48
United States	0.31	0.36	0.35	0.35	0.36	0.39	..
Total OECD	**0.35**	**0.39**	**0.39**	**0.39**	**0.40**	**0.44**	**..**
EU27	0.37	0.39	0.40	0.40	0.43	0.47	0.47

Source: OECD Main Science and Technology Indicators 2012/1, p. 69.

Direct government funding for teaching of first- and second-cycle courses at Swedish universities is allocated according to a number of indicators, including number of degrees per discipline, number of students per discipline or special assignments. Each main discipline has a certain monetary value. There is an overall ceiling and higher education institutes are free to distribute the lump sums as they choose (Jongbloed, 2009, p. 44, for an overview). A funding cap set annually by the government for each HEI which determines the upper limit that can be paid to a HEI (Inkinen, 2011, p. 17). This system is complemented by a centralised student selection system (Aghion *et al*., 2008, p. 14). Swedish universities in general do not own their buildings, which are administered by a central public agency (Estermann and Nokkala, 2009, p. 25).

Researchers in higher education

Table 3.9 shows the share of higher education researchers in the national total of researchers for selected countries. Roughly one-third of Swedish researchers are employed in higher education, a share comparable to that in many other countries. The share of higher education researchers increased from 27.5% in 2005 to 34.4% in 2010. Denmark is the only comparator country with available data that showed a similar increase over the period, but this includes the results of mergers of research institutes into universities. In FTE terms, 15 000 researchers worked in HEIs in 2005 and 17 000 in 2010.

Table 3.9. Higher education researchers as a percentage of the national total (full-time equivalents)

	2000	2005	2006	2007	2008	2009	2010
Austria	..	31.5	31.7	31.9	31.9	32.5	32.5
Canada	30.8	31.7	30.9	31.7	33.1	..	..
China	21.3	19.8	19.3	17.4	16.4	19.5	..
Denmark	..	29.2	30.4	32.0	30.7	34.4	35.5
Finland	31.6	32.5	31.8	31.2	29.0	30.1	32.7
France	35.8	32.7	32.3	30.4	30.1	29.3	..
Germany	26.0	24.0	24.0	25.1	25.4	26.7	27.4
Israel	..	..	..	..	..	..	..
Italy	38.9	44.9	42.6	41.8	..	42.3	41.1
Japan	27.7	22.9	23.3	23.3	18.8	19.0	..
Korea	21.8	15.2	14.2	16.9	14.7	15.6	14.9
Netherlands	36.9	37.5	33.9	35.5	37.1	41.9	38.8
Norway	..	35.4	34.9	34.8	34.3	34.9	35.7
Sweden	**..**	**27.5**	**26.4**	**32.5**	**29.7**	**34.7**	**34.4**
Switzerland	36.1	..	..	..	57.0	..	..
United Kingdom	..	57.0	58.0	59.6	60.6	61.7	60.6
United States	..	..	..	..	..	..	..
Total OECD	**..**	**..**	**27.5**	**..**	**..**	**..**	**..**
EU-27	36.9	40.1	39.8	40.1	40.5	41.4	41.4

Source: OECD Main Science and Technology Indicators 2012/1, p. 73.

Academic career norms and incentives appear to favour those who stay in place and accumulate external funding. Well-developed career programmes beyond post-doc stages and career tracks for younger people are reported to be rare. There is therefore little mobility. In a ten-country comparison, Sweden ranked third at 58% in terms of the percentage of faculty members with a PhD degree from their employing higher education institute. Only Spain and Belgium ranked higher, with 69% and 63%, respectively. Comparator countries show much higher levels of mobility: for example, home-grown faculty were only 24% in Switzerland, 33% in the Netherlands and 40% in Denmark. Larger countries, such as the United Kingdom and Germany, have high levels of academic mobility with only 8% of home-grown faculty (Aghion *et al*., 2008, pp. 36 and 38). The relative lack of mobility in Swedish universities may indicate a lack of dynamism in the sector.

Recent bibliometric analysis of the “recruitment” (in the general sense of having them rather than in the strict sense of formally hiring them) of top performers among university faculty is perhaps an even greater cause for concern. Comparing Sweden to other leading science countries, Karlsson and Persson (2012) show that Sweden has relatively low rates of elite author recruitment. Table 3.10 presents part of their results over three partially overlapping time periods corresponding to the years 1986-2000, 1991-2000 and 1996-2010. Among the comparator group of countries Sweden experienced the lowest recruitment rate over the first period and came second-last in the two following periods (Table 3.10). Sweden also comes second-last in terms of growth rates of total publication volume and of the size of the elite author community (Karlsson and Persson, 2012).

Table 3.10. Recruitment rates in six countries

Percentage of elite authors emerging during the last five years of a 15-year period

Country	Period			Mean growth of publication volume	Mean growth of no. of authors, 1986-2010
	1986-2000	1991-2005	1996-2010		
Denmark	8.1	5.3	5.0	2.8	5.9
Finland	7.7	4.0	3.1	3.2	6.2
Netherlands	9.5	6.5	5.2	3.5	6.1
Sweden	**5.4**	**4.4**	**3.7**	**1.9**	**5.2**
Switzerland	10.6	6.3	7.7	3.0	6.3
United Kingdom	6.6	4.7	4.8	1.4	4.5

Source: Karlsson and Persson (2012).

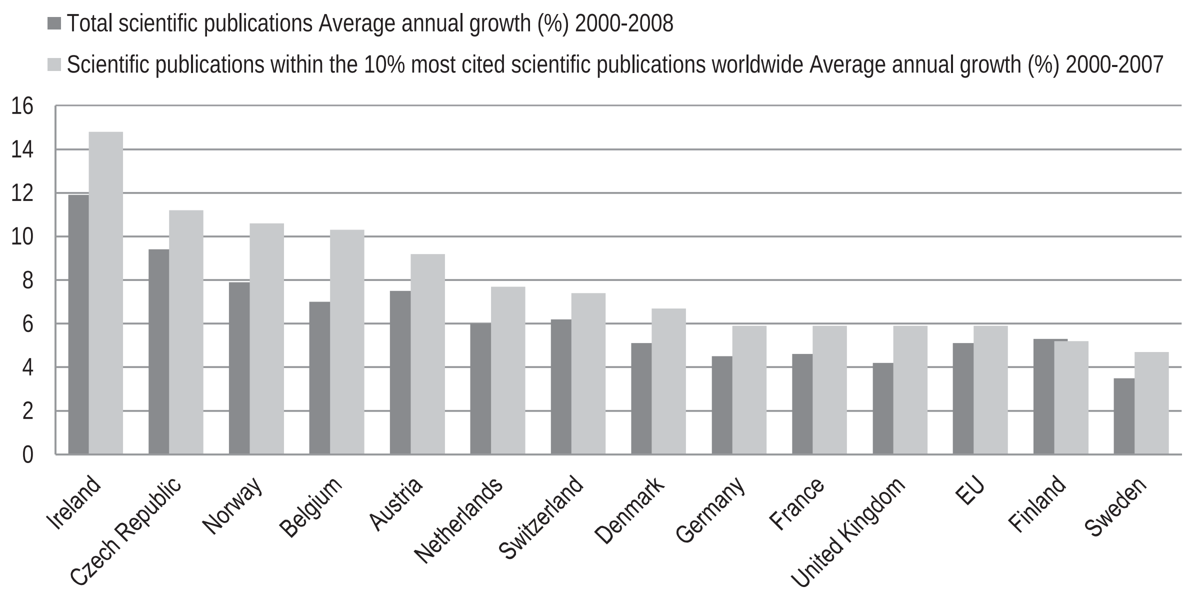
3.2.3. Research output, impact and success

Ideally, large expenditures result in equally large outputs and impacts. This section examines various indicators to explore the extent to which the Swedish university system, particularly its traditional, well-endowed universities, performs compared to countries with top outputs, such as Switzerland. For this comparison, publication and citation data are used together with data on Sweden's performance in attracting European excellence funding.

Publications and citations

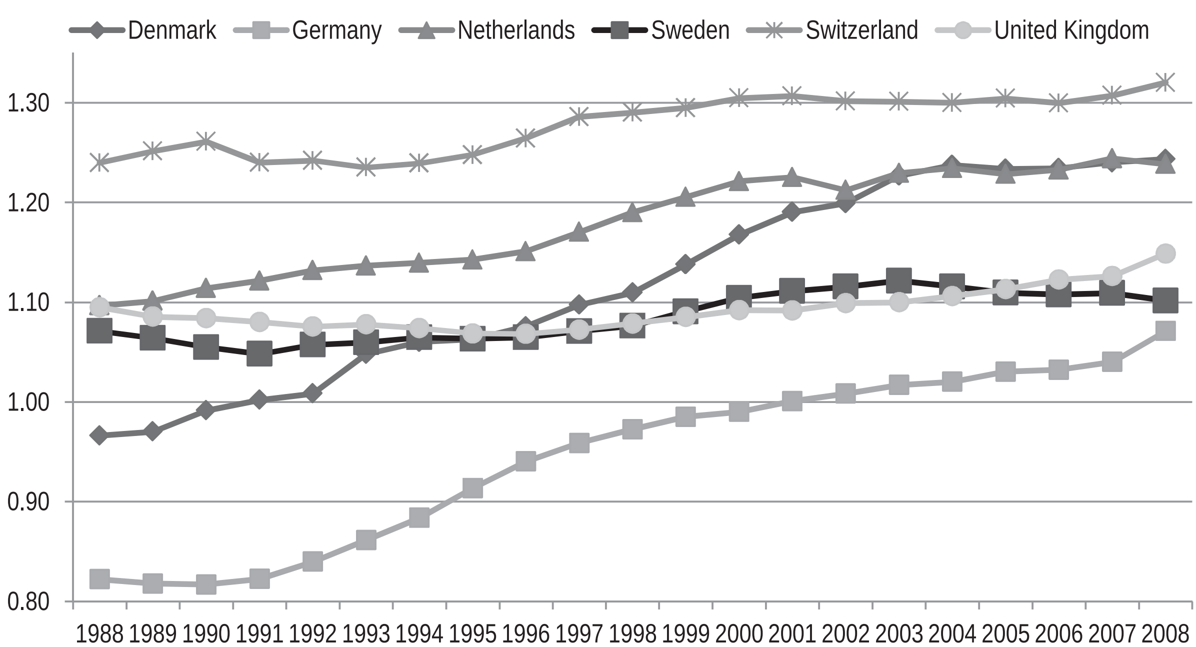
Overall the Swedish research system has a good publication record and compares well internationally in terms of scientific publications per 1 000 inhabitants (see Chapter 2). The scientific community is internationally well connected and international scientific co-publication patterns are stronger than in a number of comparator countries (Growth Analysis, 2011, p. 40). However, Sweden's 3.5% average annual growth in total scientific publications for 2000-08 is comparatively low and below the 5.1% EU27 average (Figure 3.9). More worrying still is the impact of research, as measured by citations. Compared to high-performing benchmark countries and to the large input into the system, the share of publication output that is highly cited is not very impressive (Figure 3.10). For the 10% most-cited scientific publications as a percentage of total scientific publications, Sweden has stagnated on a mid-level compared to other countries. Growth in Germany and Austria have brought them to a position very close to Sweden's, and the Netherlands, Denmark and Switzerland have increased their advantage over Sweden (Figure 3.11). This can be interpreted as a loss of scientific competitiveness.

Figure 3.9. Average annual growth rate in scientific articles and the 10% most cited articles



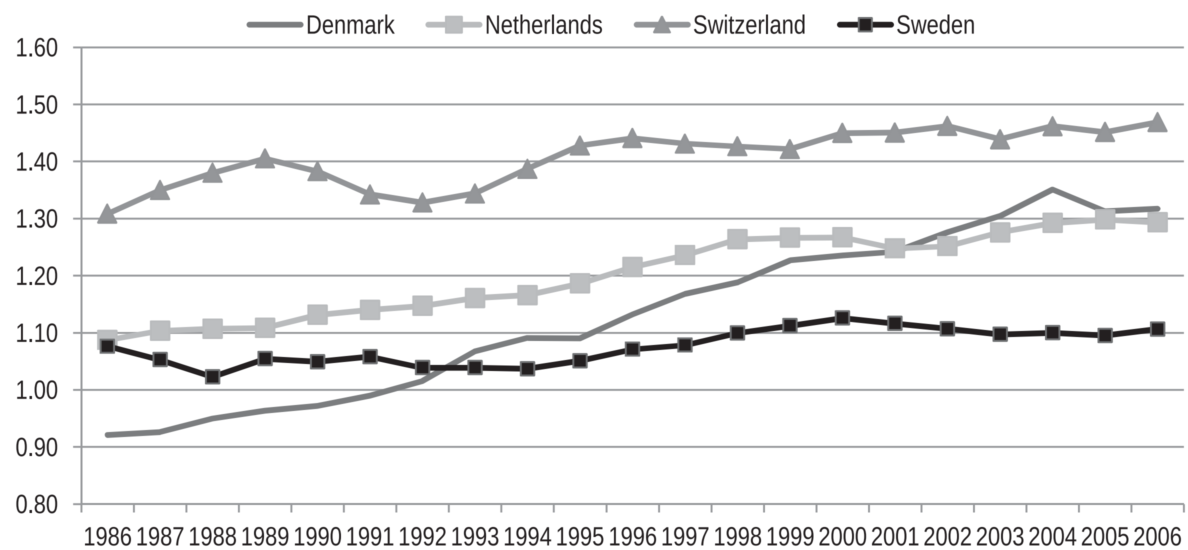
Source: European Commission (2011), p.139.

Figure 3.10. Field-adjusted citations for selected countries, 1988-2008



Source: Growth Analysis (2011, p. 56), based on Vetenskapsradet (2010)

Figure 3.11. Field-adjusted citation frequency in relation to top 10% most cited publications for selected countries, 1986-2006



Source: Growth Analysis (2011), p. 57, based on Vetenskapsradet data (2010).

Furthermore, Swedish universities have a relatively small share of highly successful subject fields. They also yield comparatively few top publications (see Bonaccorsi, 2007, pp. 305 *ff.*). One of the main features here is the strong reliance on biomedicine, including clinical research, which accounts for half of the Swedish publication volume but has a declining relative impact and generally lacks dynamism. Table 3.11, drawing on the findings of Karlsson and Persson (2012), shows the share of papers published in prestigious journals during 2005-09, as a proportion within three broad subject profiles (Medicine, Natural Science and Other) and as a proportion of total volume and of citations. First, the table figures confirm the dominance of the broader field of medicine. Second, Sweden has the second largest share of papers appearing in prestige-journals, after Switzerland. Third, and notably, prestige-journal citations account for a smaller share of total citations than most other countries in the group, with the exception of Finland.

