The Swedish Research Barometer 2019

The Swedish Research System in International Comparison

Swedish Research Council

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Foreword

The Swedish Research Council's the Swedish Research Barometer provides an overall description of research and development (R&D) in Sweden, and highlights how Sweden compares internationally as a research nation. In addition, the Swedish Research Barometer places particular focus on the research conducted within the higher education sector in Sweden. The Swedish Research Barometer is now published every two years, and previous editions were published in 2016 and 2017. The purpose of a regularly published report is to describe the changes made to the R&D system in Sweden and internationally.

As previously, this year's edition of the Swedish Research Barometer consists of around thirty indicators, building on statistics from a variety of sources: OECD, Statistics Sweden, Swedish Higher Education Authority, eCORDA and the publication database Web of Science. A novelty is that this year's report consists of three main chapters: research funding, research personnel and scientific publication. Each chapter presents an international comparison of the Swedish R&D system as well as a description with particular focus on the higher education sector in Sweden. The report also includes a new graphic design, as well as an increased usage of fact boxes, which we hope will increase the readability and accessibility of the report.

The report is authored by a group at the Swedish Research Council, consisting of Stina Gerdes Barriere, Jonas Gurell, Maria Lindholm, Peter Lundin, Marianne Wikgren and Gustav Hansson (project manager).

It is my hope, and that of the Swedish Research Council, that the Swedish Research Barometer 2019 will constitute an important source of information and statistics on the Swedish R&D system, and that the report will be used as the basis for discussion about the future of Swedish research. I hope you find it interesting!

Stockholm, 3 june 2019

Sven Stafström
Director General, Swedish Research Council

Summary

The Swedish Research Barometer provides an overall description of Swedish research and development (R&D), and highlights how Sweden compares internationally as a research nation. In addition, the Swedish Research Barometer places particular focus on the Swedish higher education sector. The report consists of three chapters: research funding, research personnel and scientific publication.

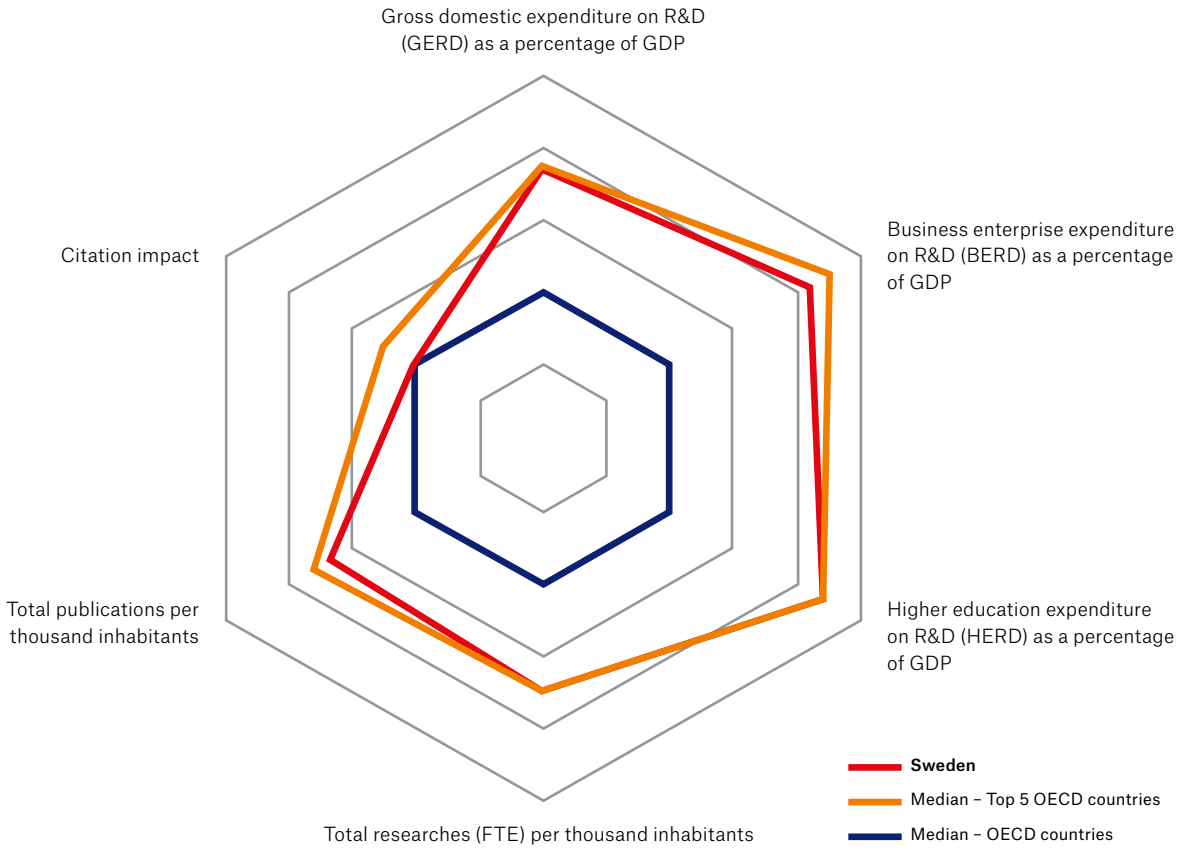


Figure 1. The Swedish research system in international comparison 2017.
Note: Sweden's position is shown in relation to the median value for all OECD countries and the median value for the five top countries in the OECD per indicator (normalised values).[1] Data from 2017 or latest available year. Source: OECD MSTI and Clarivate Analytics.

1 The top countries are the countries with the highest values for each indicator: Gross domestic expenditure on R&D as a percentage of GDP (South Korea, Israel, Switzerland, Sweden and Japan); Business expenditure on R&D as a percentage of GDP (Israel, South Korea, Japan, Switzerland and Sweden); Higher education expenditure on R&D as a percentage of GDP (Denmark, Switzerland, Sweden, Norway and Austria); Percentage of researchers (full time equivalents) per thousand inhabitants (Denmark, Sweden, South Korea, Finland and Iceland); Number of publications per thousand inhabitants (Switzerland, Denmark, Australia, Sweden and Iceland); Citation impact (Switzerland, United Kingdom, USA, Netherlands and Luxembourg).

Swedish research in international comparison

Sweden has long been an internationally prominent research nation, with high R&D intensity, a large percentage of researchers in the population, a large production of scientific publications and with a citation impact above the world average.

The spider diagram in Figure 1 provides an overall picture of Sweden's position in comparison with the OECD and the five countries in the OECD with the highest values for each indicator. The figure brings together six indicators from the three main sections, and shows both the R&D resources (measured as R&D expenditure and number of researchers) and the research performance (measured as number of scientific publications and the citation impact of the publications).

The figure shows that Sweden is one of the five countries in the OECD with the highest R&D expenditure as a percentage of GDP. In this category, Sweden is one of the top five in terms of both overall R&D expenditure and R&D expenditure of the business enterprise sector and higher education sector respectively. Sweden is also one of the five countries in the OECD with the greatest number of researchers in relation to the population. This shows that overall, Sweden is a country that has high research intensity in international comparison.

Sweden is also one of the top five countries in the OECD when it comes to the number of scientific publications in relation to population. On the other hand, Sweden is not one of the top five countries in terms of citation impact. Sweden's citation impact (percentage of highly cited publications) is above the world average, but at the same level as the median for the OECD countries. This means that Sweden is ranked in as number 13 among the countries with the highest citation impact in the world.

Research funding

Sweden's overall R&D expenditure amounted to around 155 billion SEK in 2017, which equals more than 3 per cent of GDP. This means that Sweden is one of the few countries that exceeds the goal of 3 per cent set by the EU in its Europe 2020 strategy.

A majority of the R&D performed in Sweden is conducted in the business sector, which covers around 70 per cent of the overall R&D expenditure, while the higher education sector covers around 25 per cent. Research performed in the government sector (excluding HEIs) is marginal in Sweden, while it represents a larger part in countries such as Norway, Netherlands and Germany. Overall, this means that Sweden's division of R&D expenditure across different sectors is very similar to how R&D expenditure is divided up in Denmark and Switzerland.

The largest source of R&D funding in Sweden is the business enterprise sector, followed by the government sector and funding from abroad. The funding from the business sector goes primarily to R&D conducted within the business sector, while R&D funding in the higher education sector comes primarily from government funding. The largest sources of funding for R&D in the higher education sector in 2017 were direct government funding (40 per cent), governmental research councils (18 per cent) and private non-profit organisations (13 per cent). These three sources of funding are also responsible for the increase in R&D revenues within the higher education sector during the period 2011–2017.

Research personnel

Sweden is one of the five countries in the OECD with the highest percentage of researchers in relation to the population. The percentage of researchers in the population of Sweden is at roughly the same level as in Norway, Denmark and Finland. These countries are also similar when it comes to the percentage of researchers who are women and men respectively.

Most researchers in Sweden are employed in the business enterprise sector, followed by the higher education sector and the government sector. Internationally, the distribution of researchers in different sectors varies. South Korea and Japan, for example, have a higher percentage of researchers employed in the business enterprise sector than Sweden does, while the United Kingdom, Norway and Switzerland have a higher percentage employed within the higher education sector.

In the Swedish higher education sector, the research and teaching personnel has increased greatly during the period 2008–2018, and the number of employees has increased within most employment categories. The number of senior lecturers and postdocs has increased steadily, while the increase in the number of professors has slowed down slightly in recent years.

The percentage of women and men in the Swedish higher education sector was equal at all career stages apart from professors. The gender distribution for professorships was equal for persons awarded doctoral degrees 2004–2008, but unequal for persons awarded doctoral degrees in 2003 and earlier.