Table 3.11. Subject profile for papers in prestige-journals, 2005-09

Country	Subject profile			Volume	Citations
	Medicine	Natural science	Other		
Denmark	54%	38%	8%	0.46%	2.2%
Finland	62%	32%	6%	0.27%	1.3%
Netherlands	56%	34%	10%	0.42%	1.8%
Sweden	71%	23%	6%	**0.55%**	**1.9%**
Switzerland	63%	29%	8%	0.80%	3.4%
United Kingdom	54%	31%	14%	0.62%	2.5%

Source: Karlsson and Persson (2012).

A further question is whether Swedish universities tend to build critical mass. It is difficult to answer because it is difficult to make internationally valid comparisons. A study from the mid-2000s shows that the universities of Lund, Uppsala, Gothenburg and Stockholm as well as the Karolinska Institutet show some concentration effects: they have larger numbers of senior researchers active in the same field in a larger number of fields (*i.e.* "high density across research subjects", Ljungberg *et al*., 2009, pp. 145 *ff.*). However, lack of context and difficulties for defining fields and density make comparisons difficult.

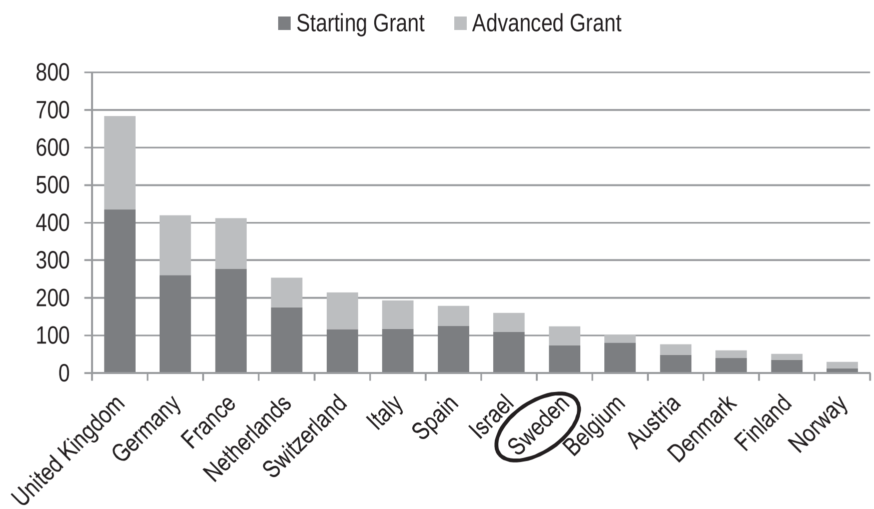
The European Research Council and its funding of frontier research in Sweden

The European counterpart to the Swedish Research Council is the European Research Council (ERC), established under the EU 7th Framework Programme (FP7), which has 15% of the overall FP7 budget, *i.e.* EUR 7.5 billion during 2007-13. The ERC supports excellence in frontier research in all fields of science through pan-European competition by individual researchers for significant funding of bottom-up research projects. The two major grants are the ERC Starting Grants and the ERC Advanced Grants. The former target promising, up-and-coming researchers with proven potential of becoming independent research leaders. The latter allow exceptional established research leaders of any nationality and any age to pursue ground-breaking, high-risk projects that open new directions in their respective research fields or domains. Recent findings (Edler *et al.*, 2012) show that the ERC has already had a certain impact on universities, including recognition as a new quality indicator across Europe.

In the ERC calls during 2007-12, researchers working at Swedish host institutes received 74 Starting Grants and 50 Advanced Grants. The success rate of around 9% during 2007-11 is comparable to the EU average but is lower than that of Belgium, Germany, the Netherlands, Austria, the United Kingdom, France and Israel, all of which range between 10% and 16%. Switzerland is in a class of its own, with a success rate of 22%. One possible explanation for Sweden's average performance might be the high numbers of applications from Swedish researchers: one out of 14 public researchers submitted an ERC application in 2007-11, a figure nearly twice the number for comparator countries.

In terms of the number of grants (Figure 3.12) Sweden has a good record in relation to the size of the country, better than Denmark, Austria and Finland, but is outperformed by Switzerland and the Netherlands (and by Israel). Per million population, Switzerland leads with 24 grants, followed by Israel with 19, the Netherlands with 12 and Sweden with 11. The balance between starting and advanced grantees varies from country to country, though Sweden scores well in both categories. Given the high inputs into the university system, this record is good but not first-rate. Why Swedish researchers are less successful than academics working in the strongest of the (small) countries eligible for ERC funding should be further investigated.

Figure 3.12. Distribution of ERC Starting and Advanced Grants, 2007-12



Source: ERC data information, September 2012.

In a university ranking of grantees (Table 3.12) 25 European and 3 Israeli universities hosted at least 16 ERC grantees from the eight starting and advanced grant calls during 2007-11. These 28 research institutes received almost one-third of the grants, *i.e.* 809 out of 2 556. Six are located in the United Kingdom, six in the Netherlands, four in Switzerland, three in Israel, two each in Denmark, Germany and Sweden and one each in Austria, Belgium and Finland. The two Swedish universities are the Karolinska Institutet with 20 grantees (18th position) and Lund University with 16 (28th position), *i.e.* the same universities that lead in funding from the Swedish Research Council (see Figure 3.6 above). These two Swedish universities host more than one-third of the 100 or so ERC grantees in Sweden.

The European Institute of Technology and Swedish university participation

Another recent introduction to the EU funding landscape is the European Institute of Technology (EIT) established in 2008. Originally foreseen as the European counterpart to the Massachusetts Institute of Technology (MIT) in the United States, the EIT did not become a single science and engineering institute but operates through knowledge and innovation communities (KICs) in co-location centres across Europe. They link higher education, research and business to train a new generation of innovators and entrepreneurs. In a first funding round in 2009, three KICs were selected; Sweden hosts the co-location centres for two of them, the EIT ICT Labs and the KIC InnoEnergy.

The Swedish EIT ICT Labs node in Stockholm comprises three core partners, KTH, Ericsson AB and the SICS research institute, and several affiliated partners, including Lund University and Luleå University of Technology. The Swedish KIC InnoEnergy node is in Stockholm and Uppsala. The four core partners are KTH, Uppsala University, ABB and Vattenfall. It receives one-sixth of the KICs funding to develop smart grids and energy storage. Participation in the EIT has been a government priority in Sweden with strong support and encouragement for Swedish participation in applications. While this commitment clearly paid off in the short term, it is too early to assess its long-term strategic impact.

Table 3.12. Top 28 European universities hosting at least 16 ERC grantees, by funding scheme

Country	Higher-education institution	StG	AdG	Total
United Kingdom	University of Cambridge	44	32	76
United Kingdom	University of Oxford	38	34	72
Switzerland	Swiss Federal Institute of Technology Lausanne	27	25	52
Israel	Hebrew University of Jerusalem	28	17	45
Switzerland	ETH Zurich	14	29	43
United Kingdom	University College London	23	19	42
United Kingdom	Imperial College	22	20	42
Israel	Weizmann Institute	21	18	39
Belgium	University of Leuven	19	7	26
United Kingdom	University of Bristol	9	15	24
Germany	University of Munich	8	15	23
Netherlands	Leiden University	12	11	23
Switzerland	University of Zurich	10	13	23
United Kingdom	University of Edinburgh	11	12	23
Finland	University of Helsinki	12	9	21
Netherlands	University of Amsterdam	13	8	21
Israel	Technion	17	3	20
Sweden	**Karolinska Institutet**	**11**	**9**	**20**
Netherlands	Free University of Amsterdam	13	6	19
Netherlands	Radboud University Nijmegen	13	6	19
Netherlands	University of Groningen	16	2	18
Denmark	Aarhus University	9	9	18
Austria	University of Vienna	8	9	17
Netherlands	Utrecht University	11	6	17
Switzerland	University of Geneva	6	11	17
Denmark	University of Heidelberg	10	7	17
Denmark	University of Copenhagen	9	7	16
Sweden	**Lund University**	**8**	**8**	**16**

Source: ERC data information, September 2012.

Could Sweden's universities do even better?

In spite of its comparative success in competing for European funding, Sweden's relatively weak performance in citations over the last 20 years is worrying. The stagnation suggested by bibliometric data is not easily explained and is likely influenced by a mix of factors. Karlsson and Persson (2012) note that the most successful countries – Switzerland, the Netherlands and Denmark – do not depend on a few elite institutes for their success. They have strong university systems, with few universities performing below the world average. Another contributing factor could be the relative "endogamy" of the faculty in Sweden's universities and the comparatively weak renewal of the scientific elite. It could also be that the relatively fragmented research funding system – some 20 mid-sized funding organisations with mid-sized instruments – tends to fund good quality but "safe" research (see Chapter 4) which is less likely to be widely cited.

Box 3.7. The Swiss EPFL: An example of the successful evolution of a higher education institute

Switzerland is among the OECD innovation leaders (OECD, 2006). Its higher education and public research system is at the forefront of European performance. It has ten cantonal universities, two federal institutes of technology (ETH Zurich and EPF Lausanne), four federal research institutes and eight universities of applied sciences.

The *École Polytechnique Fédérale de Lausanne* (EPFL) was founded in 1853 as a private technical college and later became part of the University of Lausanne. Since 1969 it is a separate federal institute whose campus is located next to the campus of the University of Lausanne. Together they form the largest research and education centre in Switzerland. EPF Lausanne and ETH Zurich are Switzerland’s two technical universities. The ETH system receives substantial general university funds from the federal government and the presidents of the universities have a strong role which includes overall management responsibility and an active part in the hiring of professors. At EPFL, Patrick Aebischer, university president since 2000, has used his strong position to help transform the university by hiring top researchers worldwide and by fostering strong relationships between the academic community and industry.

On the academic side, EPFL integrated mathematics, physics and chemistry from the University of Lausanne, restructured into five schools, each of which manages its own budget, and established a completely new school of life sciences with a strong focus on biomedical engineering, which already had in 2010 about 650 FTE research and teaching staff. At the interface of academia and industry the EPFL campus hosts, in its newly established *Quartier de l’innovation* (Innovation Square), research centres of companies that collaborate scientifically with EPFL in medical technology, biotechnology, green technology or ICT. In 2012 these companies included Logitech, Debiopharm, Cisco, Alcan, Nokia, Crédit Suisse and the Nestlé Institute of Health Sciences. In all EPFL has about 4 400 FTE research and teaching staff. This increasingly international staff educates about 7 700 students to become engineers and scientists. EPFL actively promotes interdisciplinarity at the student level and participates in high-visibility projects such as Solar Impulse or l’Hydroptère[1] to brand the university. The internationalisation strategy of EPFL includes strong agreements with universities in Asia.

In the space of about ten years, EPFL has been transformed from a good engineering school to a world-class technical research university. This is reflected in various rankings; for example, EPFL follows only the universities of Oxford and Cambridge in terms of receipt of ERC Starting Grants and ERC Advanced Grants from the European Research Council (see Table 3.12) and also ranks prominently in international university rankings. In one ranking, EPFL takes second place among the top 100 universities under 50 years of age (Times Higher Education, 2012).

1. EPFL (2012a), EPFL (2012b).

A further possible explanation might be a gap between the level of resources nominally allocated to university research and what is actually spent. For example, Granberg and Jacobsson (2006) argue that Swedish PhD students are very expensive, that block funding is mainly used for teaching and other non-research matters, and that university researchers’ time for scientific research has been squeezed out of the system. The authors claim that Swedish universities have fewer person-years engaged in R&D per million inhabitants than their counterparts in a number of other countries (pp. 324 *ff.*, with data for around 2000).[9] Similarly, data from the European Commission (2011, p. 152) suggest that public expenditure on R&D per public-sector researcher has been lower in Sweden than in most other advanced small European countries.[10] However, academic researchers and universities can draw on more than 20 public, semi-public and private foundations for research funding, much of which is excluded in international comparisons.[11] In a ten-country comparison, the average Swedish university can draw on the highest share of competitive research grants relative to overall budget (Aghion *et al.*, 2008, p. 31), and overall university budgets in Sweden are high as well.

Another important consideration is university governance. Individual professors have a strong role in Swedish universities, so that Swedish universities are rather decentralised organisations and their leadership is not comparable to that of some Swiss or American counterparts, where the president or vice–president plays a very strong role. The extremely rich competitive funding landscape, which is a positive feature of the Swedish system, empowers researchers who are able to acquire funds directly. University leadership seems to have limited control over research allocations and much core funding probably tends to follow the pattern of external funding. The governance of universities seems to come from research departments, from many strong individuals and from a chorus of outside (funding and social) organisations, with impacts on recruitment, careers and the development of new fields. This stands in contrast to the strengthening of the formal powers of the leadership since 1993 and the enlarged political and industry representation on university boards (Jongbloed, 2009, p. 42) and to certain formal powers of university leadership for recruiting senior academic staff, as in most European countries (Estermann and Nokkala, 2009, p. 28). Box 3.7 describes the Swiss Federal Institute of Technology in Lausanne, which, through strong leadership, has transformed itself into one of the world's leading universities in a relatively short time.

A recent study of the Royal Swedish Academy of Sciences (Öquist and Benner, 2012) confirms such findings. Based on a comparison with Finland, the Netherlands, Denmark and Switzerland, it identifies weaknesses in the ability of the Swedish academic system to produce sufficient scientific work of high global impact. The study identifies a number of structural problems relating to recruiting top people, safeguarding career tracks, supporting top quality and providing effective academic leadership. Moreover, the generous funding streams include a number of disincentives and do not sufficiently encourage frontier research. In sum, the study finds that the drawbacks of the general university funding (and the internal university allocation) along with too many small multi-goal external funding sources create a situation in which universities become "research hotels", "an effect of the skewed funding and authority structure" (Öquist and Benner, 2012, p. 31).

3.2.4. Third mission and commercialisation

Sweden has long recognised the so-called "third mission" of universities and considered ways to realise the commercial potential of Swedish academic research. Starting with the academic inventors of the late 19th century, academic and industrial research co-evolved over long periods in sectors such as telecommunications and energy. In recent decades, academic researchers have contributed to industrial competitiveness, sometimes very strongly (see Box 3.8), sometimes through (personal) consulting and other forms of non-institutional technology transfer. Nevertheless, on one measure of the relationship between industry and HEIs, *i.e.* the percentage of higher education expenditure on R&D (HERD) financed by industry (Table 3.13), Sweden is below the OECD average of 6.3% and the EU27 average of 6.4% and the percentage has decreased slightly from 5.1% in 2005 to 4.5% in 2009. Germany is clearly the outlier among European comparator countries with 14.3% of HERD financed by industry in 2009, more than twice the OECD average and more than three times Sweden's share.

The third mission of Swedish universities was officially mandated in 1975 and initially realised in terms of communication and strengthening of linkages. The task of disseminating results came in the new university regulation of 1998 (Bourelos *et al.*, 2012, pp. 753 *ff.*). In parallel, most universities built up technology transfer offices (TTOs),[12] incubators and science parks, and universities such as Chalmers developed entrepreneurship schools or courses as part of their overall academic portfolio (Åstebro *et al*., 2012, p. 673). Given these developments, there is little doubt that academic entrepreneurship is an important goal of the Swedish academic sector.

Table 3.13. Percentage of higher education expenditure on R&D financed by industry

	2000	2005	2006	2007	2008	2009	2010
Austria	..	..	5.0	5.7	..	5.2	..
Canada	9.5	8.4	8.4	8.5	8.2	8.2	8.2
China	32.4	36.7	36.6	35.1	34.6	36.7	..
Denmark	2.0	2.4	2.5	2.1	..	3.4	3.4
Finland	5.6	6.5	6.6.	7.0	7.2	6.4	5.7
France	2.7	1.6	1.7	1.6	2.2	1.8	1.8
Germany	11.6	14.1	15.1	15.5	15.1	14.3	..
Israel	3.7	7.3	7.2	7.2	7.2	..	..
Italy	..	1.4	1.2	1.3	1.2	1.1	1.1
Japan	2.5	2.8	2.9	3.0	3.0	2.5	..
Korea	15.9	15.2	13.7	14.2	12.0	11.3	11.3
Netherlands	..	7.8	..	7.5	..	8.2	..
Norway	..	4.7	..	4.0	..	3.8	..
Sweden	**..**	**5.1**	**5.1**	**4.9**	**..**	**4.5**	**..**
Switzerland	5.1	..	8.7	..	6.9	..	..
United Kingdom	7.1	4.6	4.8	4.5	4.6	3.9	4.6
United States	7.1	5.1	5.3	5.6	5.8	6.0	..
Total OECD	**6.4**	**6.1**	**6.3**	**6.6**	**6.4**	**6.3**	**..**
EU27	6.3	6.4	6.7	6.9	6.7	6.4	..

Source: OECD Main Science and Technology Indicators, February 2012.

Box 3.8. The GSM story

The development of mobile phone technology, especially the GSM standard, is a major success of Swedish government research funding which benefited both universities and industry (Arnold *et al*., 2008). From 1975 to 1998 the predecessors of VINNOVA, STU and NUTEK (see Chapter 4) played an important role in building up ICT research capacity at universities and institutes of technology (especially at Lund, Linköping, Chalmers, KTH, Uppsala and Luleå). According to Arnold *et al*. (2008), the research and teaching capacity in digital mobile telephony increased at least ten-fold owing to government stimulus of the digital communication programme. The universities were therefore both enablers and beneficiaries of Ericsson's success. As enablers they supplied well-educated engineers and scientists, and they benefited because applied scientific research and engineering thrive on access to emerging problems.

Box 3.9. "From our pipeline to your bottom line": The YEDA story

Only a few top universities and research organisations across the world have meaningful income from the commercialisation of research. Israel's Weizmann Institute is such an organisation, although it is neither exceptionally big nor can it look back on a long tradition. The Institute was founded in the 1930s in the Israeli countryside, mainly by Chaim Weizmann, without surrounding industries or public infrastructures. In 1949 it was named after the founder, a famous inventor and first president of Israel. The idea behind this stand-alone institute was to establish basic science and advanced learning as an integral part of the new state's development. It grew rapidly and attracted talented people and ample funding from Israel and from around the world. Success factors included concentration on high-quality basic scientific research ("seeking revolutions instead of evolutions"), often at the interface between disciplines, and emphasis on PhD formation. Today the Institute has 50 interdisciplinary centres, around 2 500 employees, including 250 professors and 1 000 mainly doctoral students on a small campus. More than half of the post-docs are not Israeli citizens. It has a number of eminent scientists, including the winner of a Nobel prize, and around 40 ERC grantees. As Table 3.12 shows, Israeli research institutes are highly successful at winning ERC grants. The Weizmann Institute is nearly as successful as the much larger Hebrew University, and both are among the top ten recipients of these grants.

Weizmann representatives emphasise the focus on excellence in basic science and on the following elements: bottom-up approach, curiosity-driven research, "publish or perish", long-term orientation and shielding the Institute from commercial risks. Scientists – many of them live on the campus – are not to be concerned with application and can devote only limited time for activities other than scientific research. A VP for Technology Transfer is part of the executive leadership of the Institute.

YEDA is Weizmann's TTO. It was founded in 1959 – decades before the US Bayh-Dole legislation – and it took several years to deliver returns. The office takes care of identification, application, licensing and protection of all Weizmann IP. Weizmanns' VP for Technology Transfer is YEDA's chairman, and YEDA is to be informed about scientists' inventions. YEDA is the exclusive channel for patenting, commercialisation and protection, and inventors have to co-operate and disclose relevant knowledge. Life sciences are the most important source of patents and revenues. If YEDA does not submit a patent, inventors can try to commercialise their invention on their own but still have to reimburse part of any profits to YEDA. If YEDA decides to patent, they are in full charge of the process and – like nearly all TTOs – focus on licensing contracts, often with Israeli firms. For some, like the pharmaceutical company Teva, Weizmann IP led to the development of blockbusters. Companies such as Adobe or Johnson and Johnson also profit from licence agreements with YEDA. Revenue is distributed as follows: 40% to the scientists, 60% to the Institute (minus a commission for the TTO). Some researchers have become wealthy through these agreements.

YEDA has filed or participated in filing 1 400 patent families, has signed many licensing agreements and established around 50 spin-off companies based on Weizmann knowledge and IP. Currently YEDA owns 660 live patent families. The total annual royalty-generating sales in 2010 amounted to USD 15 billion.

The Weizmann budget is approximately USD 300 million. A third comes from the Israeli government for basic funding, while the rest comes from international donations, international and national competitive funding, and revenues of the Institutes' endowment. YEDA currently contributes USD 15-20 million a year to the Institute's budget, although its contribution was significantly higher in the mid-2000s. YEDA also organises money flows for pre-competitive research from industry to the Institute. A large industrial park next to the Institute hosts a number of successful firms.

A key lesson from Israel's experience is the need to work on a high professional level to commercialise research. All Israeli TTOs have clear missions and top staff. YEDA representatives know what researchers have accomplished and have more than 1 000 industry contacts a year. Another lesson is that academic excellence and commercial success are not incompatible but can be mutually reinforcing. Studies show that there is a strong positive correlation between scientific excellence and the intensity of industry contacts of individual researchers in Sweden (Bourelos *et al*., 2012, pp. 759 *ff*.). A further lesson is that professional TTOs and a focus on licensing do not automatically preclude spin-offs. Patience and the nurturing of a certain culture is another important factor. Finally the Weizmann Institute shows that it pays to be not just a very good but a top academic environment with professional gateways to the outer world in order to attract top talent and industrial partners.

Source: Own research and *www.yedarnd.com/images/pics/UserImages/24h.pdf*; *www.weizmann.ac.il; www.ishitech.co.il/0904ar5.htm*.

Policy discussions of a “Swedish paradox” (high R&D input and low innovation output) (*e.g.* Bitard and Edquist, 2008; Edquist, 2010) question whether the knowledge created in universities is sufficiently “transformed” into innovations. Critics have argued that inputs into the academic system should yield more outputs in terms of patents, new firms and growth through entrepreneurship. In a discussion of the literature, however, Bourelos *et al*. (2012, pp. 753 *ff*.) do not support claims of an “ivory tower” mentality or of wrong incentives. On the contrary, they find evidence of complex, often soft forms of collaboration patterns, mainly on the individual or group level. As in many countries they find a positive correlation between publication records and transfer activities. This is confirmed by a survey of academics that finds positive attitudes towards collaboration and entrepreneurship.

Levels of academic patenting can be considered satisfactory if individual inventors who are academics are included in patent counts. Universities hold about 5% of total academic patents, with the other 95% held by individuals (without their university affiliation) (Bourelos *et al*., 2012, p. 755, referring to Lissoni *et al*., 2008). This is due to the so-called “professor’s privilege” (*lärarundantaget*), which was introduced in 1949 in *Act 345 on the Right to Employees’ Inventions* which states in paragraph 1 that academics at universities, technical colleges and other academic institutions shall not be considered as employees under the Act. While other Nordic countries have removed this exemption – Denmark in 2000, Norway in 2003 and Finland in 2007 – it is still in place in Sweden. Sweden and Italy are the only European countries with considerable academic R&D activity that retain the academic exemption.

There are two main arguments in favour of the professor’s privilege. The first concerns expertise and red tape and the second incentives for spin-offs and entrepreneurship. Both can adduce supporting evidence but face counter-arguments. The “expertise” argument concerns the researcher-inventor’s intimate knowledge of the invention compared to (often less experienced) TTO staff and potentially burdensome regulations. This line of argument is supported to some extent by the high hopes and meagre success of universities in many countries in building up, defending and profiting from their intellectual property (IP). Therefore, it is argued, it is better to let experienced researchers take care of their inventions and either create a firm or collaborate directly with firms that will offer a down payment and royalties to the inventor, who may then accumulate some personal wealth. One counter-argument in support of institutionalised IP portfolios is that universities are financed through taxpayers’ money and provide the infrastructure and staff and a secure position for researchers, so that revenues from the invention should not belong to the individual inventor alone. Another argument is that universities need to know about their IP potential (and portfolio) in order to build a coherent transfer and commercialisation policy; however, an obligation placed on all staff to disclose inventions and ensuing deals would in part overcome this problem. The main counter-argument to the expertise argument seems to be that a long-term, highly professionalised transfer and commercialisation policy can succeed and contribute both to revenue streams to the university and to industrial development close to the campus. The example of the Weizmann Institute in Israel, a research institute with graduate students, offers an example (see Box 3.9) and provides potential lessons for smaller countries.

The second argument is that professional TTO structures prevent the creation of spin-offs, as there are clear incentives for TTO managers to license out IP to existing firms and receive quick and relatively safe returns. Spin-offs bring more long-term profit, as more patents appear to be actually used, the new firms may grow quickly, and will probably be located close to the university, with the possibility of constant interaction with academics. Finally successful entrepreneurs often donate generously to their former universities. In a study of six North American universities (Kenney and Patton, 2011), one Canadian university still using a kind of professor's privilege had a much higher rate of academic spin-offs than the comparable but larger, richer and more research-intensive US universities included in the study. Arguments against the privilege include the relatively low number of direct academic spin-offs and strong incentives for academic researchers to enter "cheap" personal IP deals with industry. Moreover, in the last 20 years the number of academic spin-offs in the United States has increased nearly tenfold annually under the Bayh-Dole regime (Åstebro *et al*., 2012, p. 663, note 1). Åstebro *et al*. further argue that policy and universities should put more emphasis on spin-offs of graduates than on encouraging their staff to create firms. They show – with Halmstad, Chalmers and US universities as examples – that many graduates create their own firms within a few years after leaving university. They claim that such spin-offs are often of high quality in terms of technology, growth and profit. Therefore, universities should train students to become entrepreneurs and worry less about the ideal incentive structures for professors.

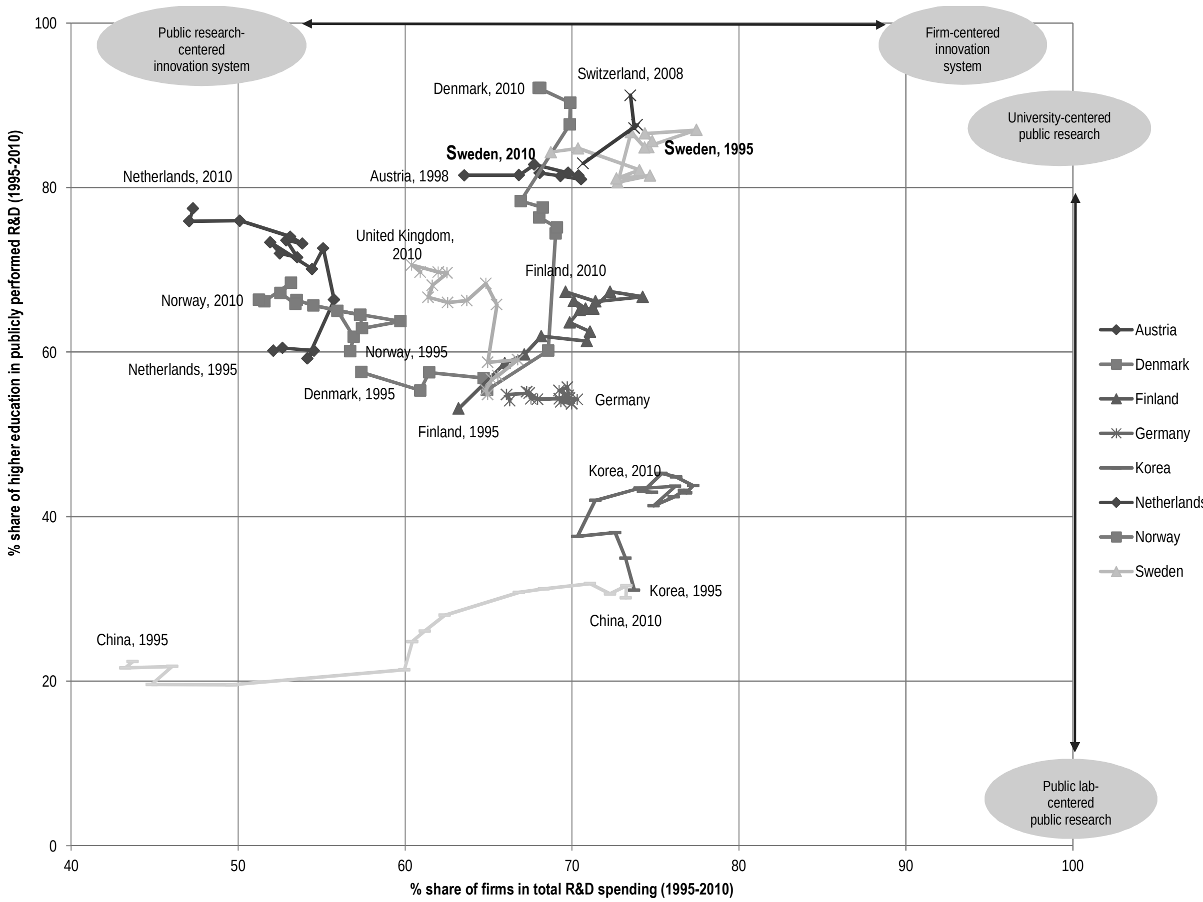
All in all, there are arguments for both forms of IP ownership. The issue has long been discussed in Sweden, but in contrast to most European countries, the professor's privilege has not been abolished. The issue should be considered again to see how to improve commercialisation arrangements, including some sort of institutional solution. At the very least, it would seem prudent to have academics report their IP holdings to their universities. The difficulty with full institutional solutions is the need for a long period of time to build portfolios and for highly professional staff. If this cannot be guaranteed it may be better to retain the professor's privilege.