Scientific publication

Sweden is one of the five countries in the OECD with the highest number of scientific publications in relation to the population. For example, Sweden produces more publications per inhabitant than Netherlands and Belgium, but slightly fewer than Denmark and Switzerland.

Researchers in Sweden often take part in international collaboration, and the percentage of international co-publications has increased markedly over a long period. Out of all publications in Sweden in 2017, the percentage of international co-publications amounted to 70 per cent.

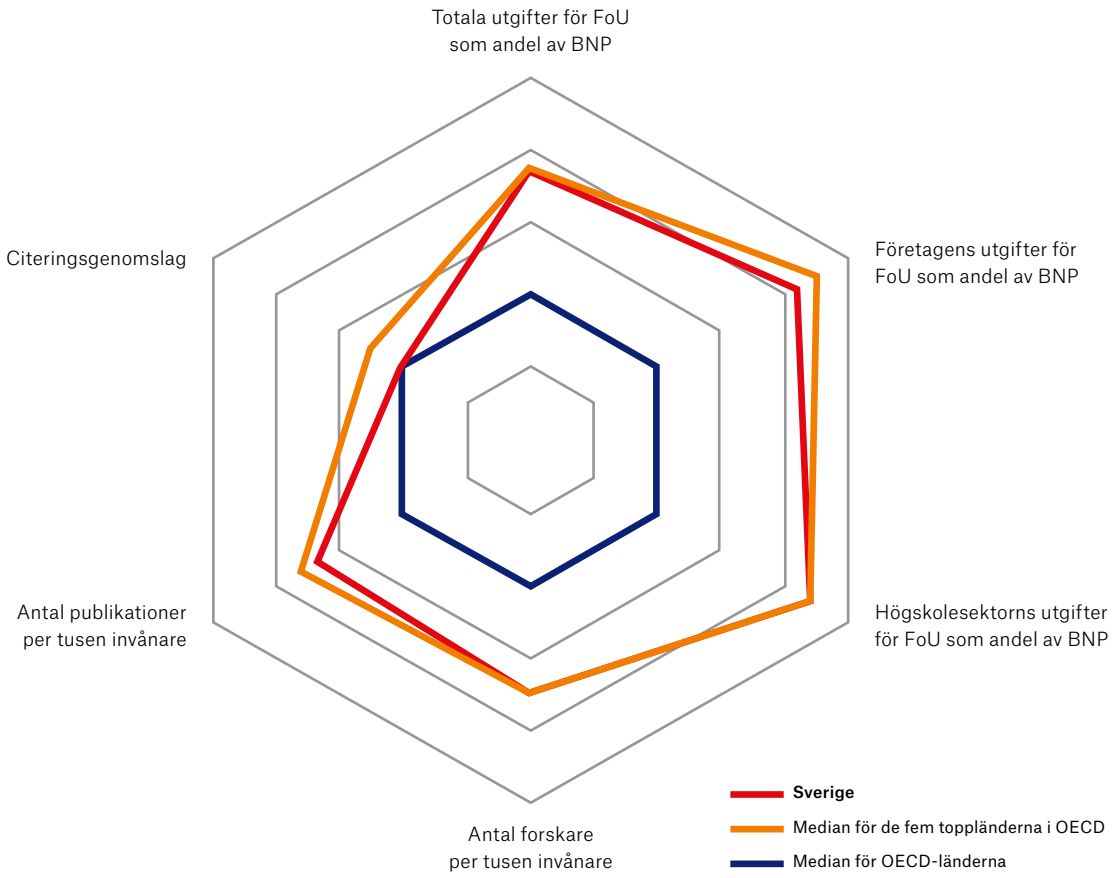
Sweden is above the world average, and is ranked in at number 13 among the countries with the highest citation impact in the world. This means that Sweden has lower citation impact than countries such as Switzerland, Netherlands and Denmark, but higher citation impact than Norway and Finland.

In terms of different subject areas, Sweden has a citation impact that is above the world average in most areas, and agriculture, biology, clinical medicine, geosciences and chemistry have the highest citation impact.

In 2017, the broad-based established universities produced half of the published articles in Sweden, while the specialised universities produced almost one third. The university colleges and new universities produced 4 per cent each of the Swedish published articles. During the period 2015–2017, the broad-based established universities and specialised universities had citation impacts above the world average.

Sammanfattning

Forskningsbarometern 2019 ger en övergripande beskrivning av svensk forskning och utveckling (FoU) och belyser hur Sverige som forskningsnation står sig i internationell jämförelse. Forskningsbarometern har därutöver ett särskilt fokus på den svenska högskolesektorn. Rapporten består av tre kapitel: forskningens finansiering, forskningens personal och vetenskaplig publicering.



Figur 1. Det svenska forskningssystemet i internationell jämförelse 2017.
Not: Sveriges värden jämförs med medianen för OECD-länderna och med medianen för de fem toppländerna i OECD per indikator (normaliserade värden).[2] Värden för år 2017 eller senast tillgängliga.
Källa: OECD MSTI och Clarivate Analytics.

2 Toppländerna är de länder med högst värden för respektive indikator: Totala utgifter för FoU som andel av BNP (Sydkorea, Israel, Schweiz, Sverige och Japan); Företagens utgifter för FoU som andel av BNP (Israel, Sydkorea, Japan, Schweiz och Sverige); Högskolesektorns utgifter för FoU som andel av BNP (Danmark, Schweiz, Sverige, Norge och Österrike); Andel forskare (heltidsekvivalenter) per tusen invånare (Danmark, Sverige, Sydkorea, Finland och Island); Antal publikationer per tusen invånare (Schweiz, Danmark, Australien, Sverige och Island); Citeringsgenomslag (Schweiz, Storbritannien, USA, Nederländerna och Luxemburg).

Svensk forskning i internationell jämförelse

Sverige är sedan länge en internationellt framstående forskningsnation, med hög FoU-intensitet, en stor andel forskare i befolkningen, en stor produktion av vetenskapliga publikationer, och med ett citeringsgenomslag över världsgenomsnittet. Spindeldiagrammet i Figur 1 ger en sammanfattande bild av svensk forsknings position i jämförelse med OECD och de fem länder i OECD med högsta värdena för respektive indikator. Figuren för samman sex indikatorer från de tre huvudavsnitten och visar såväl resurserna för FoU (vilka mäts i utgifter för FoU och antal forskare), som forskningens prestationer (vilka mätas i antal vetenskapliga publikationer och publikationernas citeringsgenomslag).

Figuren visar att Sverige är ett av de fem länder i OECD med högst utgifter för FoU som andel av BNP. I denna kategori tillhör Sverige topp fem avseende såväl FoU utgifter totalt som i företagssektorn respektive högskolesektorn. Sverige är även ett av de fem länder i OECD med störst antal forskare i relation till sin befolkning. Detta visar sammantaget att Sverige är ett land som i internationell jämförelse har en hög forskningsintensitet.

Sverige tillhör även topp fem i OECD när det gäller antal vetenskapliga publikationer i relation till folkmängd. Sverige är däremot inte ett av de främsta länderna när det gäller citeringsgenomslag. Sveriges citeringsgenomslag (andel högciterade publikationer) ligger över världsgenomsnittet, men på samma nivå som medianen för OECD länderna. Det innebär att Sverige rankas till plats 13 bland de länder med högst citeringsgenomslag i världen.

Forskningens finansiering

Sveriges sammanlagda FoU-utgifter uppgick år 2017 till cirka 155 miljarder kronor, vilket motsvarar mer än tre procent av BNP. Detta innebär att Sverige är ett av få länder som överskrider det mål på tre procent som EU har satt upp i Europa 2020 strategin.

En övervägande del av den FoU som utförs i Sverige sker i företagssektorn, vilken står för omkring 70 procent av de totala FoU-utgifterna, samtidigt som högskolesektorn står för omkring 25 procent. Forskning som utförs i övrig offentlig sektor är i Sverige marginell, medan den i exempelvis Norge, Nederländerna och Tyskland är mer betydande. Detta innebär sammantaget att Sveriges fördelning av FoU-utgifter på olika sektorer har stora likheter med hur FoU-utgifterna är fördelade i Danmark och Schweiz.

Den största finansiären av FoU i Sverige är företagssektorn, följd av offentlig sektor och finansiering från utlandet. Företagssektorns finansiering går främst till FoU som utförs i företagssektorn, medan finansiering av FoU i högskolesektorn kommer främst från statliga finansieringskällor. De största finansieringskällorna för FoU i högskolesektorn 2017 var de direkta statsanslagen (40 procent), de statliga forskningsråden (18 procent), samt privata icke vinstdrivande organisationer (13 procent). Det är även dessa tre finansieringskällor som står bakom FoU-intäkternas ökning i högskolesektorn under perioden 2011–2017.

Forskningens personal

Sverige är ett av de fem länder i OECD med högst andel forskare i relation till sin befolkning. Andelen forskare i befolkningen i Sverige är ungefär på samma nivå

som i Norge, Danmark och Finland. Dessa länder är även lika när det gäller andelen forskare som är kvinnor respektive män.

De flesta forskarna i Sverige är anställda inom näringslivssektorn, följt av högskolesektorn och övrig statlig sektor. Internationellt sett varierar fördelningen av forskare i olika sektorer. Sydkorea och Japan har till exempel en högre andel sysselsatta i näringslivet än Sverige, medan Storbritannien, Norge och Schweiz har en högre andel forskare sysselsatta inom högskolesektorn.

Den forskande och undervisande personalen har i den svenska högskolesektorn ökat starkt under perioden 2008–2018, och antalet anställda har ökat inom de flesta anställningskategorier. Antalet lektorer och postdoktorer har ökat stadigt, samtidigt som ökningen av antalet professorer har avtagit något under senare år.

Andelen kvinnor och män var i den svenska högskolesektorn jämn i alla karriärsteg förutom för professorer. Könsfördelningen för professorer var jämn för dem som tog sin doktorsexamen år 2004–2008, men ojämn för dem med examensår 2003 och tidigare.

Vetenskaplig publicering

Sverige är ett av de fem länder i OECD med högst antal vetenskapliga publikationer i relation till folkmängd. Sverige producerar exempelvis fler publikationer per invånare än Nederländerna och Belgien, men något färre än Danmark och Schweiz.

Forskare i Sverige deltar ofta i internationella samarbeten och andelen internationella sampublikationer har ökat markant under en längre tid. Av alla publikationer i Sverige 2017 uppgick andelen internationellt samförfattade publikationer till 70 procent.

Sverige ligger över världsgenomsnittet och rankas till plats 13 bland de länder med högst citeringsgenomslag i världen. Detta innebär att Sverige har ett lägre citeringsgenomslag än bland annat Schweiz, Nederländerna och Danmark, men ett högre citeringsgenomslag än Norge och Finland.

Sett till olika ämnesområden har Sverige ett högre citeringsgenomslag än världsgenomsnittet inom de flesta ämnen, där agronomi, biologi, klinisk medicin, geovetenskap och kemi har högst citeringsgenomslag.

De breda etablerade universiteten stod år 2017 för hälften av antalet publicerade artiklar i Sverige, medan de fackinriktade universiteten stod för närmare en tredjedel. Högskolorna och de nya universiteten stod för fyra procent vardera av den svenska produktionen. De breda etablerade universiteten och fackuniversiteten har under perioden 2015–2017 haft ett citeringsgenomslag över världsgenomsnittet.

Research funding

1. Research funding

Research funding is the focus of this chapter. The chapter is divided up into two sections. The first section includes a description of the funding of the Swedish R&D system in international comparison, and the second section a description of research funding within the Swedish higher education sector.

1.1 The Swedish R&D system in international comparison

R&D expenditure

Sweden has long been a country that invests considerable resources in research and development (R&D). In financial terms, the scope of an R&D system can be measured in terms of expenditure on R&D. A country's R&D expenditure measures the overall expenditure on research and development carried out within a country over a given period of time. R&D expenditure as a percentage of gross domestic product (GDP) or per capita is defined as a country's R&D intensity. Figure 2 shows R&D expenditure as a percentage of GDP and per capita for a large number of countries.

Figure 2 shows that there are big differences between countries. Some countries have R&D expenditure of 3 to 4 per cent of GDP, while other countries have R&D expenditure of 0.5 or 1 per cent of GDP. South Korea and Israel stand out, as these

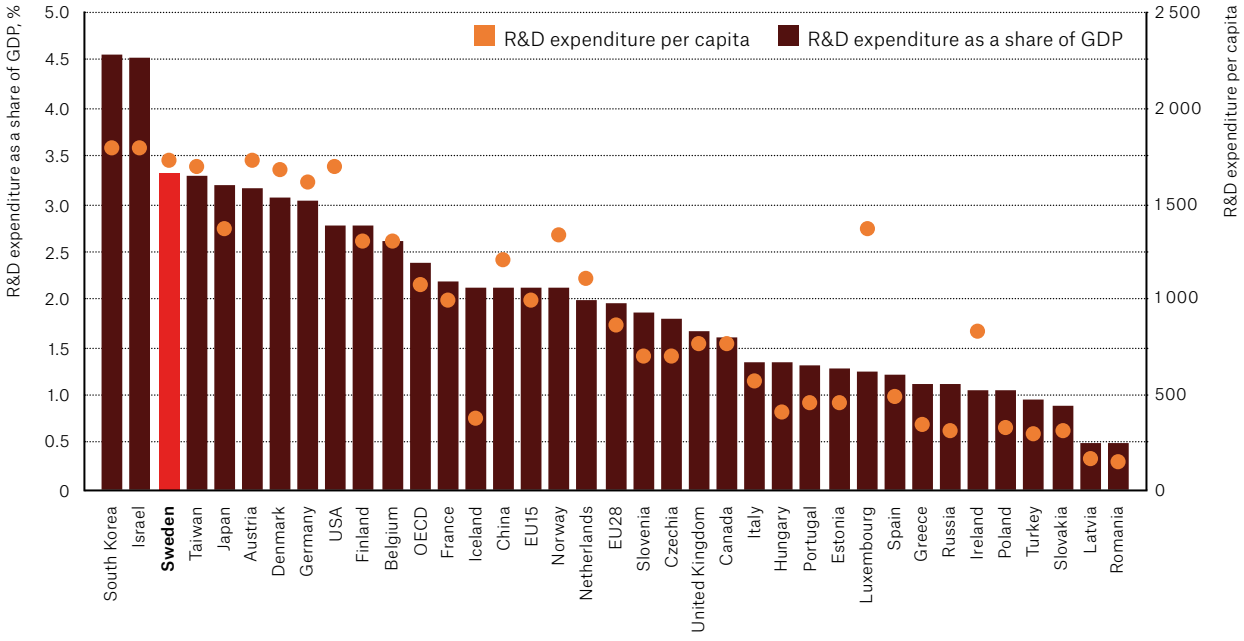


Figure 2. Gross domestic expenditure on R&D (GERD) as a percentage of GDP and per capita (PPP$) 2017, for a selection of countries. Source: OECD MSTI.

two countries are the only ones where R&D expenditure exceeds 4 per cent of GDP.

Sweden's R&D expenditure makes up 3.3 per cent of GDP, which is higher than most comparable countries, such as Denmark, Finland and Norway. Sweden has even higher R&D expenditure as a percentage of GDP than several prominent research nations, such as the USA, France and the United Kingdom, and compared to the EU's member states (EU28) and the OECD countries.

Sweden's goal is for overall R&D expenditure in relation to GDP to exceed the EU's goal of 3 per cent, at the same time as the Swedish national goal within the framework of the Europe 2020 strategy is for R&D expenditure to amount to around 4 per cent of GDP by 2020.[3] This therefore means that Sweden is well on the way, but that some distance remains to achieving the Swedish goal of 4 per cent.

It is worth noting that the EU's goal in the Europe 2020 strategy is also that the EU's overall R&D expenditure shall amount to 3 per cent of GDP by 2020. This, however, is a goal that is far above the current level for the EU member states, where R&D expenditure as a percentage of GDP amounts to just under 2 per cent.

How is R&D defined?

The OECD defines research and development as follows: "Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge."

R&D includes both basic research, applied research and experimental development. In order for an activity to be classified as R&D, it should be characterised by: Novelty – the purpose of R&D is to create new knowledge and to find new applications for existing knowledge. Creativity – R&D is based on original concepts and hypotheses. Uncertainty – the outcome of R&D activities, including economic and personal resources, cannot be known in advance. Systematic – R&D is carried out systematically, and is planned and budgeted. Transferable and/or reproducible – R&D is carried out in order achieve result which can be transferable and/or reproducible.[4]

The definition and guideline has been developed by the OECD in order to allow international comparison of R&D statistics, and the guidelines are used by Statistics Sweden among others.[5]

Figure 2 shows R&D expenditure per capita, in addition to R&D expenditure as a percentage of GDP. This measure also shows that Sweden has a high research intensity, and that only South Korea and Israel have higher R&D expenditure per capita of the countries in the figure. The figure shows too that countries where R&D expenditure as a percentage of GDP is high generally, have high R&D expenditure per capita as well. This relationship does not always apply, however: For example, China (which has a relatively large population) has relatively low R&D expenditure per capita, while Luxembourg (which has a relatively small population) has relatively high R&D expenditure per capita. The two measures, R&D expenditure per GDP and per capita, are therefore related, but do not give the same description of the R&D intensity of different countries. The report will hereafter use R&D expenditure as a percentage of GDP.

As the Swedish Research Barometer aims to describe the Swedish research system

3 Prop. 2018/19:1 Utgiftsområde 16, page 140.

4 OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris.

5 SCB (2018). Statistikens framställning – Forskning och utveckling i Sverige. UF0301.

in international comparison, the selection of countries to compare Sweden with is of great importance. Figure 2 above uses all the countries in OECDs database with values for 2017. Hereafter, Sweden will be compared both with various comparison groups, such as EU28, OECD and the world, and also with individual countries, categorised within three groups of countries. These comparisons aim to provide as nuanced and fair a picture as possible of how Sweden compares as a research nation with other countries (see the fact box and appendix for further information).

What selection of countries has been used?

International comparison between countries in terms of research and development is not easy, as different countries have differing organisation structures and funding models. The Swedish Research Barometer makes international comparisons with the following selection of countries:

- **Comparable countries:** Belgium, Denmark, Finland, Netherlands, Norway, Switzerland, and Austria
- **Large established research countries:** France, Japan, United Kingdom, Germany, and USA
- **Fast-growing research countries:** China and South Korea
- **Comparison groups:** EU28, OECD and the world.

Comparable countries to Sweden are countries where the prerequisites for R&D are similar to those that apply for Sweden, and that are also comparable in terms of number of publications in relation to population and in terms of citation impact. The large established research countries are countries that are often perceived as major actors in international comparisons and are characterised by large volume and high quality. The fast-growing research countries are countries that have had a rapid expansion of their research systems over the last ten-year period. The comparison groups represent frequently used comparison groups, but are at the same time dependent on the statistics available. For example, comparisons with the "world" are only made in relation to scientific publications.