3.3. Public research institutes

Across OECD countries, non-industrial research performance varies widely. Large countries such as Russia, but also to a certain extent the United States, rely on a large public research institute (PRI) sector, as do many smaller countries, such as the Czech Republic, Hungary or Slovenia. France, and to a lesser extent Italy and Spain, have a strong PRI sector which is closely linked to university research. A number of countries comparable to Sweden, such as Austria, Denmark and Switzerland, perform pre-competitive research mostly in the public university system. Finland and Korea have a more balanced distribution. Over time there has been a shift towards university-based research across the OECD (Figure 3.13). In Denmark recent university mergers have integrated a number of PRIs into a smaller number of large universities. Many industrialised countries in Europe have a strong industry-oriented PRI sector: Finland with VTT, the Netherlands with TNO or Germany with Fraunhofer. Switzerland does not have such applied research centres.

In Sweden most precompetitive and public research takes place in universities. Traditionally there has been a small PRI sector that accounts for just 3-5% of GERD (for the lower figure, see RISE, 2011, p. 6), in contrast to an EU average of 12%. In recent years, the PRI sector has grown; it is seen as an instrument of innovation policy for linking actors and serving industry as well as public needs. There are two main types of PRIs in Sweden; a third type, which focuses on scientific research (the Max Planck or the CNRS model), is covered in Sweden by the universities.

Figure 3.13. Proportion of R&D expenditures in firms, higher education and public research institutes in selected countries, 2010



Source: OECD Main Science and Technology Indicators, 2012/1.

First, there are PRIs which are more or less government agencies but have permission to charge for services performed. These include the Swedish Defence Research Agency (FOI) and VTI, which focuses on construction and analysis of the transport system. These agencies' main customers are the Defence and Transport ministries, respectively, and are covered here only briefly. Some of them are the legacy of a sectoral focus and/or follow the long-term trajectories of public-private technological developments, as in the defence sector.

The second type of PRI undertakes industrial research. Their main mission is to provide R&D services for the Swedish business sector. Private-sector businesses buy R&D services from the PRIs, while the state funds their facilities and skills development. The PRIs' work is largely demand-driven and acts as an interface between academic research and product development in the business sector. Their existence dates from the pre-war period, when they were run as purely industrial initiatives in sectors such as pulp and paper, metals, or power and fuels. An interesting outcome of this period was the use of the Royal Swedish Academy of Engineering Sciences (IVA) as a kind of holding structure which received and distributed public funding. On the public side the research councils did not run institutes. From the 1940s more than 20 industrial research institutes were created and received public support through funding and collaboration with sector agencies (Kaiserfeld, 2010, pp. 42 *ff.*; Arnold *et al*., 2007, pp. 12 *ff.*). The aim was to boost applied research in and for different industrial fields. The sector grew in the 1960s but in the 1970s and 1980s basic public financing shrank sharply. There was a moratorium on new institutes with the government decision to focus on universities as providers of public knowledge. A parliamentary decision in 1979 stated that “the universities shall undertake a significant proportion of sector-related research, viz. research that aims to support or develop state agencies’ activities”. Universities were to function as “research institutes for the whole of society” (quoted in Arnold *et al*., 2007, p. 15). This went along with a strong budget increase for universities, mainly in the 1990s; PRI core funding was halved in the early 2000s (Arnold *et al*., 2007, p. 17).

The PRIs with a focus on industrial research have been consolidated into an umbrella holding, RISE (Research Institutes of Sweden) in order to improve strategic orientation, pool resources and exploit complementarities. The 22 RISE institutes have an annual budget of around SEK 2.5 billion (RISE, 2012, p. 41), an increase of 25% over the last four to five years. More than 20% of the budget appears to come from international sources, including industry sources and the EU Framework Programme. RISE is the fifth largest Swedish FP7 recipient (RISE, 2011, pp. 6 and 31). In general more than 50% of turnover comes from industry projects, 19% comes from government funding in the form of strategic competence funds (RISE, 2011, p. 30) and another 18% from various public sources. RISE has a large number of SME clients and SME-targeted activities and a large number of testing facilities for enterprises of all sizes.

RISE continues to be developed as one of the priorities of the 2008 Research and Innovation Bill (Swedish Government, 2008, pp. 128 *ff.*). A main development goal is to strengthen the institutes as interfaces between academia and industry and as providers of useful research for firms. An additional EUR 20 million was provided in the research bill for 2009-12 to achieve this goal and to strengthen basic budgets and strategic options. An effective board structure was also created.

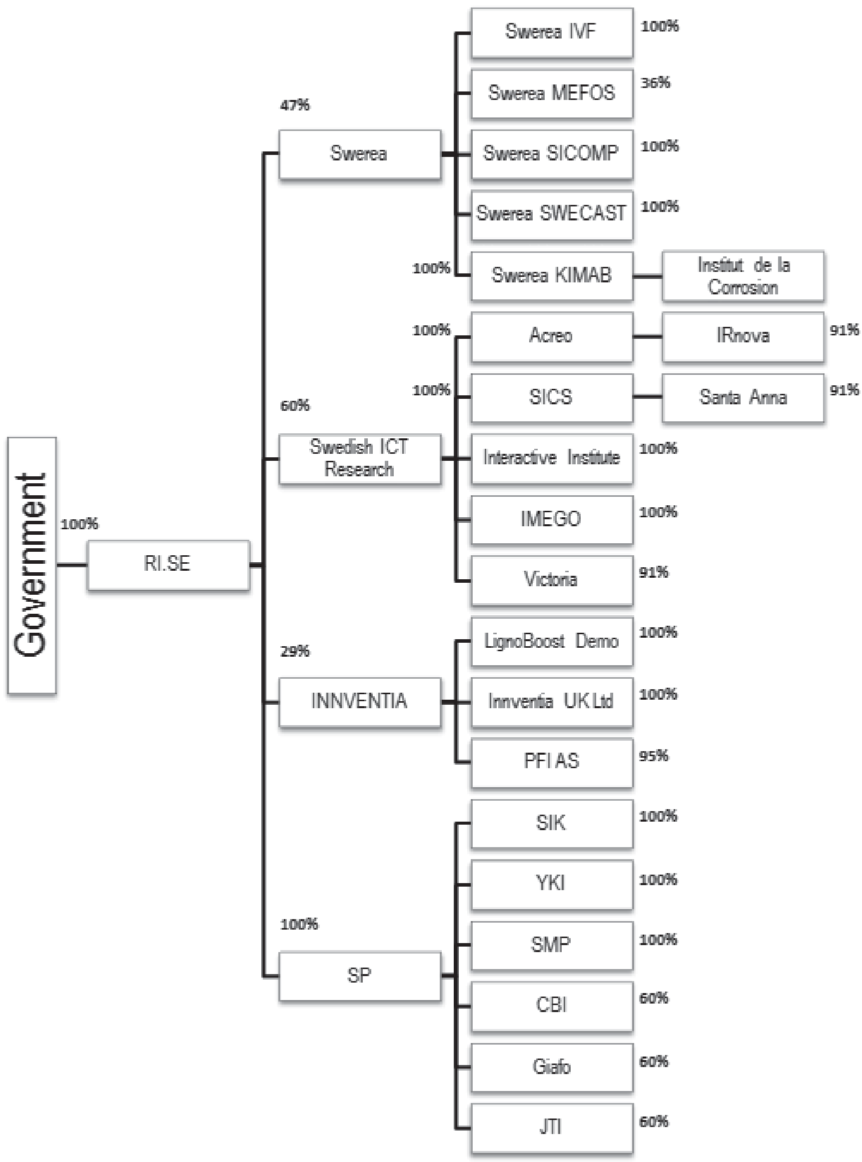
RISE has four main sub-structures with a number of individual institutes clustered around broad topics, such as ICT. The institutes are all organised as non-profit limited liability companies and have different business approaches depending on the sectors they serve. The models range from testing contracts to research consortia involving business enterprises and universities. Taken together, the institutes employ more than 2 200 people; more than a third have PhDs and 65 are also professors at universities.

Figure 3.14 shows the structure of the RISE institutes. The four clusters of institutes, each of which is located in five to ten different places all over Sweden, are as follows:

- The largest is SP, the Swedish Technical Research Institute, with six institutes for various forms of technical research with a strong focus on testing and measurement in fields such as building, life sciences, energy, environment or transport. It employs more than 1 000 people, and accounts for half of RISE staff. SP is fully owned by the government.
- Swedish ICT has six institutes and about 420 staff for microelectronics, computer sciences and informatics for specific industrial sectors, some with strong links to technical universities. The government has a 60% share in Swedish ICT.
- Swerea has six institutes in fields such as production technology, eco-design, process technology and materials and employs 570 staff. The Swedish government owns less than 50% of Swerea.

- Innventia has three institutes whose mission is to perform R&D in forest-based biomaterials, including pulp and paper, printing and packaging. With nearly 340 staff this is the smallest of the four RISE sectors and the government has only a 29% share.

Figure 3.14 Structure of the RISE institutes



Source: Adapted from RISE (2012). The numbers indicate direct and indirect public ownership shares.

Overall RISE seems to be on a satisfactory path, although it has a broad range of institute set-ups, sizes, business models and success. The two historically strong forms of activities, applied research for product and process development and testing, training and prototyping (Arnold *et al*., 2007, p. 55), continue to dominate. RISE sees a number of challenges ahead:[13] to increase synergies between institutes, to build a stronger customer orientation, to form alliances with universities with work shared along the basic-applied research borderline, to brand RISE as a sector, to increase internationalisation with more EU FP participation, to develop a stable financial business model, to seek more impact, and to provide incentives for collaboration.

Government support for research institutes has been increasing in recent years. Specific support mechanisms include VINNOVA's Institute Excellence Programme for RISE institutes and public-sector agencies such as FOI (see Chapter 4). It currently has eight centres which run for six years and aim to strengthen research consortia involving the institutes, academia and various firms. At the same time, like the competence centres and excellence centres for universities, these centres support new planning and management tools in the institutes funded, apparently with some success (Märtensson *et al*., 2009; Stenius *et al*., 2008). However, these initial findings also highlight the need for stronger strategic orientation.

A number of successful institutes work in "triangles" with the universities and the private sector. The development of links between universities and RISE is seen as an opportunity for collaboration. The EIT KICs appear to be a valuable example in the field of ICT, as they build on long-standing collaboration between Ericsson, RISE institutes and KTH. A number of RISE institutes play useful roles in cluster settings and production networks of multinational enterprises (MNEs). In the case of the latter, they tend to work more with second-tier suppliers than directly with core MNE research facilities. RISE also benefits from government policy initiatives at the regional level where RISE institutes have successfully participated in VINNVÄXT consortia (see Chapter 4).

There is clearly a role for RISE in the Swedish innovation system and institutes and universities should not be viewed as substitutes (Arnold *et al*., 2007, p. 81). Given that the PRI sector is still rather small by international standards, there is probably room for a step-wise expansion of RISE and its networks. However, two important caveats should be borne in mind. First, knowledge about Swedish firms, particularly SMEs but also larger firms that are not MNEs (referred to as the *Mittelstand* in German-speaking countries), and about their innovation and R&D needs could be improved. It has proved difficult for this review to obtain information about such firms, their needs and strategies, and their positions in value chains. Industrial research institutes like the RISE centres have only one reason to exist, and that is their usefulness to customers. It would therefore be important to know more about these customers and then to strengthen the institutes with high (potential) demand for their services.

Second, universities and PRIs often form alliances; this is a good thing, as the two types of organisation are complementary. However, the immediate need to strengthen the research capacities of PRIs engaged in such alliances is less obvious than the need for them to respond to SMEs with innovation competences and help them reduce their innovation-related risks. This need for a clear focus is underlined by the currently low flows of industry money to public research institutes (see Figure 3.1).

3.4. Non-governmental intermediary organisations

As in many other OECD countries, Sweden has a rich landscape of non-governmental organisations that support innovation and R&D activities in one way or another. Some represent the interests of specific groups, such as industry associations, trade unions and professions, and seek to influence public policy on innovation. Others, including private foundations and medical charities, provide funding for R&D. There is also a widely distributed network of incubators, science parks and other support organisations for entrepreneurship and innovation. Given the large number of intermediary organisations in Sweden, only a few are briefly covered here.

Industry associations

The Confederation of Swedish Industries (*Svenskt Näringsliv*) is Sweden's largest business federation. It represents 49 member organisations and 60 000 member companies employing over 1.6 million people. Member organisations are a mix of industry associations and employer trade associations.[14] The Confederation seeks to influence politicians and other decisions makers to achieve a better business climate and has a keen interest in seeing improvements to Sweden's education and research system, including greater attention to entrepreneurship education.

The Association of Swedish Engineering Industries (*Teknikföretagen*) is a prominent example of an employer trade association with a strong emphasis on technological innovation. It has 3 500 member companies with 300 000 employees. Its stated mission is to know the needs of its members and to represent these in relevant policy dialogue. It works on a range of issues, notably improving the efficiency of Swedish R&D, supporting co-operation between education institutes and industry, and inspiring young people to pursue engineering careers. For example, in collaboration with several partner organisations, including VINNOVA, the Association developed a research agenda, *Swedish Production Research 2020* (Teknikföretagen, 2009), which identified the need for more co-ordinated research in the production sector. This project served to bring together representatives from industry, academia, research institutes and research funding agencies to identify and implement strategic projects in both established and new areas of production. More recently, the Association formulated a policy agenda, the Industrial Policy Programme (Teknikföretagen, 2011), to strengthen innovation through a range of measures, including labour market reforms and changes to the education system.

Almega represents the services sector. It has 10 000 member companies employing some 500 000 people. As with similar organisations in other sectors, Almega supports its members in their relations with trade unions and seeks to shape public policy agendas, particularly on issues of skills development and labour market regulations. It also has a strong interest in promoting the notion of services innovation and in making better known the close relationship between Swedish manufacturing and services. For example, it published a report (Edquist, 2011) highlighting a structural shift in the Swedish economy since the mid-1990s whereby investment in intangible assets has become increasingly important for productivity growth. While productivity growth in Swedish manufacturing has been particularly impressive, the report argues that intangible investment in knowledge-intensive services has played an important role in this growth. The report concludes that it is not manufacturing alone but the interaction between manufacturing and services that has been crucial for the Swedish economy's strong productivity performance since 1995. Almega has to make this point often to ensure that policy debates are not framed in terms of support for manufacturing *or* services but are instead sensitive to the interdependencies between them. More recently, as part of its input to the government's 2012 Research and Innovation Bill, Almega published a report (*Tjänsteinnovationer – för ökad konkurrenskraft*) highlighting the importance of innovation in services and setting out a number of priorities for research in the field.

Professional associations

Founded in 1739, the Royal Swedish Academy of Sciences (*KVA – Kungliga Vetenskaps Akademien*) is an independent organisation whose overall objective is to promote the sciences and strengthen their influence in society. The Academy is perhaps best known internationally for its awards for prominent contributions to research: it grants the Nobel Prizes in Physics and Chemistry and the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (Box 3.10). At a national (and increasingly European and global level), the Academy seeks to act as a voice for science and influence research policy priorities. For example, in the run-up to the new 2012 Research and Innovation Policy Bill, the Academy called on the government to provide quality assurance for government research appropriations; ensure long-term co-ordination of Swedish research policy; work to strengthen basic research in Europe; foster academic mobility and the long-term supply of knowledge; invest in individual creative researchers; improve infrastructure; and rehabilitate know-how in mathematics, natural sciences and technology (KVA, 2011). More recently, the Academy has published a comparative study chronicling Sweden's decline in fostering breakthrough research (Öquist and Benner, 2012). The Academy also works to stimulate interest in mathematics and the natural sciences in schools and supports young researchers.

Box 3.10. Nobel prizes

The Nobel Prize is the world-renowned award for physics, chemistry, physiology or medicine, literature and peace which is given to individuals for their intellectual achievements. It has its source in the last will and testament of the Swedish chemist and industrialist Alfred Nobel (1833-96). Since 1969 the Prize in Economic Sciences in Memory of Alfred Nobel is awarded by the Royal Swedish Academy of Sciences on the same principles as those applied to the five Nobel Prizes that have been awarded since 1901. Swedish institutes generally play a prominent role in the selection process and award ceremony. The institute responsible for the selection of the Nobel laureates in physics and chemistry is the approximately 600 member strong Royal Swedish Academy of Sciences, for physiology or medicine it is the Karolinska Institutet, and for literature it is the 18 member Swedish Academy. The Nobel Peace Prize is in the responsibility of the Norwegian Nobel Committee. Between 1901 and 2011, the Nobel Prizes and the Prize in Economic Sciences were awarded 549 times to 853 Nobel laureates (23 organisations and 830 laureates, only 43 of whom have been women). The countries with the most Nobel Prizes are the United States, the United Kingdom, Germany, France, Sweden and Switzerland. The Nobel Prize helps to put Sweden firmly on the global science map.

The Royal Swedish Academy of Engineering Sciences (*IVA – Kungliga Ingenjörs Vetenskaps Akademien*) was founded in 1919 and is the world's oldest academy of engineering sciences. It describes itself as a "bridge builder" to promote cross-fertilisation among industry, academia, public administration and various interest groups. It does this through a range of activities, including conferences and research projects. It is built around an expert network of close to 1 000 distinguished engineers and economists from business and industry, education and public administration. Its reports are highly regarded and often take a long-term perspective. IVA has been responsible for leading several technology foresight studies over the last decade, often in partnership with other interested actors. In recent years, it has led the *Innovation for Growth* dialogue, which provided inputs to the government's Innovation Strategy process and culminated in the publication of *Innovation Plan Sweden* (IVA, 2011), and has initiated a large project on a future research agenda for Sweden (Box 3.11).

Box 3.11. IVA's Agenda for Research project (2010-12)

In 2010, IVA initiated a three-year project, *Agenda for Research*, to discuss the long-term strengthening of research and innovation in Sweden. The project provides a forum for discussion of research policy issues between elected officials in the government and in Parliament, research funders, organisations that conduct research (universities and public research institutes) and users of research results (trade and industry, the public sector and non-governmental organisations). The aim is to help move research and innovation issues higher up on the political agenda. Discussion is based on existing reports and on studies commissioned when target groups saw a need for further analysis. These include *University of the Future*, *Research and Innovation Foresight, Sweden and European Research*, and *Prioritising Research and Innovation*. Through this process, the project has generated inputs to the government's 2012 Research and Innovation Policy Bill. Roundtable discussions, hearings and seminars are also important components of the project.

Source: IVA website, *www.iva.se.*

Private foundations funding research

Taken together, private non-profit organisations contribute around EUR 230 million to Swedish research.[15] According to one source (European Foundation Centre, 2009, pp. 95 *ff.*), around 2 000 foundations support research in Sweden in some way. This study claims that EUR 400 million in R&D funding is provided by private foundations, although the figure includes the wage-owner funds' foundations, which are best described as semi-public (see Chapter 4). Even if these last funds are discounted, the amount is very high in a comparative European context and puts Sweden at the forefront in philanthropic funding of research. The study suggests that the number of foundations is more or less the same as in the much bigger United Kingdom.

Prominent among Swedish foundations are the various Wallenberg Foundations created by members of the powerful industry and banking dynasty. The largest and most important is the Knut and Alice Wallenberg Foundation (KAW), which dates from 1917. KAW can currently spend nearly SEK 1 billion a year, mainly on larger research projects and major infrastructure investments, complemented by scholarships and fellowships and strategic projects. KAW is therefore a major actor in the Swedish research funding landscape. The larger projects and infrastructure funding are evaluated externally and are preceded by joint planning activities with the universities. Major funding initiatives (though not in the form of thematic programmes) include genomics, proteomics, neurosciences, ICT and bioengineering. In contrast to most other Swedish research funders (see Chapter 4), KAW puts no emphasis on co-financing activities with other funding sources (Forskning.se, 2010, p. 23). Besides KAW, half a dozen other Wallenberg Foundations support different kinds of activities and projects in research and higher education.

The Swedish Cancer Society can distribute nearly EUR 40 million a year for oncological research and finances a large number of projects each year. Other notable foundations focus on clinical research on childhood cancers or heart-lung diseases. These medical foundations are organised as fundraisers (Forskning.se, 2010, pp. 20-22). Besides these larger actors, many other smaller and mid-sized private foundations, such as the Söderberg Foundation or Kempe Foundation, provide funding for different kinds of research.

Incubation and entrepreneurship support

Swedish Incubators & Science Parks (SISP)[16] is a member-based, non-profit association of Sweden's incubators and science parks. SISP was founded in 2005 through a merger of two voluntary organisations, SwedSpin (incubators) and Swede Park (science parks). SISP has 65 member organisations which seek to act as nodes in regional Swedish innovation systems. Its members include over 5 000 companies employing more than 72 000 people. Swedish incubators provide dedicated business support services to start-up and early-stage firms. They evaluate approximately 4 000 business ideas a year and have almost 800 companies in their environments employing around 3 500 people. Some 150 of these firms annually attract venture capital funding. Swedish science parks seek to stimulate the flow of technology and knowledge among university research departments, technology development institutes and firms. They are connected to more than 4 000 companies, most of which are SMEs. However, there is a growing trend to connect to large firms which seek access to "open innovation" arenas that the science parks can provide.

The Swedish Entrepreneurship Forum describes itself as a network organisation for generating and transferring policy-relevant research in the field of entrepreneurship and small enterprise development. It aims to serve as a bridge between the small business research community and the various actors concerned with development of new and small enterprises. It has recently published reports on topics such as venture capital, the role of entrepreneurship and innovation in economic growth, and barriers to the adoption of ICTs in SMEs.

The Forum for Social Innovation Sweden is a meeting place for academia, industry, government, civic society and non-profit organisations to come together to create an understanding of social innovation and social entrepreneurship and how it can contribute to Swedish and global development. The Forum is a collaborative effort supported by some 20 stakeholder groups, including national funding agencies, local authorities, universities and large firms. It focuses on areas such as sustainable urban development, rural development, leadership, social financing and corporate social responsibility.The Forum develops joint projects, partnerships and new products and services. It supports, scales up and disseminates social innovations and supports social entrepreneurs working in the field.

3.5. Human resources for science, technology and innovation

Human resources are a main pillar of knowledge-based economies and as such are a major concern of innovation policy. Box 3.12 highlights the many ways in which human resources spur innovation and points to the importance of a broad set of knowledge and skills beyond science and engineering. These broad human resources can be built and accumulated through education and training, work-place experience, and international migration, for example. Existing human resources, particularly women, can also often be better utilised in research and innovation. This section discusses Sweden's stock of human capital and the roles of education, migration and gender equality in renewing and making use of it.

Box 3.12. How do human resources spur innovation?

Generating new knowledge

Skilled people generate knowledge that can be used to create and introduce an innovation. For instance, Carlino and Hunt (2009) found that the presence of an educated workforce is the decisive factor in the inventive output of American cities; a 10% increase in the share of the workforce with at least a college degree raises (quality-adjusted) patenting per capita by about 10%. Data on Spanish regions also found a positive relationship between levels of human capital and the number of patent applications (Gumbau-Albert and Maudos, 2009). In an alternative approach, using "new work" (*i.e.* new statistical occupational categories) as an indicator of innovation, Lin (2009) found that locations with a high share of college graduates have more jobs requiring new combinations of activities or techniques. Such jobs appeared in the labour market along with the application of new technologies and knowledge.

Adopting and adapting existing ideas

For many countries, incremental innovations involving modifications and improvements to existing products, processes and systems can represent the bulk of innovation activity and can have great significance for productivity and the quality of goods or services. Higher skill levels raise economies' absorptive capacities and ability to perform incremental innovation by enabling people to understand how things work and how ideas or technologies can be improved or applied to other areas. Importantly, skills for adoption and adaptation are beneficial across the wider workforce and population, not just in R&D teams. Toner (2007) argued that the production workforce plays a particularly strong role in incremental innovation when management encourages and acts on suggestions for improvement. Skills and absorptive capacity are also required in functions and activities such as marketing. At the same time, more skilled users and consumers of products and services can contribute to the adaptation of existing offerings by providing the supplier with ideas for improvement.

Enabling innovation through capacity to learn

Skilled people have a greater ability to learn new skills, to adapt to changing circumstances and to do things differently. In the workplace, educated workers have a better set of tools and a more solid base for further "learning", thereby enhancing their ability to contribute to innovation. Leiponen (2000) found that, in contrast to non-innovating firms, innovators' profitability was significantly influenced by the amount of higher education, higher technical skills and research skills possessed by employees.

Complementing other inputs to innovation

By interacting with other inputs to the innovation process, such as capital investment, people with better skills can spur innovation. For instance, Australian research has shown that human capital complements investment in ICTs, with the uptake and productive use of ICTs significantly influenced by management and employee skills (Gretton *et al*., 2004). A Canadian study found that a firm's human resource strategy, as well as its innovation strategy and business practices, influenced the extent to which it adopted new advanced technologies (Baldwin *et al*., 2004). Equally, because of its complementary nature, a firm's lack of human capital is likely to exacerbate other constraints on innovation. Mohnen and Röller (2001) concluded that measures aimed at removing barriers to innovation may be more effective if also explicitly directed at increasing levels of internal human capital.

Generating spillovers

Human capital can contribute indirectly to innovation through the "spillovers" generated by skilled people. For instance, not only do skilled workers diffuse their knowledge throughout their workplace and the wider environment, they may also, through their interactions and their explicit or implicit actions as role models, spur faster human capital accumulation by other workers. Both of these factors can spur innovation through the spread of ideas and the upgrading of competencies. It has also been suggested that entrepreneurs "spill" knowledge by commercialising ideas that would otherwise not be pursued within the organisational structure of an existing firm (Acs *et al*., 2009).

…/…

Box 3.12. How do human resources spur innovation? *(continued)*

Contributing to social capital

Higher levels of human capital enhance social capital, and social capital can support innovation in several ways, predominantly through its effect on trust, shared norms and networking, which improve the efficiency and exchange of knowledge. Some studies suggest that improved levels of trust can promote venture capital financing of risky projects, owing to factors such as reduced monitoring costs (Akçomak and ter Weel, 2009). Closer relationships between actors can lead to the exchange of proprietary information and underpin more formal ties (Powell and Grodal, 2005), while social networks may also enable firms to work through problems and get feedback more easily, thereby increasing learning and the discovery of new combinations (Uzzi, 1997). Firms with higher levels of social capital are more likely to engage specialist knowledge providers, such as the public science base, to complement their internal innovation activities (Tether and Tajar, 2008). Social capital is also a feature of "invisible colleges" that bind researchers across geographic space in pursuit of common research interests.

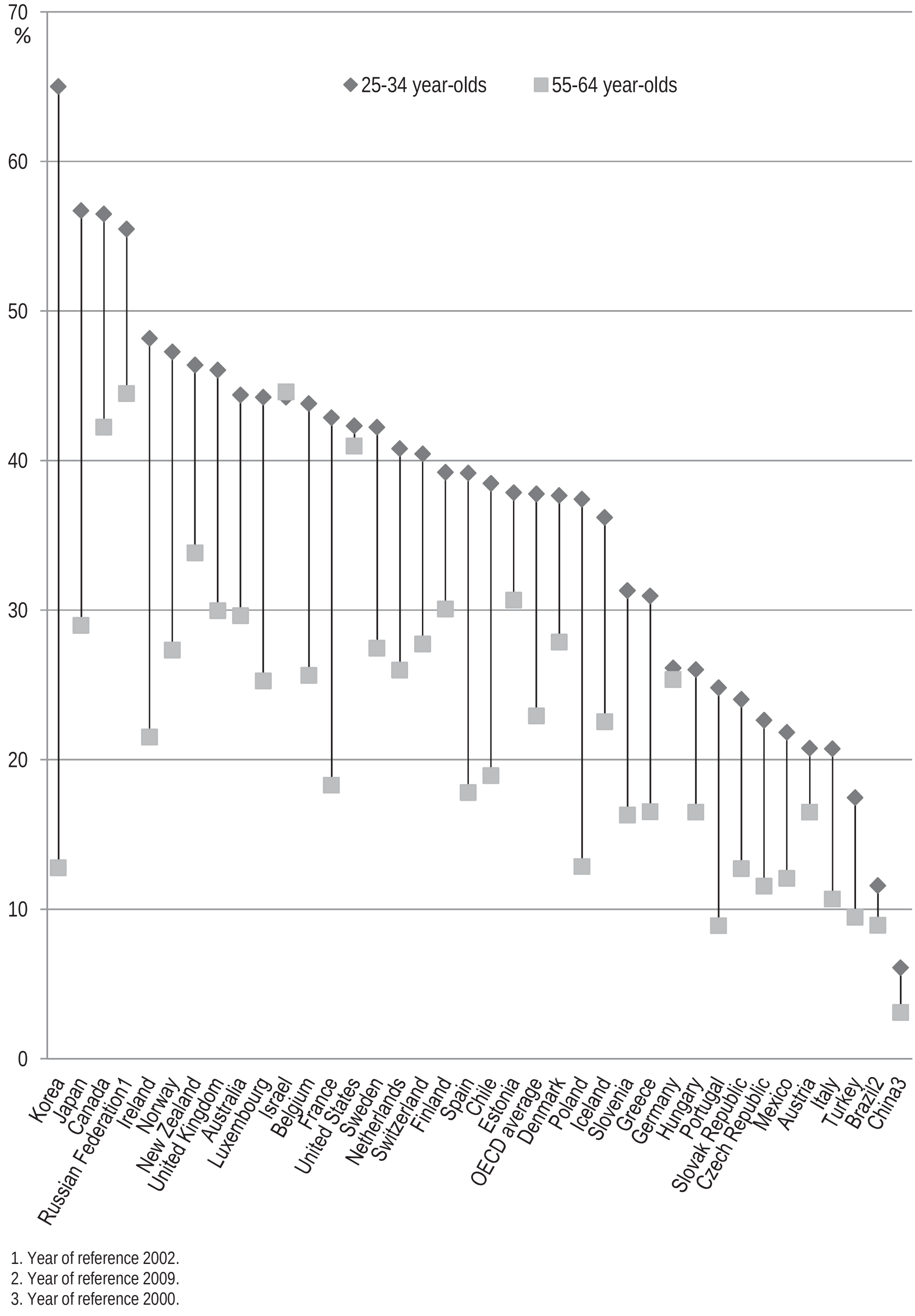
Source: OECD (2011), *Skills for Innovation and Research*, OECD, Paris.