Figure 3 shows how R&D expenditure as a percentage of GDP has developed over time divided up into our selection of countries: comparable countries, large established research countries, and fast-growing research countries.

Over the period 2008 to 2017, Sweden's R&D expenditure as a percentage of GDP has fallen from 3.5 to 3.3 per cent. 2008 was something of a "peak year", and R&D expenditure as a percentage of GDP has since then fallen, only to rise again lately. Between 2015 and 2017, R&D expenditure per GDP has remained relatively unchanged at around 3.3 per cent. As 70 per cent of the R&D expenditure in Sweden consists of expenditure within the business enterprise sector, changes in R&D expenditure are mainly due to changes in R&D expenditure within the business enterprise sector.

Sweden has higher R&D expenditure per GDP than practically all countries in the selection. This has not always been the case, however, as Finland, Switzerland and Japan at times has had greater research intensity than Sweden. Furthermore, Austria, Denmark and Germany have in recent years seen an increase, and now have R&D expenditure of more than 3 per cent of GDP. It is also worth noting that statistics for Switzerland are lacking for 2017, which makes comparison more difficult.

Figure 3 shows that the large established research countries have had relatively stable levels of R&D expenditure as a percentage of GDP over time. The countries compara-

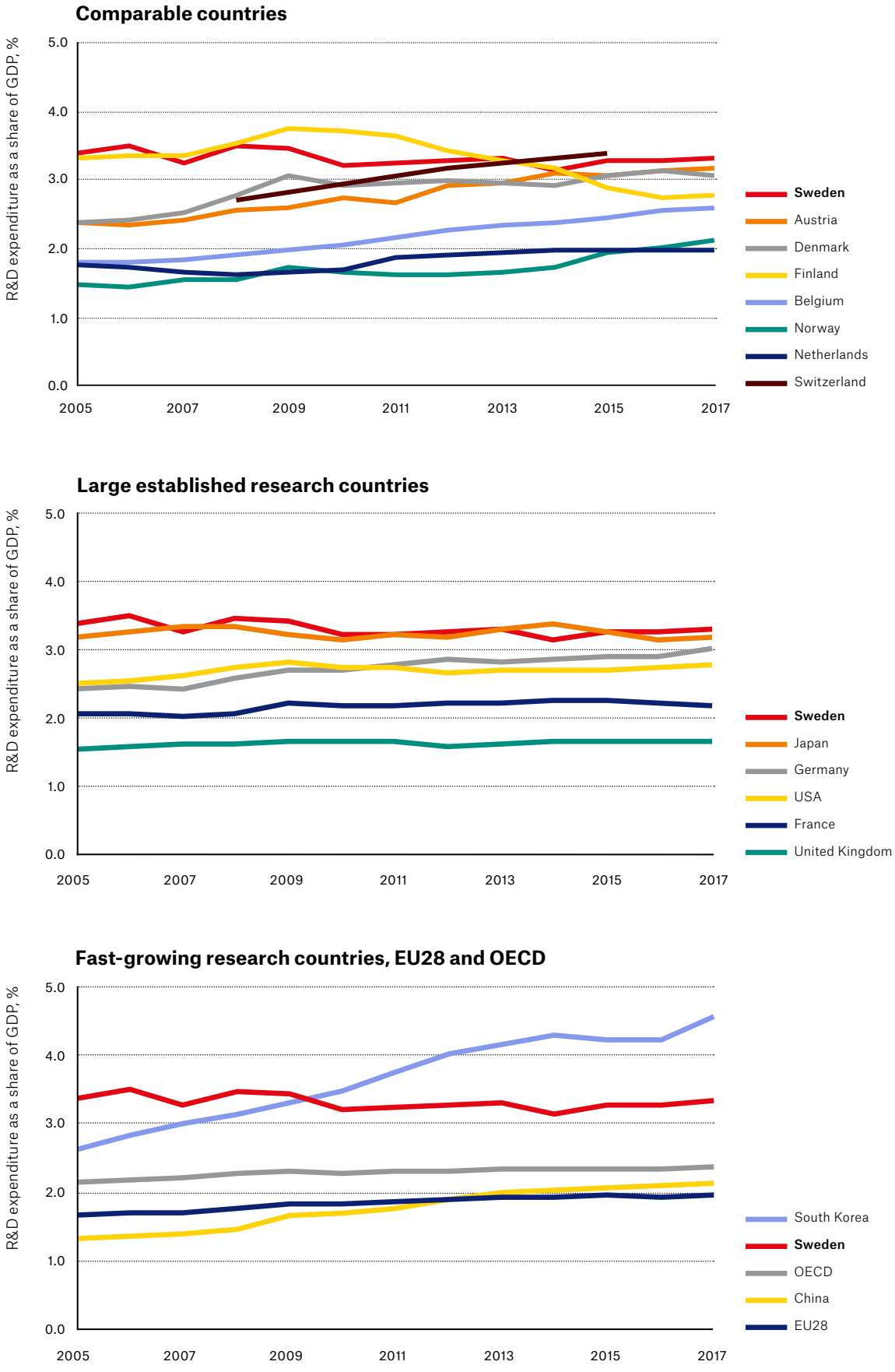


Figure 3. Gross domestic expenditure on R&D (GERD) as a percentage of GDP over time, for a selection of countries, EU 28 and OECD. Source: OECD MSTI.

ble to Sweden show a greater variation. Over the last ten-year period, Belgium, Netherlands, Norway and Austria show considerable increases in their R&D expenditure per GDP. Denmark too showed increased R&D expenditure over the last ten years, although not to the same extent as the other comparable countries. Finland is the only country that stands out with considerably reduced R&D expenditure as a percentage of GDP.

The largest increase in Figure 3 is shown by China and South Korea, which have both increased their R&D expenditure as a percentage of GDP by almost 50 per cent over the last ten years. The difference between the EU28 and China in R&D expenditure as a percentage of GDP has continued to increase since 2013, when China exceeded the EU28 for the first time. Since 2015, China's overall R&D expenditure has also been greater than the overall R&D expenditure for the EU28.

Financing and performing sector

A country's R&D expenditure describes the scope of the country's R&D activities. It refers to overall expenditure on the research system as a whole, that is to say the R&D performed by the higher education sector, the business enterprise sector, other government sector, and so on. A country's overall R&D expenditure can therefore be described based on the sectors carrying out the R&D work (performing sector) or the sectors funding the R&D work (source of funding)

Figure 4 shows the gross domestic expenditure on R&D as a percentage of GDP, divided up by source of funding. Where data for source of funding is lacking, GERD as a percentage of GDP has been marked with a grey bar.

Figure 4 shows that more than half of each country's R&D expenditure was funded by the business enterprise sectors in almost all the countries studied. Furthermore, the funding derived from foreign sources may also include funds paid to and from busi-

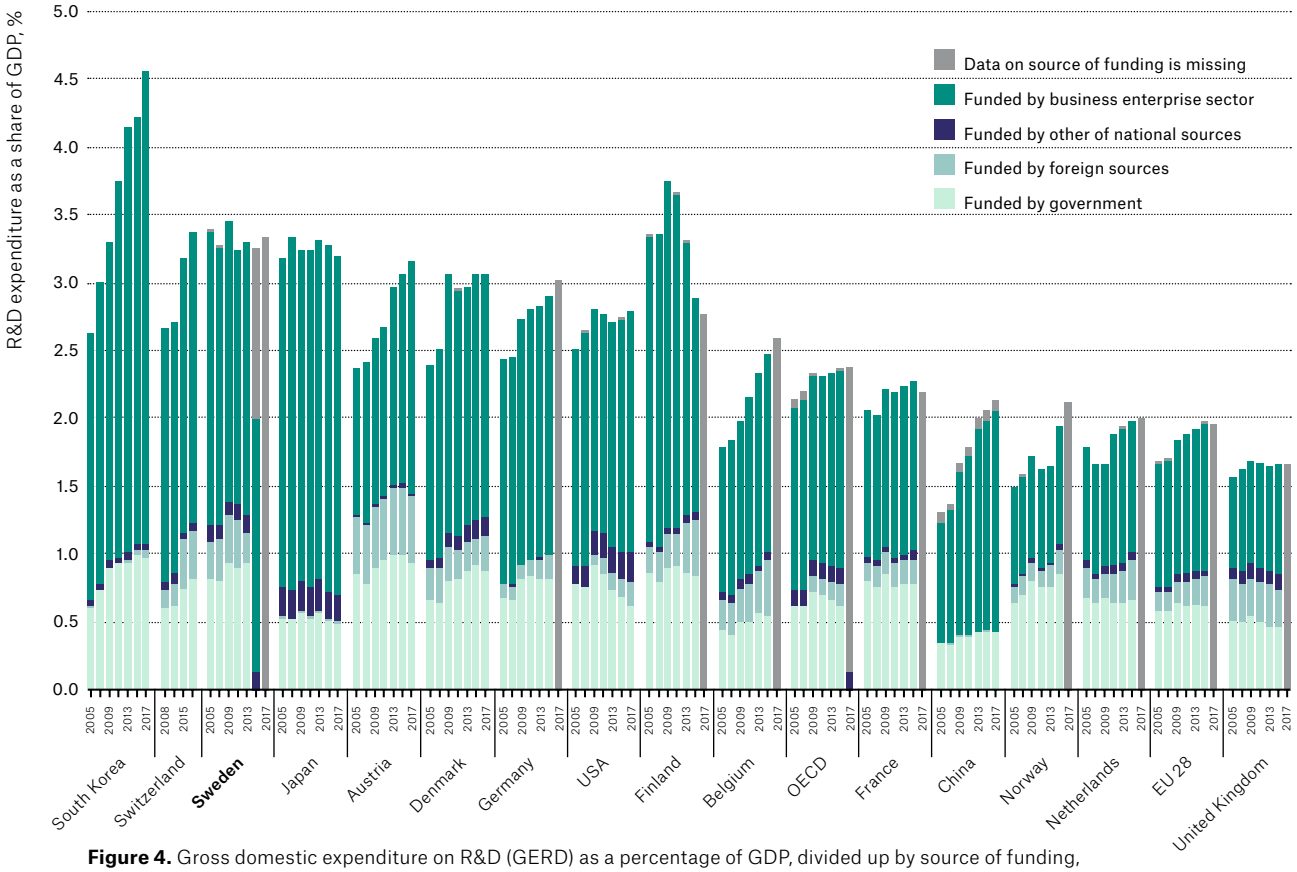


Figure 4. Gross domestic expenditure on R&D (GERD) as a percentage of GDP, divided up by source of funding, for 2005–2017 (every second years). **Note:** Switzerland data for the years 2004, 2008, 2012 and 2015. Source: OECD MSTI.

ness, for example through a company funding research outside the country's borders. The majority of the countries investigated show larger relative changes in business funding of R&D than in government funding of R&D. This, in combination with the scope of business funding of R&D, means that overall R&D funding at national level is largely dependent on the business enterprise sector. This is clearly illustrated in Figure 4, for example by China's very positive development and Finland's negative development at national level, despite government funding of R&D having been relatively stable in both countries. Norway is an example of a country where funding from the business enterprise sector does not play such a dominant role, as its funding from the business sector and the government sector constitute roughly equal percentages.

The most recent and internationally comparable statistics for R&D funding in Sweden date from 2013. Between the years 2005 and 2013, Sweden's R&D expenditure as a percentage of GDP fell from 3.4 to 3.3 per cent. As R&D expenditure is largely funded by the business enterprise sector and the government sector, the changes in R&D expenditure are also largely explained by changes in the funding from these sectors. During the period 2005–2013, funding from the government increased from 22.3 to 28.3 per cent, at the same time as funding from the business sector fell from 71.7 to 61.0 per cent.

Figure 5 shows a comparison of R&D expenditure by source of funding for the last available year. Similar to Figure 4, Figure 5 shows that R&D activities are mainly funded by the business enterprise sector, and that it is the Asiatic countries South Korea, China and Japan that has the largest percentage of funding by the business enterprise sector. The other countries in the selection also have a large percentage of funding from the business sector, and only Norway has funding from the business sector of less than 50 per cent of overall funding. On the other hand, Norway has the highest percentage of government funding of all the countries in the figure, amounting to 46 per cent of overall funding. The Swedish distribution of R&D expenditure based on source of funding is very reminiscent of the OECD distribution.

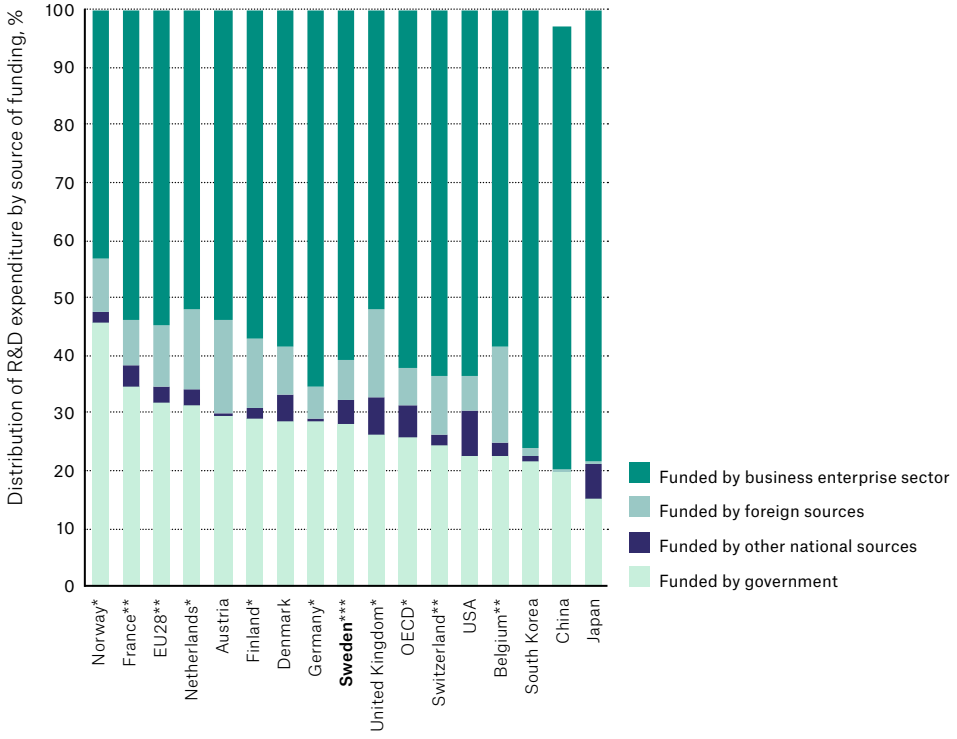


Figure 5. Gross domestic expenditure on R&D (GERD) divided up by source of funding, for 2017 or last available year* **Note:** *Values for 2016, **for 2015, ***for 2013. China's values do not add up to 100%. Source: OECD MSTI.

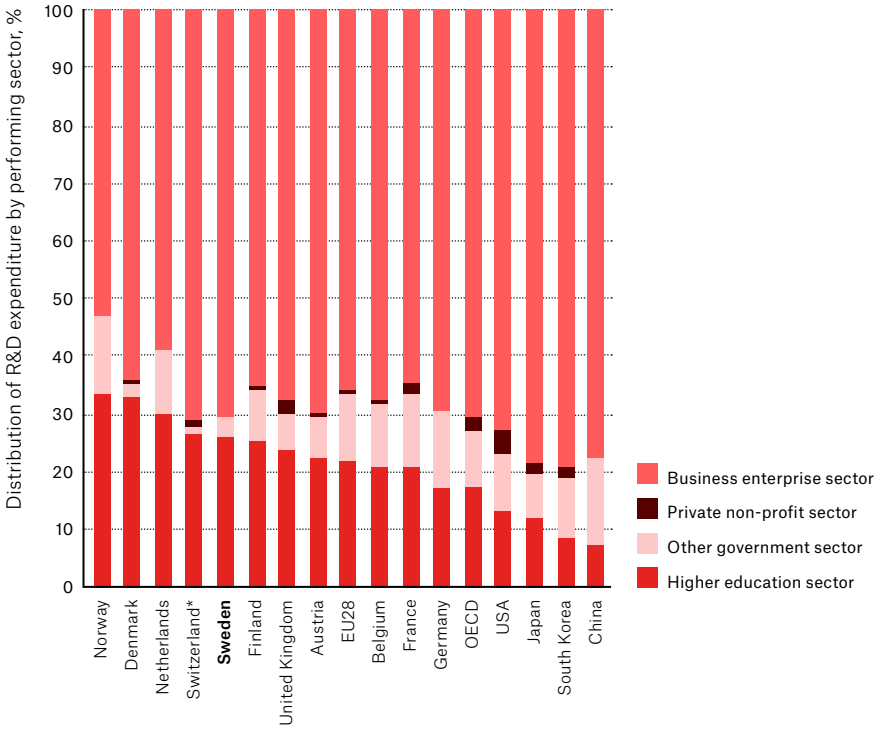


Figure 6. Gross domestic expenditure on R&D (GERD) divided up by performing sector, for 2017 or last available year*. **Note:** *Values for 2015. Source: OECD MSTI.

The final figure in this section, Figure 6, concerns the performing sector, that is to say expenditure divided up by the sectors performing the R&D activities.

Figure 6 shows that R&D has primarily been performed within the business enterprise sector, and secondarily within the higher education sector. The percentage of R&D expenditure used by the business enterprise sector varies from 79 per cent (South Korea) to 53 per cent (Norway). The percentage of R&D expenditure used by the higher education sector varies from 33 per cent (Norway) to 7 per cent (China). In Denmark, Switzerland and Sweden, nearly all R&D is performed either by the business enterprise sector or the higher education sector. R&D carried out in the other national sector, such as public agencies outside the higher education sector, is marginal in Sweden, and the percentage of R&D performed within the private non-profit sector is very small.

The percentage of R&D performed in the other government sector varies greatly between countries. This is partly due to the structure of the various research systems, but may also be caused by differences in ownership structure, for example whether a research institute is operated in a company format or public agency format. Differences between countries can also be caused by the production of statistics in various countries diverging from the OECD's guidelines, even if the OECD considers that these divergences are generally fairly small.[6]

Sweden's participation in Horizon 2020

An important source of funding for Swedish research is Horizon 2020, the EU framework programme for research and innovation. Table 1 and Table 2 show the top countries based on four aspects: funds awarded overall and per capita, and the success rate per application and per funds applied for.

The countries whose participating organisations (higher education institutions (HEIs), companies, etc.) have been awarded the most funds from Horizon 2020 are Germany, United Kingdom, France, Spain and Italy. Sweden has been awarded 1.4

6 OECD (2019). Main Science and Technology Indicators 2018-2. Full documentation.

billion EUR, and is in eighth place of the countries awarded the most funds (see Table 1). This means that Sweden has been awarded more funds than Denmark, Norway and Finland, but less funds than Netherlands and Belgium.