3.5.1. Education and training

Educational attainment is a commonly used proxy for assessing a country's overall performance with respect to human resources and Sweden's position is strong in this respect. In Sweden 34% of adults have a tertiary qualification (2010) compared to an average of 31% across OECD countries. Figure 3.15 shows the share of different population age-groups with tertiary education. For both older and younger cohorts, Sweden is above the OECD averages. Moreover, in 2010, 87% of Swedes between 25 and 64 years of age had attained upper secondary education, significantly above the OECD average of 74% (OECD, 2012). While now more than a decade old, the International Adult Literacy Survey (OECD and Statistics Canada, 2000) found that Sweden had the highest level of adult literacy among the 20 countries surveyed and the narrowest distribution of literacy skills.

One way of assessing the recent output and uptake of high-level skills is to consider the number of graduates in science-related fields (science and engineering, manufacturing and construction) per 100 000 25-34 year-olds in employment (Figure 3.16). This indicator does not show the number of graduates actually employed in scientific fields or deploying their scientific skills at work, only their presence in the workforce. The indicator ranges from below 1 000 in Hungary to above 3 500 in Korea. At 1 596, Sweden ranks somewhat below the OECD average of 1 829. However, other indicators suggest comparatively stronger performance in science-related human resources: in 2008, of every thousand persons in employment in Sweden 11 were researchers, the fourth highest number in the OECD area. In the same year, a quarter of all new degrees were awarded in science and engineering fields, above the OECD average.

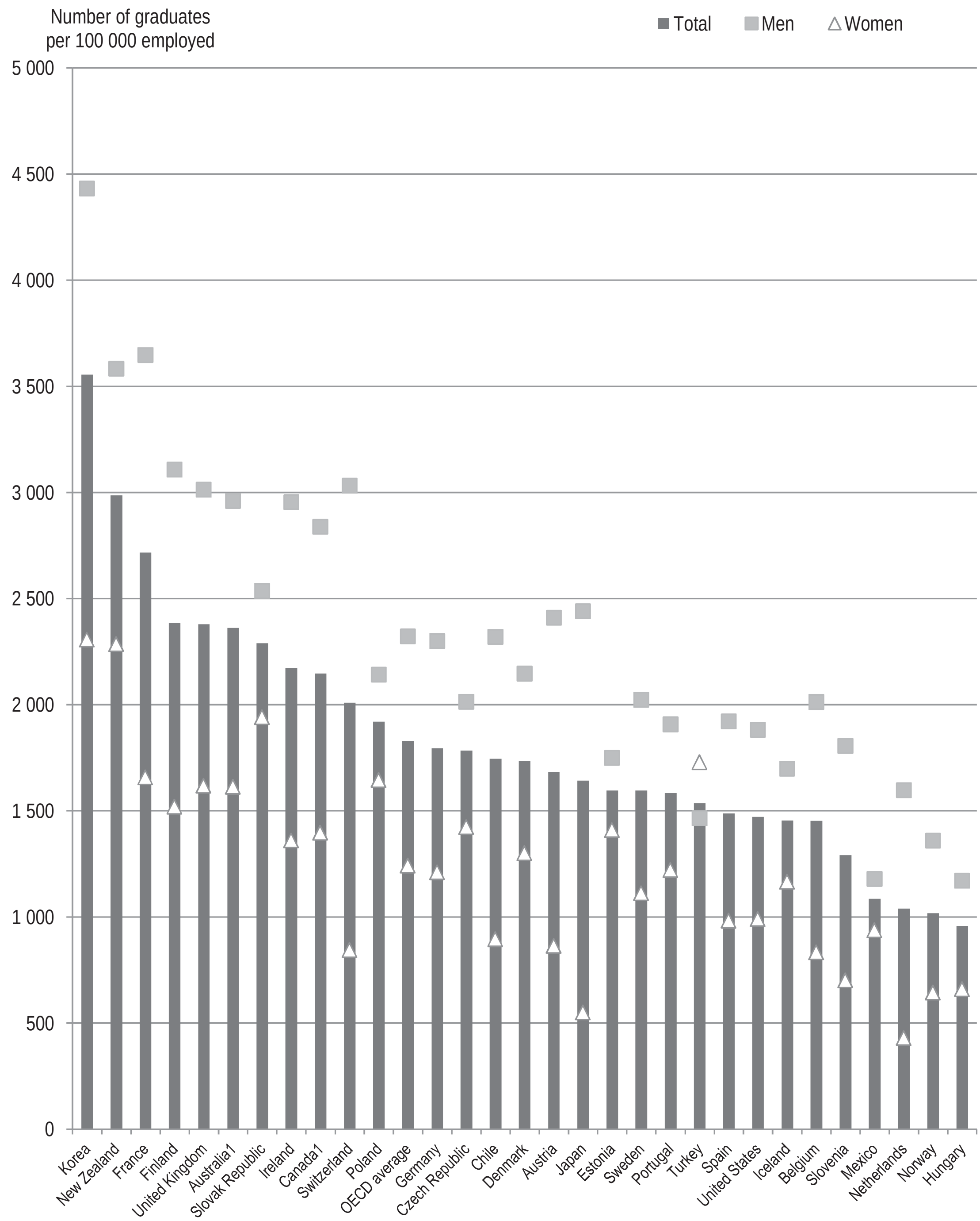
Figure 3.15. Percentage of the population with tertiary education, by age group (2010)



1. Year of reference 2002.
2. Year of reference 2009.
3. Year of reference 2000.

Source: OECD, *Education at a Glance 2012*.

Figure 3.16. Tertiary graduates in science-related fields among 25-34 year-olds in employment, by gender, 2009



Note: Science-related fields include life sciences; physical sciences, mathematics and statistics, computing; engineering and engineering trades, manufacturing and processing, architecture and building.

1. Year of reference 2008 for the number of graduates.

Countries are ranked in descending order of the percentage of tertiary science-related graduates in tertiary-type A programmes per 100 000 employed 25-34 year-olds.

Source: OECD, *Education at a Glance 2011*.

In terms of production of new graduates, 36.3% of the Swedish population aged 20-29 were in tertiary education in 2008, above the EU27 average of 29.8% (Table 3.14). Tertiary students in science, mathematics, computing, engineering, manufacturing and construction account for 24.7% of students, comparable to the EU27 average of 24.3%. However, when broken down, the percentage of tertiary students in science, mathematics and computing is 8.9%, below the EU27 average of 10.3%, but in engineering, manufacturing and construction it is 15.8%, slightly above the EU27 average of 14.1%. The average annual growth rate (AAGR) of tertiary students in all fields and in science and engineering (S&E) during 2003-08 is negative for Sweden with -0.3% AAGR for all fields and -2.3% AAGR for S&E; the EU27 averages are 4.2% and 3.3%, respectively.

Table 3.14. Students participating in tertiary education, total and selected field of study

Share of the population aged 20–29 and of all tertiary students, EU27 and selected countries, 2008

	All fields			**S&E ([1])**			**Science, mathematics and computing**	**Engineering, manufacturing and construction**
	Total number in 1000s	As a % of population aged 20-29	AAGR 2003-2008	As a % of population aged 20-29	As a % of all tertiary students	AAGR 2003-2008	As a % of all tertiary students	As a % of all tertiary students
Austria	285	27.2	4.4	7.0	25.5	4.7	11.6	13.9
Denmark	231	37.2	2.8	6.7	18.0	0.9	8.2	9.8
Finland	310	49.0	1.3	17.6	35.9	0.0	10.9	24.9
France	2 165	28.5	-0.8	7.2	25.3	0.0	12.3	13.0
Germany	2 245	23.3	0.2	7.2	31.0	0.8	15.2	15.8
Italy	2 014	30.1	1.1	6.9	22.9	0.2	7.6	15.3
Netherlands	602	30.8	2.8	4.4	14.3	0.3	6.2	8.1
Norway	213	36.1	0.2	5.8	16.0	-1.9	8.5	7.5
Sweden	**407**	**36.3**	**-0.3**	**9.0**	**24.7**	**-2.3**	**8.9**	**15.8**
Switzerland	224	24.0	5.5	5.4	22.7	1.6	9.9	12.7
United Kingdom	2 329	28.7	0.4	6.1	21.1	0.3	12.9	8.2
EU-27	**19 040**	**29.8**	**4.2**	**7.3**	**24.3**	**3.3**	**10.3**	**14.1**

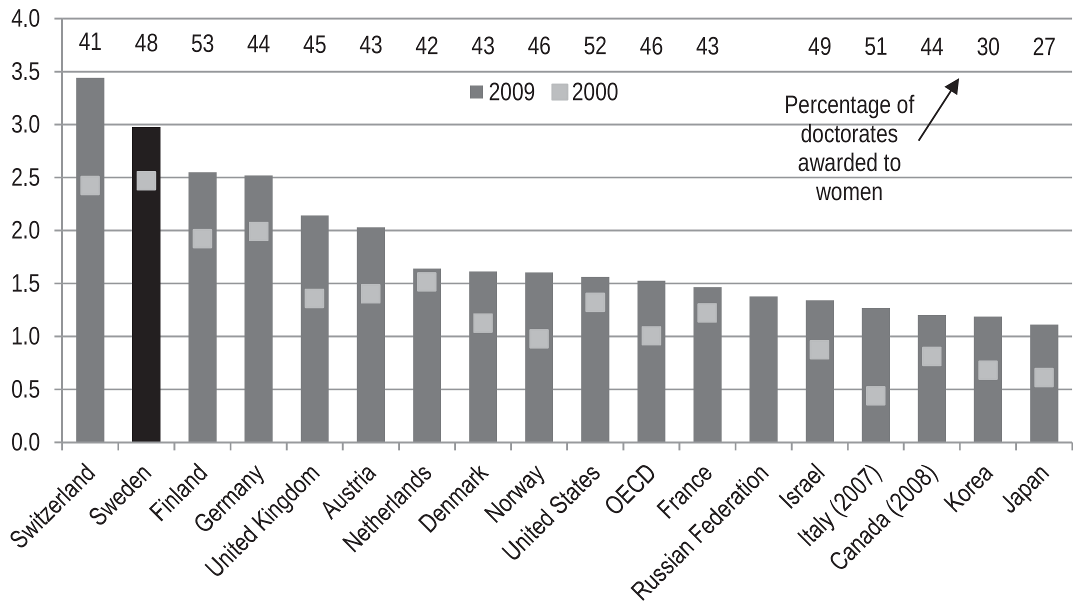
1. S&E = science, mathematics, computing + engineering, manufacturing and construction.

Sources: Eurostat (2011c), p. 61 and for AAGR p. 63.

Sweden has relatively high graduation rates at the doctoral level (Figure 3.17). Among comparator countries, Sweden had the highest and second-highest (behind Switzerland) rates for 2000 and 2009, respectively. Sweden's rate of doctorates increased over time from 2.5% in 2000 to 3% in 2009, an increase analogous to that of most other comparator countries. Switzerland and Italy and to a lesser extent the United Kingdom and Norway stand out as the countries with the largest gains. Sweden also compares very favourably in terms of gender equality (defined as the absolute difference from 50%), with female graduates accounting for 48% of total graduates, only marginally behind Israel and Italy.

Figure 3.17. Graduation rates at the doctoral level, 2000 and 2009

As a percentage of the population in the reference age cohort

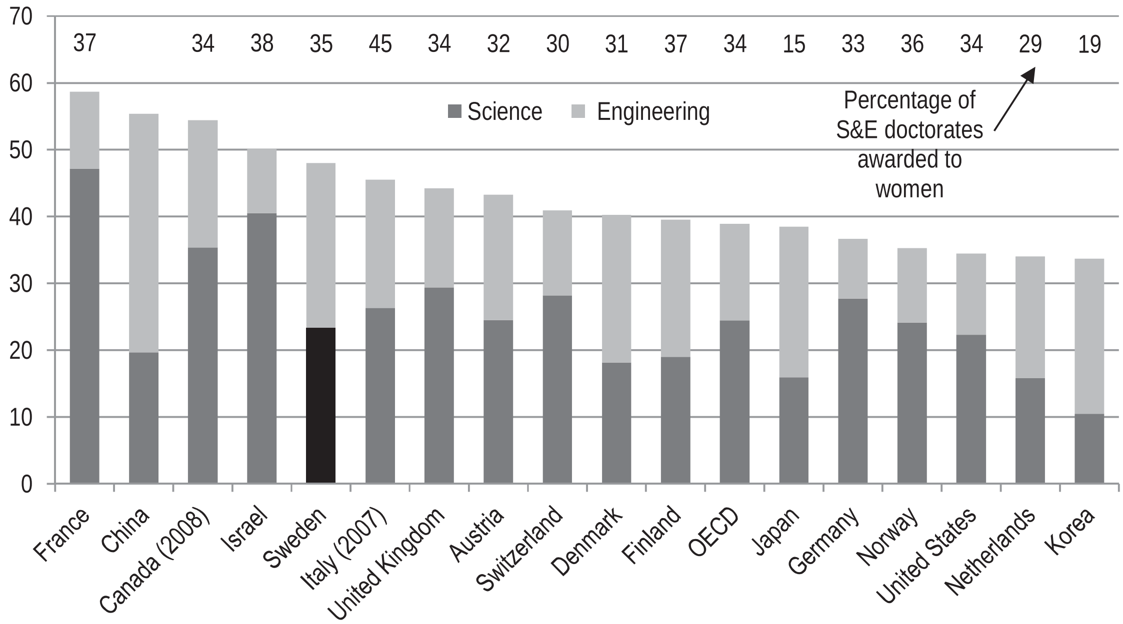


Source: OECD Science, Technology and Industry Scoreboard 2011, p. 68, based on OECD (2011), *Education at a Glance 2011: OECD Indicators* and (2009) *Education at a Glance 2009: OECD Indicators*, OECD, Paris.

The share of science and engineering doctoral graduates in Sweden in high, but lower than in countries such as France, China, Canada and Israel. In 2009, 48% of graduates at the doctoral level had completed either a science or engineering degree (Figure 3.18). The share of students graduating in engineering is particularly high, but in science (23.3%) it is below the OECD average of 24.4%. Across countries, women are less well represented in science and engineering doctorates; this is also true in Sweden, where women are awarded only 35% of S&E doctorates, compared to 48% across all subject areas. Italy and Israel, but also France and Finland, have a distribution that is closer to gender parity than Sweden.

Figure 3.18. Science and engineering graduates at the doctoral level, 2009

As a percentage of all new degrees awarded at the doctoral level

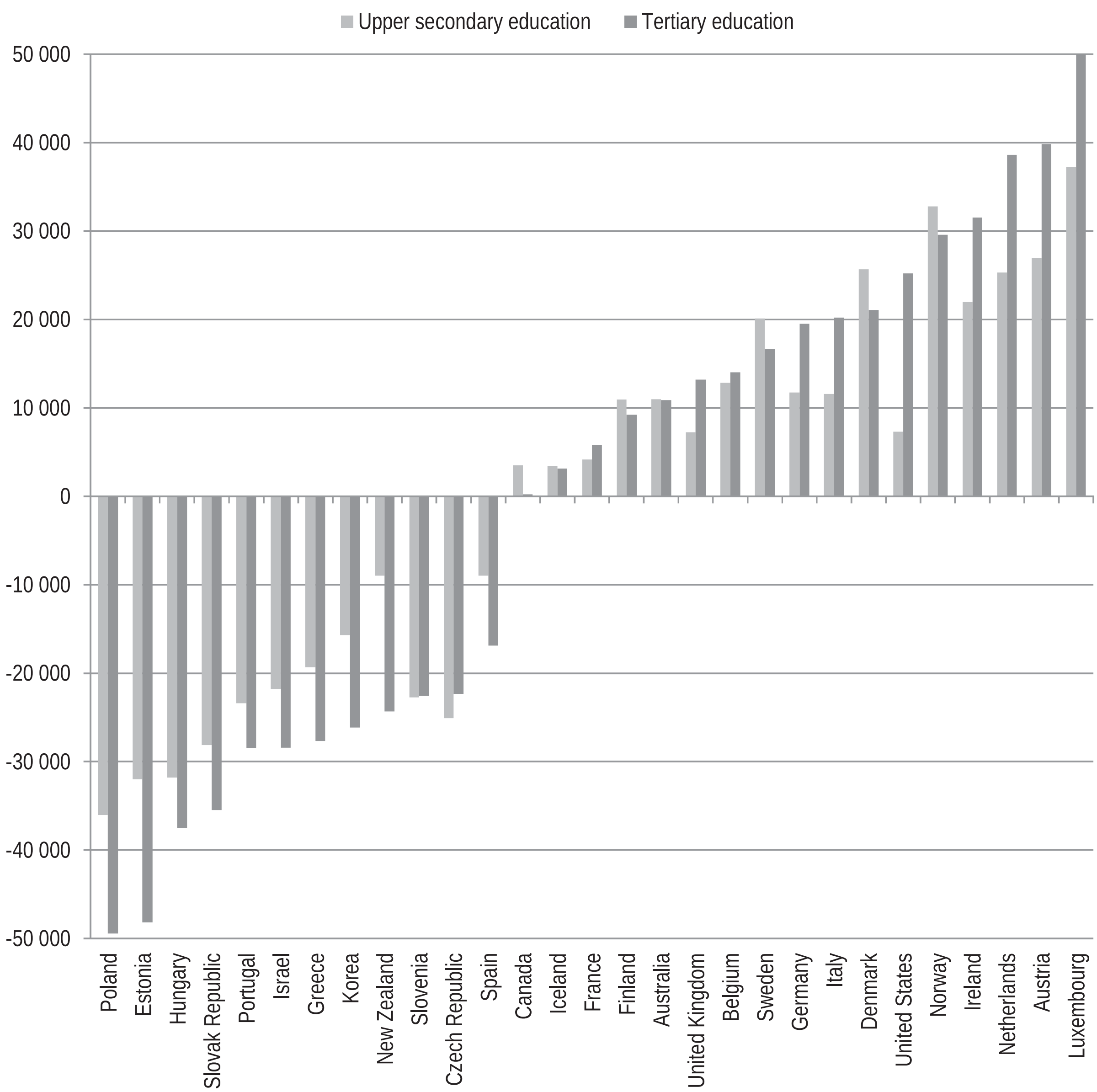


Source: *OECD Science, Technology and Industry Scoreboard 2011*, p. 69, based on OECD Education Database, September 2011 and OECD calculations based on national sources, May 2011.

Some employers indicated to the OECD review team that Swedish companies face a shortage of engineers. This claim was disputed by people working in education. No empirical evidence to determine whether the purported shortages are real or significant was available to the team. Nevertheless, there is an ongoing debate in Sweden regarding salaries for engineers. Some argue that large companies in particular need to make salaries more attractive to increase the supply of engineers. One way to consider this issue is to compare cost structures across countries. Figure 3.19 shows cross-country variations in the price of labour by educational attainment. For those with upper secondary and tertiary education, the height of the bars indicates the difference in average earnings from the OECD average for persons in the two categories of educational attainment (on average, across the OECD, annual labour costs for men and women with an upper secondary education are USD 46 000; for those with tertiary education they are USD 68 000). For Sweden, Figure 3.19 shows that the annual average cost of employing persons with upper secondary education is about USD 20 000 higher than the OECD average. The cost of employing persons with tertiary education is also higher than the OECD average, but by a smaller margin (some USD 17 000). Stated differently, from an OECD perspective, Swedish individuals with tertiary education (as well as those in Belgium, Denmark and Finland) are less expensive to employ than those with less education. A compressed wage structure and strong labour unions may help to explain these results. As these data are not occupation-specific, they cannot shed light directly on a possible scarcity of engineers. But they do indicate that remuneration of the better educated – possibly including engineers – might not be as attractive in Sweden as in some other countries. In the context of an increasingly internationally integrated labour market – in which the more skilled are also more mobile – this could affect the labour supply.

Figure 3.19. Deviation from the OECD mean in annual labour costs, by educational attainment

In equivalent USD for the 25-64 year-old population

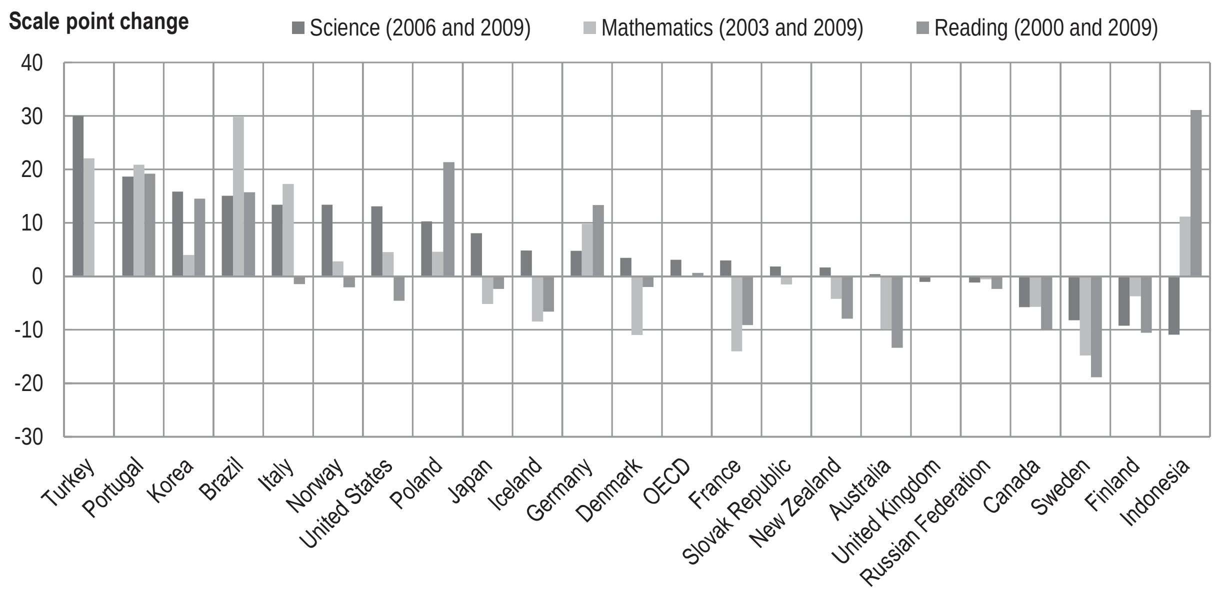


Countries are ranked in ascending order of the deviation from the OECD mean in annual labour costs of tertiary educated individuals.

Source: OECD, LSO Network special data collection on full time, full year earnings, Economic Working Group. Table A10.1. See Annex 3 for notes (*www.oecd.org/edu/eag2011*).

There are also some problematic developments in earlier stages of education in Sweden. Specifically, as measured in international surveys such as PIRLS, TIMMS and PISA, educational results in Swedish schools have been declining since the mid-1990s in all subjects.[17] Results have worsened most in upper secondary schools and in mathematics and science. Figure 3.20 shows evidence of strong performance declines in all three areas (science, mathematics and reading) in Sweden's PISA performance over the last decade or so.

Figure 3.20. Changes in PISA performance, 2009.



Source: OECD (2010), *PISA 2009 at a Glance,* OECD, Paris.

Sweden invests heavily in education. It allocated 7.3% of GDP to education in 2010 (including R&D in HEIs), compared to the OECD average of 5.8%, a share that has been increasing since the mid-1990s. In 2010, Sweden spent USD 11 400 per student from primary to tertiary education, more than USD 2 000 more per student than the OECD average (OECD, 2012). Financing of education is therefore unlikely to be an important factor in explaining declining student performance. There is, however, evidence that for some years the teaching profession has become a less attractive vocation, with high-performing students opting for studies other than teaching (Swedish Fiscal Policy Council, 2011). This has also led to shifts in the age distribution of teachers in secondary schools: in 2010, less than 7% of teachers were younger than 30 and around 41% were older than 50. This is a serious challenge for Sweden, and several reforms are attempting to make the teaching profession more attractive (Box 3.13).

Box 3.13. Making teaching more attractive

Between 2000 and 2010, teachers' salaries increased by an average of 22% across all OECD countries, while in Sweden, they increased by only 8%. Except for starting salaries, there is a wide gap between teachers' salaries in Sweden and the OECD average. The starting salary for a primary school teacher is USD 28 937, just above the OECD average of USD 28 523. However, after ten years of experience, Swedish primary school teachers earn USD 32 182 (the OECD average is USD 34 968); and at the top of the pay scale, Swedish teachers earn USD 38 696 compared to the OECD average of USD 45 100. At the same time, the total statutory working time for teachers in Sweden is one the highest in the world, although the ratio of students to teaching staff in primary and secondary education is far below the OECD average. Sweden is implementing reforms to raise the status of the teaching profession by focusing on continuous professional development and by launching a campaign to attract teachers. Additional resources of up to SEK 3.8 billion have been allocated in the 2011 budget bill to "break the downward trend in learning outcomes among Swedish pupils" (Swedish Government, 2011). In the bill, the government also proposes to explore the prerequisites for implementing a state-financed incentive payment.

Source: OECD (2012).

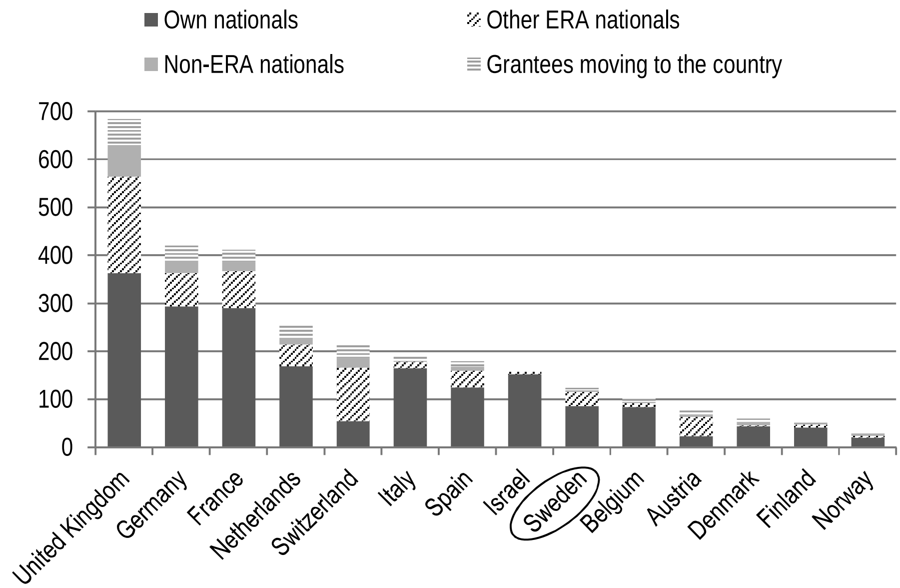
Public provision of adult education (AE) at compulsory, secondary and tertiary levels is relatively generous (Stenberg, 2012). Since 1974 employees have a legal right to leave for study purposes, as well as to reinstatement with equal working conditions and wages. Since 1969 municipalities must by law offer AE at compulsory and upper secondary level. Publicly funded schooling is free of charge and full-time students are entitled to some degree of financial support. Those undertaking AE on at least a 50% full-time basis are entitled to study allowances. However, the OECD (2011b) points out that the dual system of employment protection legislation (EPL), with high protection for workers with permanent contracts but low protection for workers with temporary contracts, could hinder investment in human capital, given that firms have less incentive to provide temporary workers with on-the-job training. Sweden also helps disadvantaged populations to access science and technology education by offering science classes to persons with grades that are too low to enter university. After completing one year (and passing the exams) a place at university in natural science or engineering is guaranteed.

3.5.2. International migration of human resources for S&T and innovation

Migration of highly skilled human resources contributes to the creation and diffusion of knowledge. An inflow of talent can increase R&D and economic activity, improve knowledge flows and collaboration with sending countries, and lead to firm and job creation by immigrant entrepreneurs. In addition to economic incentives, other factors contribute to flows of the highly skilled, such as high-quality research infrastructure and the opportunity to work with "star" scientists. Language and quality of life issues are also important considerations (OECD, 2008).

Swedish universities could profit from higher mobility of human resources within Sweden as well as internationally. As mentioned above, 58% of Swedish faculty members have their PhD from their own university (Aghion *et al*., 2008), owing to a model of lifelong employment after a few years at an HEI instead of a tenure track model. High-quality inward mobility may also be an issue. For example, the proportion of non-Swedish-born Swedish ERC grantees is comparable to that of other prominent European science nations such as Germany, France, the Netherlands and Spain, each of which has around 30% of internationals among their ERC grantees. However, Figure 3.21 shows how effective Switzerland, Austria and the United Kingdom have been in attracting top international researchers who obtain ERC grants, mostly long before they win a grant (see also Edler *et al*., 2012).