Several of the countries that top the list of funds awarded are relatively large countries in terms of population. Table 1 therefore also shows a ranking list of the countries awarded the most funds in relation to their population. This measure has been used as an indication of countries' relative competitiveness in terms of receiving research funding.[7] For the indicator "Funds awarded per capita", Sweden is in tenth place. This means that Sweden has been awarded more funds per capita than Austria and Switzerland, for example, but less funds per capita than Netherlands, Denmark, Finland and Norway, for example.

The countries awarded the most funds per capita are Iceland and Luxembourg. These countries are small in terms of population compared to the other countries in the ranking list. On the other hand, Iceland and Luxembourg are not included in the ranking list for overall funds awarded. This shows the importance of studying participation in the framework programme based on several indicators.

Table 2 shows the top countries in terms of success rate, that is success in relation to effort. The success rate can either be calculated as number of applications granted in relation to the number of applications submitted, or as funds awarded in relation to the funds applied for. Horizon 2020 consists largely of collaboration projects (consortiums), where at least three organisations (HEIs or companies, for example) from three different countries participate.[8] This means that if two countries participate in the same number of applications, the role of the participating organisations can vary in terms of scope and funds applied for. Table 2 shows that there are differences in success rate in terms of applications and in terms of funds.

Sweden is in 14th place in terms of success rate for applications, and in 13th for funds applied for. Sweden's success rate is thereby slightly higher than that of Denmark and Finland, but slightly lower than that of the Netherlands, Norway, Austria, Belgium and Switzerland. Compared to the average for the EU28 countries, Sweden's success rate is slightly higher in terms of both applications and funds.

In the tables, the ranking lists are based on the EU's 28 member states and the 16 associated countries in Horizon 2020, as the associated countries participate in the framework programme on the same terms as EU member states. Project funding is also awarded to developing countries and to the countries identified in each work programme.[9] The top ranking lists in Table 1 and Table 2 changes slightly depending on the selection of countries. It is therefore more interesting to look at Sweden's participation in relation to other comparable countries, and not to place too great an emphasis on Sweden's place in the ranking list.

Summary: Netherlands and Belgium are placed above Sweden, irrespective of which of the four indicators is used. The outcome is slightly more varied in relation to other comparable countries. Sweden compares well in terms of funds awarded in total, while Sweden is slightly less well placed in relation to comparable countries in terms of funds awarded per capita (which is a measure of competitiveness) and in terms of success rate (which takes into account the effort or commitment of each country).[10]

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7 Vinnova (2018). Årsbok 2017. Svenskt deltagande i europeiska program för forskning och innovation. Vinnova rapport VR 2018:07., page 8.

8 http://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/applying-for-funding/find-partners_en.htm Downloaded 27 Feb 2019.

9 Vinnova (2018). Årsbok 2017. Svenskt deltagande i europeiska program för forskning och innovation. Vinnova rapport. VR 2018:07

10 For more information on Sweden's participation in Horizon 2020, see Vetenskapsrådet (2017). Svenskt deltagande i Europeiska forskningsrådet. Vetenskapsrådet, Stockholm., Vinnova (2018). Årsbok 2017. Svenskt deltagande i europeiska program för forskning och innovation. Vinnova rapport. VR 2018:07.

Ranking	Country	Funds awarded (million EUR)	Country	Funds awarded per capita (EUR)
1	Germany	6 190	Iceland	252
2	United Kingdom	5 451	Luxembourg	179
3	France	4 424	Netherlands	178
4	Spain	3 651	Cyprus	174
5	Italiy	3 380	Denmark	173
6	Netherlands	3 065	Belgium	167
7	Belgium	1 898	Finland	162
8	**Sweden**	**1 403**	Norway	155
9	Austria	1 123	Ireland	142
10	Switzerland	1 122	**Sweden**	**139**
11	Denmark	1 002	Switzerland	132
12	Greece	898	Austria	127
13	Finland	895	Slovenia	109
14	Norway	821	Estonia	106
15	Israel	727	Israel	86
Average EU28		1 312	Average EU28	84
Average EU28+AC		904	Average EU28+AC	70

Table 1. Horizon 2020 funds awarded, top 15. **Note:** The values refer to accumulated funds awarded (net EU financial contribution, signed grants) for Horizon 2020 up to 13 March 2019. Sample: EU's member states (EU28) and associated countries (AC) to Horizon 2020. Source: eCORDA, Eurostat and UN.

Ranking	Country	Success rate (applications), %	Country	Success rate (funds), %
1	Faroes	22.2	Belgium	18.4
2	Iceland	20.5	Germany	18.1
3	Belgium	18.8	Netherlands	17.5
4	Austria	18.0	Switzerland	17.5
5	Tunisia	17.8	France	17.2
6	France	17.7	Austria	16.4
7	Switzerland	17.7	Norway	16.0
8	Luxembourg	17.6	Luxembourg	15.4
9	Bosnia and Herzegovina	17.5	Iceland	14.5
10	Netherlands	17.1	Tunisia	14.5
11	Germany	16.9	Faroes	14.2
12	Norway	16.4	United Kingdom	14.2
13	Montenegro	15.9	**Sweden**	**13.6**
14	**Sweden**	**15.7**	Denmark	13.1
15	Denmark	15.5	Ireland	13.0
Average EU28		14.5	Average EU28	11.9
Average EU28+AC		14.6	Average EU28+AC	11.1

Table 2. Success rate Horizon 2020, top 15. **Note:** The values refer to retained proposals for Horizon 2020 up to 13 March 2019. Sample: EU's member states (EU28) and associated countries (AC) to Horizon 2020. Source: eCORDA.

1.2 The higher education sector in Sweden

This section includes a description of R&D expenditure within the higher education sector in Sweden. The description begins with an account of the overall expenditure on R&D in Sweden.

Gross domestic expenditure on R&D and its sources of funding

Figure 7 shows the gross domestic expenditure on (intramural) R&D as well as its source of funding. The figure also gives an indication of the size of the funding streams between sources of funding and where the R&D is performed. The figure thereby gives an overall picture of the Swedish R&D system.

Gross domestic expenditure on intramural R&D was SEK 155.5 billion for 2017. The business enterprise sector's R&D expenditure amounted to 110.9 billion SEK for 2017, which corresponds to 71.3 per cent of overall R&D expenditure in Sweden. The higher education sector's R&D expenditure was 38.8 billion SEK for 2017, or around 24.9 per cent of overall R&D expenditure, corresponding to roughly one third of the R&D expenditure within the business enterprise sector.

Government agencies, excluding higher education institutions (HEIs), had R&D expenditure of 2.7 billion SEK, which amounts to 1.7 per cent of Sweden's overall R&D expenditure. Examples of government agencies with R&D expenditure are FOI Swedish Defence Research Agency (1.1 billion SEK), the Swedish Meteorological and Hydrological Institute (134 million SEK) and the Swedish Social Insurance Inspectorate (61 million SEK).

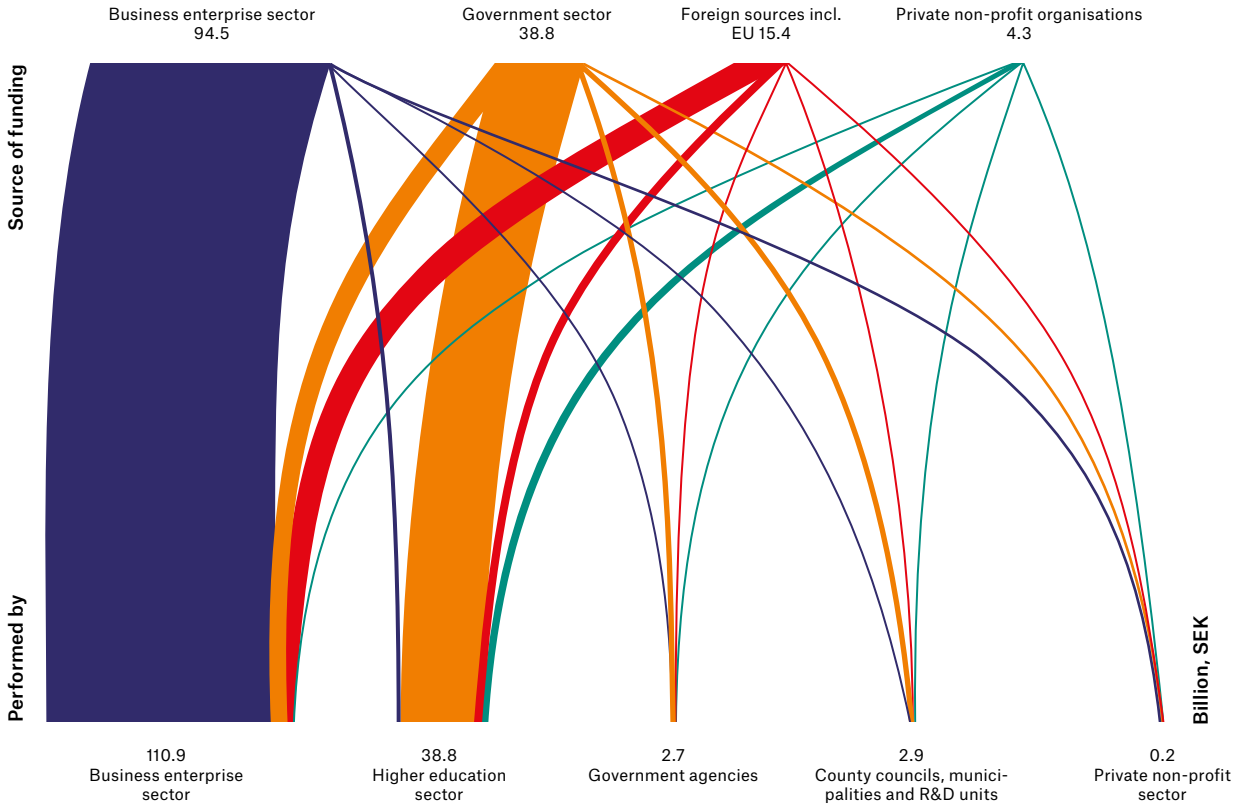


Figure 7. Gross domestic expenditure on R&D (GERD) can be seen from two perspectives: divided up by source of funding (top edge of figure) or divided up by R&D performer (bottom edge of figure). The figure shows the financial volume in billion SEK, and the funding streams in the Swedish R&D system for 2017 (expenditure on R&D performed does not equal funded R&D). Source: Statistics Sweden.