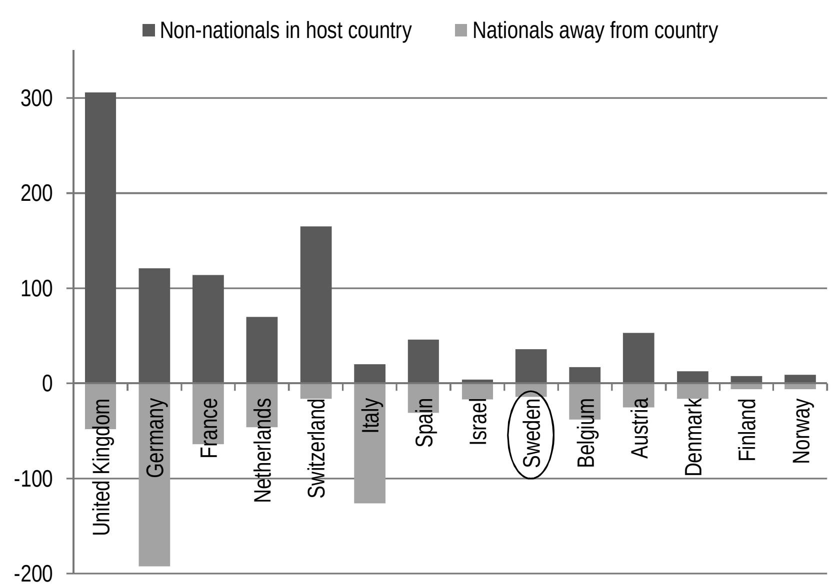
Figure 3.21. Origin of grantees in ERC Starting & Advanced Grant calls, 2007-11



Source: ERC data information, September 2012.

Figure 3.22 shows that the flow of ERC grantees in and out of Sweden is significantly lower than in comparator science countries, such as Switzerland. Still Sweden has at least a net gain of excellent researchers, attracting more than twice as many nationals as Swedish nationals leaving the country. For Italy, Germany and Belgium the difference between non-nationals in the host country and nationals away from the country is clearly negative, while in Denmark, Finland and Norway, the in and out flow results in neither a net gain nor a net loss.

Figure 3.22. International exchange of researchers in ERC Starting & Advanced Grant calls, 2007-11



Source: ERC data information, September 2012.

A global survey of scientists in four disciplines (Franzoni *et al*., 2012) places Sweden fifth among 16 countries in terms of where respondents were at age 18 ("country of origin"). Switzerland leads with more than 56% of scientists who were not in the country at that age (Germans form one of Switzerland's most geographically concentrated groups). Canada and Australia form the next groups (both around 45%) followed by the United States (38%) and Sweden (38%). While these are survey results, not national statistics, the numbers suggest that Sweden is internationally more attractive than Denmark or Germany. Another survey asking researchers working across Europe about preferred countries for future mobility ranks Sweden in the middle group, with Switzerland and the Netherlands well ahead (Reinstaller *et al*., 2012, pp. 112 *ff*.).[18]

Another aspect of mobility concerns the attractiveness of studying in Swedish universities for foreign students. Since 2011, students from countries outside the European Economic Area (EEA) and Switzerland have been charged the full costs of their chosen study programme. Previously, they were treated like their Swedish counterparts and did not have to pay tuition fees. This reform has further spurred discussions of *mångfald* (diversification of the student body), including its internationalisation. Recent data from the Swedish National Agency for Higher Education show an almost 90% fall in new entrants from non-EEA countries following the introduction of tuition fees (Table 3.15). As tertiary-level overseas students can represent an important source of human capital, the impact of this move will need to be closely monitored.

Table 3.15. New entrants to Swedish higher education institutes from abroad, 2010 and 2011

	2010 autumn intake	2011 autumn intake	Percentage change
EEA countries and Switzerland	1 391	1 763	+27
Other countries	7 564	1 601	-89

Note: Data exclude exchange programme students (who are not subject to tuition fees, irrespective of country of origin).

Source: Swedish National Agency for Higher Education (2012).

3.5.3. The status of women in Swedish research

According to *Gender Challenge in Research Funding* (European Commission, 2009b), Sweden is classified as a country with a very active policy to strengthen the representation of women in science and is considered, along with the other Nordic countries, among the global leaders in gender equality. In 2007, around 34% of all Swedish researchers were female compared to an EU average of 32%. However, the hierarchy of R&D occupations shows a clear traditional picture: for all countries and all sectors, the share of male researchers (at the top of the hierarchy) is larger than that of female researchers. On the bottom of the hierarchy the share of female technicians and other support staff exceeds the share of males.

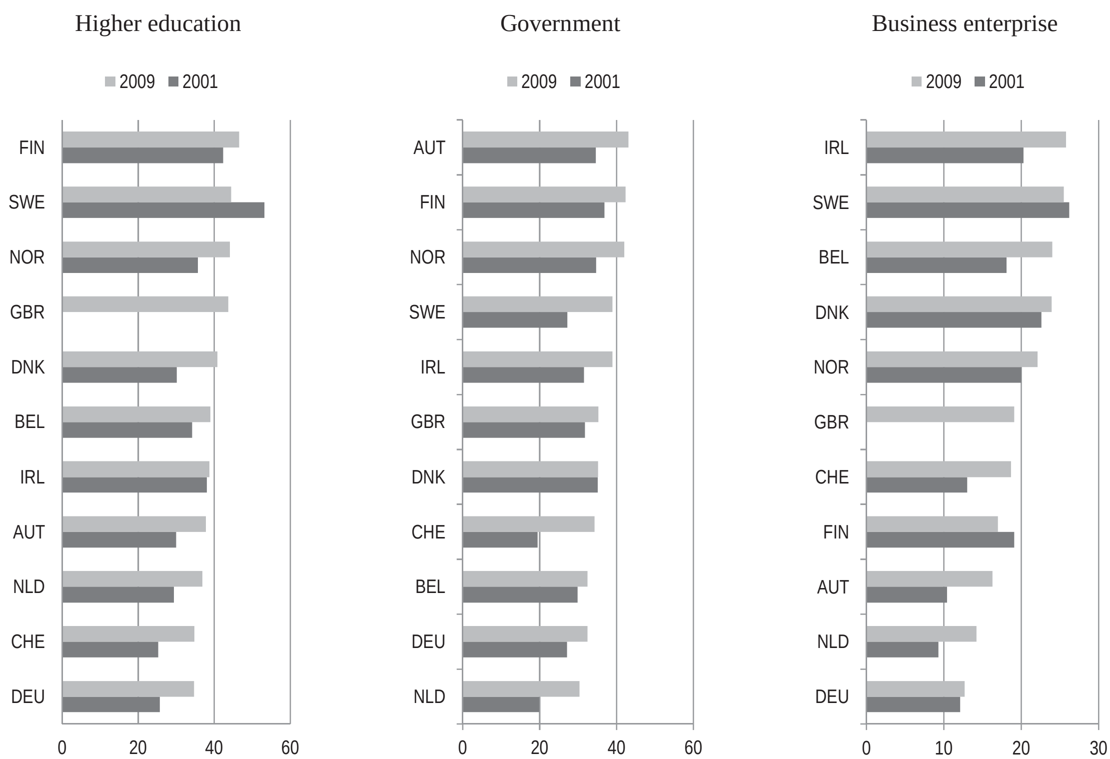
In terms of the share of female students in tertiary education, Sweden's overall share of 60.3% in all fields is above the EU27 average of 55.3%. The share of female students in science and engineering in Sweden is 34.0%, also above the EU27 average of 30.1% (Eurostat, 2011, p. 62). A notable increase in the proportion of female PhD graduates occurred between 2001 and 2008 in nearly all European countries. Norway (+10.4 percentage points), the Netherlands (+10.2 percentage points), Belgium (+10.1 percentage points) and Germany (+6.6 percentage points) show the biggest increases; Sweden's share rose from 39.2% to 44.9% (+5.7 percentage points). The compound annual growth rate of

PhD graduates, by sex, shows that in most countries the growth rate for women exceeds that for men over the period.

In general, the gender gap is closing slowly in the public sector, with the share of women in total research employment growing at a faster rate than the share of men in most European countries. However, major inequalities persist in top academic positions and in the business sector. Sweden ranks high (Figure 3.23) in terms of female researchers in higher education (45%) and in the government (39%). Nonetheless, the percentage of female researchers in higher education was significantly higher in 2000 than in 2009 (at 53%, Sweden ranked first in 2000). The proportion of female researchers in the business sector decreased by less than 1 percentage point between 2000 and 2009, while it increased by almost 12 percentage points in the government sector.

Figure 3.23. Female researchers (headcount) by sector

Females as a percentage of total, 2001 and 2009 or nearest year



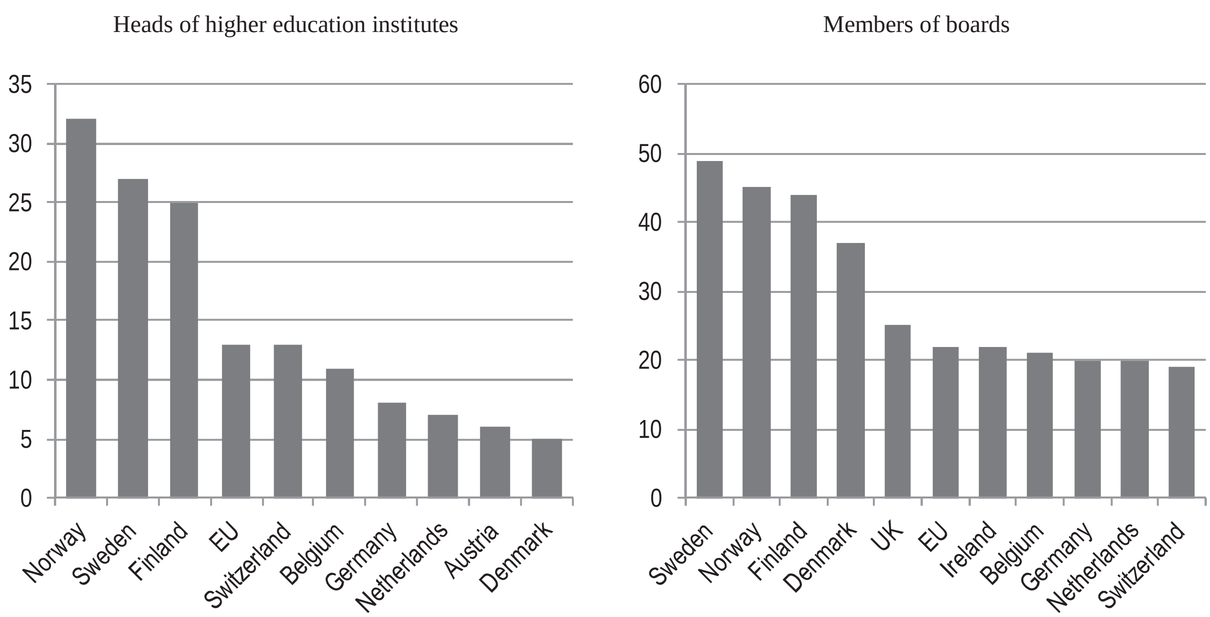
Source: Main Science and Technology Indicators, 2012/1

In Europe, despite the many cross-country differences, female researchers in the higher education sector are more concentrated in medical sciences (Sweden ranks at the top with a 51% share of female researchers in 2008) and less concentrated in engineering.[19] The same is true for Swedish female PhDs and their respective fields. Only 29% of graduates in engineering, manufacturing and construction in 2008 were female. Compared to the EU average (26%) and to the Netherlands, Ireland, Finland, Germany, Denmark, the United Kingdom and Switzerland, Sweden and Norway have the largest shares in this field. Only Belgium (30%) exceeds Sweden. The largest shares of women PhDs as a percentage of total PhD graduates in Sweden are in education

(78%), health and welfare (60%), agriculture and veterinary medicine (56%), and humanities and the arts (52%). Sweden scores lower than the EU average in the humanities and the arts, the social sciences, business and law, and science, mathematics and computing.

In Sweden women hold 18% of academic positions (equivalent to full professor). Only Finland, Switzerland and Norway have a higher proportion (23%, 22%, and 18%, respectively). Norway, Sweden and Finland also rank at the top in terms of women as heads of higher education institutes and on boards (Figure 3.24). This stems from the obligation to have at least 40% of members of each sex on all national research committees and equivalent bodies.

Figure 3.24. Proportion of women in senior positions, 2007



Source: European Commission (2011), pp. 236 *ff*.

Notes

1. Note that 40% of services sector R&D falls under "R&D institutions".

2. The term cluster is used both for the national and for the regional level and the definitions, as often with clusters, are not overly clear.

3. SBA data, in Hytti and Pulkannen (2010). The SMEs are complemented by some 1 000 large firms that employ another million people (36.3%) and contribute 44.2% to overall value added.

4. SEK 15 billion translates into about EUR 1.5 billion. Austrian SMEs have around EUR 1.5 billion in R&D expenditures (Federal Ministry of Science and Research, 2012) provides more detailed information on concentration and shares).

5. Data provided by VINNOVA and sourced from the European Commission's E-CORDA database (https://webgate.ec.europa.eu/e-corda/). Data refer to the period from 2007 (the start of FP7) to 18 October 2012.

6. The remarkably good relative position of companies from countries that are otherwise not among leading innovators (*i.e.* Greece, Cyprus or Portugal) on some IUS SME indicators indicates the possibility of strong national biases.

7. Student numbers based on Inkinen (2011).

8. The comparisons in Ljungberg *et al.* (2009) generally show, unsurprisingly, a big rift between the young and the established universities. The latter have considerably higher budgets, better student-teacher ratios, are better research performers, have some critical mass and can attract more industry money.

9. The authors aim to refute the idea that Swedish academia has an abundance of means for blue-sky research. They show that a lot of the available resources – at least in a technical university – encourage and fund "useful" applied research.

10. This message comes with two caveats: data are for 2003 and some countries with "more expensive" researchers have a higher share of public research institutes.

11. The Austrian Science Fund FWF has compared council budgets per inhabitant: the Swiss SNF leads with EUR 80, followed by the Academy of Finland with EUR 60. The Dutch NWO has more than EUR 40, while the FWF has only a little more than EUR 20. Vetenskapsradet alone can spend more than EUR 40 per inhabitant, and, together with the budgets of Formas, FAS, RJ and parts of the semi-public foundations, this sum is higher by at least 50% (source for the non-Swedish councils: FWF).

12. TTOs are often called TLOs with the "L" standing for licensing. However, Swedish universities do not have much intellectual property to license out.

13. *www.ri.se/en/about-rise/9-challenges.*

14. Industry associations provide information, training and other services to their member companies in their specific industry, sometimes on innovation-related

issues. They also seek to represent the views of their industry in policy debates. Employer trade associations enter into collective agreements with trade unions on issues such as salaries and the general terms and conditions of employment.

15 For more information on these actors, see Vetenskapsrådet (2012).

16 For more information on SISP, see *www.sisp.se*.

17 PISA is the acronym for the *Programme for International Student Assessment*. TIMMS is the *Trends in International Mathematics and Science Study* and PIRLS is the *Progress in International Reading Literacy Study*.

18 See also results of the EU MORE study (IDEA Consult *et al.*, 2010).

19 No data are available for the Swedish government sector.

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From:

OECD Reviews of Innovation Policy: Sweden 2012

Access the complete publication at:

https://doi.org/10.1787/9789264184893-en

Please cite this chapter as:

OECD (2013), “Innovation actors in Sweden”, in *OECD Reviews of Innovation Policy: Sweden 2012*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264184893-7-en