What is included in R&D expenditure?

R&D expenditure is the total of current costs and investment/capital expenditures for R&D performed in Sweden during a specific year.

Current costs for R&D are made up from personnel costs (such as salary costs and payroll tax), premises costs (such as premises rental and maintenance), and other running costs (such as administration, consumables and computer programs). Within the higher education sector, **R&D revenues** are used as an approximation of current costs.

Investment/capital expenditures for R&D are made up from expenditure on assets and equipment. Investment costs are reported at acquisition value and, for the higher education sector, are divided up into investments in "buildings, land and property", and investments in "machines and equipment".

Statistics Sweden report statistics on both intramural R&D and extramural R&D. However, for the higher education sector all R&D is designated as intramural R&D. Statistics Sweden's statistics on R&D expenditure are collected every second year, and are based on surveys.[11]

County councils, municipalities and R&D units had expenditures of 2.9 billion SEK for intramural R&D, which corresponds to 1.9 per cent of the overall R&D expenditure. County councils were responsible for most of the expenditure, with 2.5 billion SEK. Municipal R&D expenditure amounted to 230 million SEK, and the R&D units' expenditure to 168 million SEK. Local and regional R&D units are units that are largely funded by, or have an organisational link to one or more municipalities, county councils or regions.[12] The 'ALF funds' amounting to 1.8 billion SEK are not included in the county councils' expenditure. This is in order to avoid double-counting, as the ALF funds are also included in the accounts of the higher education sector, according to the practice of Statistics Sweden.[13]

Private non-profit organisations had expenditure on intramural R&D of 185 million SEK. Private non-profit organisations consist mainly of various foundations and charitable organisations. Measuring R&D expenditure for this sector is associated with some difficulty, which means that comparisons over time must be made with caution.[14]

For Sweden as a whole, expenditure on intramural R&D increased from 142.6 billion SEK to 155.5 billion SEK between 2015 and 2017 (constant prices). That is an increase of 12.9 billion SEK, or around 9.9 per cent. The business enterprise sector was responsible for most of this increase by increasing its R&D expenditure by 11.6 billion SEK (constant prices). The business enterprise sector's R&D expenditure as a percentage of GDP simultaneously increased from 2.3 to 2.4 per

11 OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris., SCB (2016). Forskning och utveckling inom universitets- och högskolesektorn 2015. UF 13 SM 1601., SCB (2018). Statistikens framställning – Forskning och utveckling i Sverige. UF0301

12 SCB (2018). Forskning och utveckling i Sverige 2017 – preliminära uppgifter. Rapport 2018-07-13.

13 ALF is the Swedish abbreviation of "Avtal om läkarutbildning och forskning", and is an agreement between the government and seven regions (county councils) relating to their participation in the training of physicians, in clinical research and in the development of health and medical care. ALF funds are paid out by the HEIs, and constitutes the government's compensation to county councils within the framework of the agreement. ALF funds are in the presentation in research barometer excluded from the county councils in order to avoid double-counting with the higher education sector. This practice follows the practice at Statistics Sweden and their reporting of R&D activities in Sweden. There are several reasons for this practice: because the research is initiated by the higher education sector, to avoid breaks in time series, and to comply with the corresponding statistics produced by the Swedish Higher Education Authority. (SCB 2015. Forskning och utveckling i Sverige 2015. UF 16 SM 1701, page 50.)

14 SCB (2015). Forskning och utveckling i Sverige 2015. UF 16 SM 1701, page 26f.

cent. The increase is assumed to be partly dependent on the OECD slightly changing its definition of R&D, which may have impacted on company's assessment of their R&D activities.[15]

R&D expenditure for the other sectors (the higher education sector, government agencies, and the county councils, municipalities and R&D units) also increased over the period 2015–2017. R&D expenditure within the higher education sector and among government agencies increased by 2 and 5 per cent respectively. County councils, municipalities and R&D units increased their R&D expenditure by around 23 per cent, and was thereby the sector with the largest percentage increase.

The largest source of funding of R&D in Sweden in 2017 was the business enterprise sector (94.5 billion SEK), followed by the government sector (38.8 billion SEK), foreign sources including EU (15.4 billion SEK) and private non-profit organisations (4.3 billion SEK).

The total expenditure on R&D differs between the funding side and the performer side in Figure 7, as the overall funding is smaller than the overall expenditure on R&D performed. Statistics Sweden's collection of R&D statistics is based primarily on a survey sent out to organisations performing R&D. It is often easier for them to report the resources that have been use (i.e. expenditures), rather than tracing the source of funding for the expenditure. For the higher education sector, for example, the source of funding is only reported for current costs. According to Statistics Sweden, it is not possible to achieve an absolute correspondence between the amount of R&D expenditures used/performed and expenditures divided by source of funding. This is assumed to be due in part to timing issues, that is to say funds that are received in one year are consumed over several years.[16]

Funding of the business enterprise sector's R&D derived mainly from in-house funding (88 billion SEK), and from foreign companies in the same company group/concern (9.7 billion SEK), which is also a form of in-house funding. The business sector's R&D funding from the government sector amounted to 5.3 billion SEK, of which funding from defence agencies represented the major share (3.7 billion SEK).

Funding of R&D in the higher education sector came mainly from the government sector (28.7 billion SEK), and primarily from direct government funding (14.5 billion SEK). In addition, 1.3 billion came from the business enterprise sector, 2.6 billion SEK from foreign sources, and 4.1 billion SEK from private non-profit organisations (for further information on funding of the higher education sector, see page 28).

The government agencies received their R&D funding mainly from the government sector (2.5 billion SEK), primarily direct government funding (1.3 billion SEK). County councils, municipalities and R&D units also received their R&D funding mainly from the government sector (2.4 billion SEK), and within this primarily as in-house funding (2.1 billion SEK).

In conclusion, it should be noted that the data in Figure 7 relates to R&D conducted in Sweden, which amounted to 155.5 billion SEK in 2017. If Swedish-funded R&D contracted out abroad (extramural R&D abroad) is included, the expenditure rises by 33.9 billion SEK. R&D contracted-out abroad was mainly contracted to foreign companies within the own group/concern of companies, and totalled 26.6 billion SEK.

15 https://www.scb.se/hitta-statistik/statistik-efter-amne/utbildning-och-forskning/forskning/forskning-och-utveckling-i-sverige/pong/statistiknyhet/forskning-och-utveckling-inom-foretagssektorn-2017/ Downloaded 27 Feb 2019.

16 SCB (2019). Forskning och utveckling i Sverige 2017.

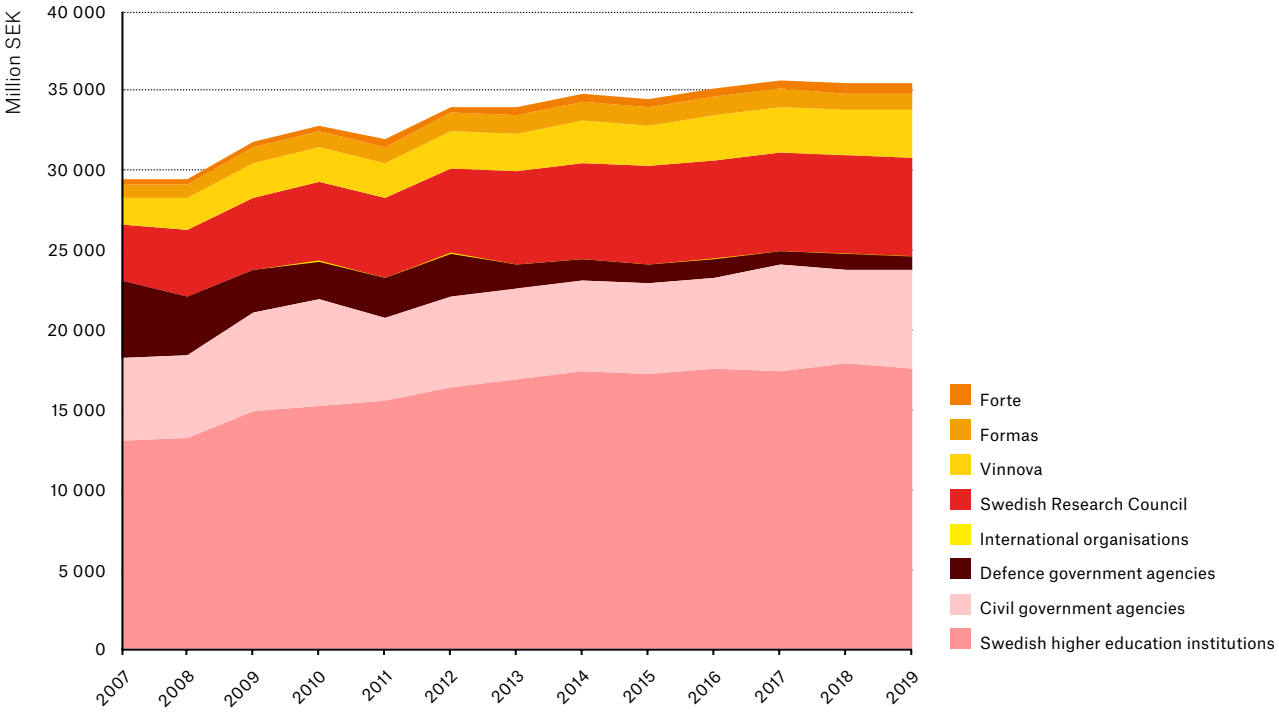


Figure 8. Government budget allocations for R&D during the period 2007–2019, divided up by recipient (million SEK, constant prices). Source: Statistics Sweden.

Government budget allocations for R&D

The government is an important source of funding of R&D in Sweden. Figure 8 shows the development of government budget allocations for R&D during the period 2007–2019, divided up by recipient. The data is from Statistics Sweden's government budget analysis, which is based on a forecast and therefore may diverge from actual government budget expenditures.[17]

The government budget allocations to R&D are estimated to 37.0 billion SEK for 2019 (current prices). Between the years 2018 and 2019, the government R&D budget increased by 0.8 million SEK in current prices, at the same time as the R&D budget in constant prices remained unchanged (that is to say taking expected inflation into account). During the period 2009–2019, the government budget for R&D increased by 11.3 per cent, or 3.6 billion SEK (constant prices). During this period, the government budget allocations for R&D in relation to the government budget in total, increased from 3.2 per cent in 2007 to 3.8 per cent in 2014, and then decreased to 3.6 per cent in 2019.

When divided up by recipient, Swedish higher education institutions (HEIs) receive around 50 per cent of the government budget for R&D, while the research councils (Swedish Research Council, Forte, Formas and Vinnova[18]) receive around 30 percent and civil government agencies receive around 17 per cent. All recipients, apart from the civil government agencies and defence agencies, have seen an increase in their government R&D grants during the period studied. Those that saw the greatest increase during the period 2009–2019 were HEIs (2.7 billion SEK), the Swedish Research Council (1.6 billion SEK) and Vinnova (0.8 billion SEK). Over the same period, the defence agencies have seen a major reduction (1.7 billion SEK).

The government R&D funds distributed to Forte, Formas and the Swedish

17 SCB (2018). Statistikens framställning – statliga anslag till forskning och utveckling. UF0306

18 Forte – Swedish Research Council for Health, Working Life and Welfare. Formas – a Swedish Research Council for Sustainable Development. Vinnova – Sweden's Innovation Agency.

Research Council are passed on primarily to HEIs. The government funds paid to Vinnova are passed on to private companies, the higher education sector and research institutes.[19] Of the government budget allocated to civil government agencies, some are passed on, and some are used for the agencies' in-house research and development. The Swedish Meteorological and Hydrological Institute, the Swedish Customs and the Swedish Agency for Health Technology Assessment and Assessment of Social Services, were the civil agencies with the greatest expenditure on intramural R&D in 2017 (134 million SEK, 131 million SEK and 128 million SEK respectively). The Swedish Energy Agency, the Swedish National Space Agency and the Swedish International Development Cooperation Agency were the civil agencies with the greatest expenditure on extramural R&D in 2017 (1 309 million SEK, 941 million SEK and 807 million SEK respectively).[20]

The statistics on government budget allocations for R&D is reported in several ways: by recipient (as in Figure 8), according to R&D purpose, and based on the various expenditure areas of the government's budget bill. The statistics show that the government's budget for R&D are allocated to several different purposes, and can be found within most expenditure areas in the government's budget bill.[21] The fact that the government's budget for R&D are allocated to several different purposes, is a reflection of the goal of the government's research policy, which states: "Sweden shall be one of the world's foremost research and innovation countries and a leading knowledge nation, where high-quality research, higher education and innovation lead to societal development and welfare, a competitive business sector, and address the societal challenges we are facing, both in Sweden and globally."[22]

It is worth noting that the Government budget consists of both expenditures and incomes, where government budget allocations for R&D constitute an expenditure. In order to consider the income side of the budget, tax subsidies should also be taken into account, as they entail a reduction in the government's tax income. The tax subsidy for R&D gives those who perform R&D for commercial purposes a lower rate of the employment payroll tax (Sw. arbetsgivaravgift) for employees working with R&D. In 2017, the tax subsidy for R&D amounted to 567 million SEK.[23]

R&D revenues in the HEI sector

Figure 9 shows the higher education sector's R&D revenues for 2017, divided up by source of funding. The government R&D funding amounted to around 68 per cent in total, and consisted of: direct government grants (40 per cent), ALF funds (4 per cent), research councils (18 per cent) and other government agencies (6 per cent). If funding from public research foundations and funding from county councils and municipalities are also included, overall government funding amounted to 74 per cent. The largest individual source of revenue was direct government grants, that is to say block grants and other grants paid direct by the government to higher education institutions (HEIs). Direct government grants constituted around 40 per cent, that is to say 14.5 billion SEK of the overall R&D revenues for the higher education sector in 2017. The second largest source of funding for R&D (18 per cent) was the research councils (Swedish Research Council, Forte, Formas and Vinnova). The largest revenue source among these was the Swedish Research Council, which contributed 4.4 billion SEK of the R&D revenues of the higher education sector.

The third largest revenue source was private non-profit organisations (13 per cent). This groups consists of sources such as private foundations and trusts in

19 Vinnova (2018). Årsredovisning 2017. Vinnova information VI 2018:01.
20 Statistics Sweden database R&D in Sweden.
21 SCB (2016). Statliga anslag till forskning och utveckling 2016). UF17SM1601.
22 Prop. 2016/2017:50. Kunskap i samverkan – för samhällets utmaningar och stärkt konkurrenskraft.
23 SCB (2019). Forskning och utveckling i Sverige 2017.

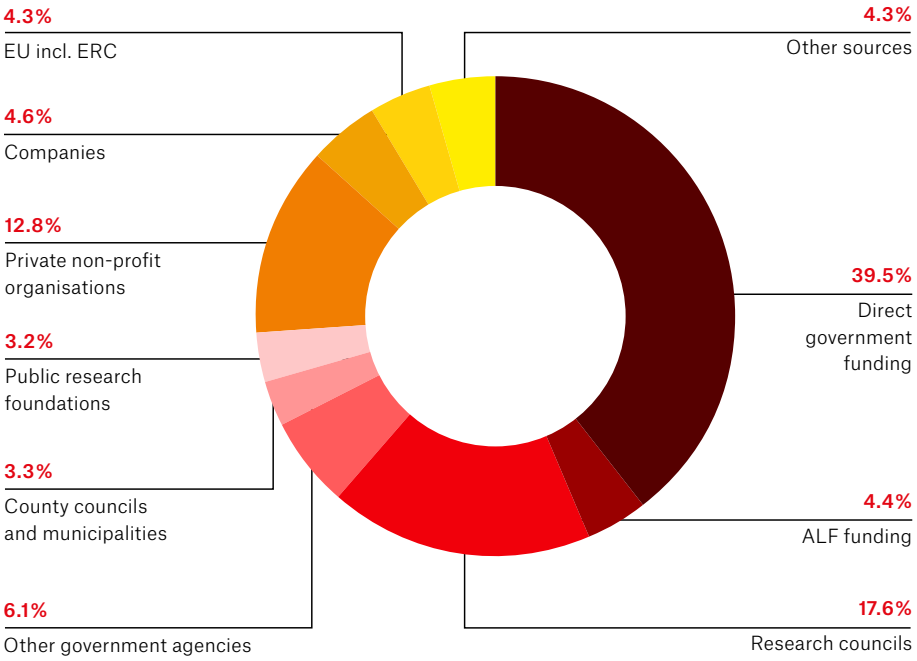


Figure 9. R&D revenues in the higher education sector 2017, by source of funding.
Source: Statistics Sweden.

Sweden and abroad. The private non-profit organisations based in Sweden form the majority, and contributed 4.1 billion SEK, or 11 per cent of the R&D revenues of the higher education sector.

R&D funding from businesses (located in Sweden and abroad) represented around 5 per cent, while funding from the EU including the ERC (the EU's framework programme for research and innovation, the European Research Council and other EU funds) represented around 4 per cent. Funding from other sources amounted to just over 4 per cent, and this includes items such as revenues from other HEIs, as well as funding from foundations and funds administered by the HEIs.

When it comes to the distribution between R&D revenues from Sweden and from abroad, funding from Sweden represented 93 per cent. The remaining 7 per cent came from the EU including the ERC (4 per cent), private non-profit organisations abroad (2 per cent), and from business abroad (1 per cent).

Over time, the percentages of funding from the various sources of funding of overall R&D revenues has changed relatively little (see Figure 10). The percentage of overall R&D revenues represented by direct government grants has decreased from 41 per cent in 2011 to just over 39 per cent in 2017. The percentage of R&D revenues from all government sources of funding (direct grants, ALF funds, research councils and other government agencies) has decreased from 69 per cent in 2011 to 68 per cent in 2017. The source of funding whose share of overall R&D revenues has increased the most over the period 2011–2017 was private non-profit organisations, where the percentage has increased from 10 to 13 per cent.

The percentages of overall R&D revenues contributed by the various sources of funding are of course dependent on the absolute development of the R&D revenues. Figure 11 shows that the higher education sector's R&D revenues over the period 2011–2017 has increased for all sources of funding, except ALF funding and revenue from county councils and municipalities. Over this period, R&D revenues increased by 4.2 billion SEK in total, and in 2017 amounted to 36.9 billion SEK (constant prices). Over the same period, revenues from ALF funds

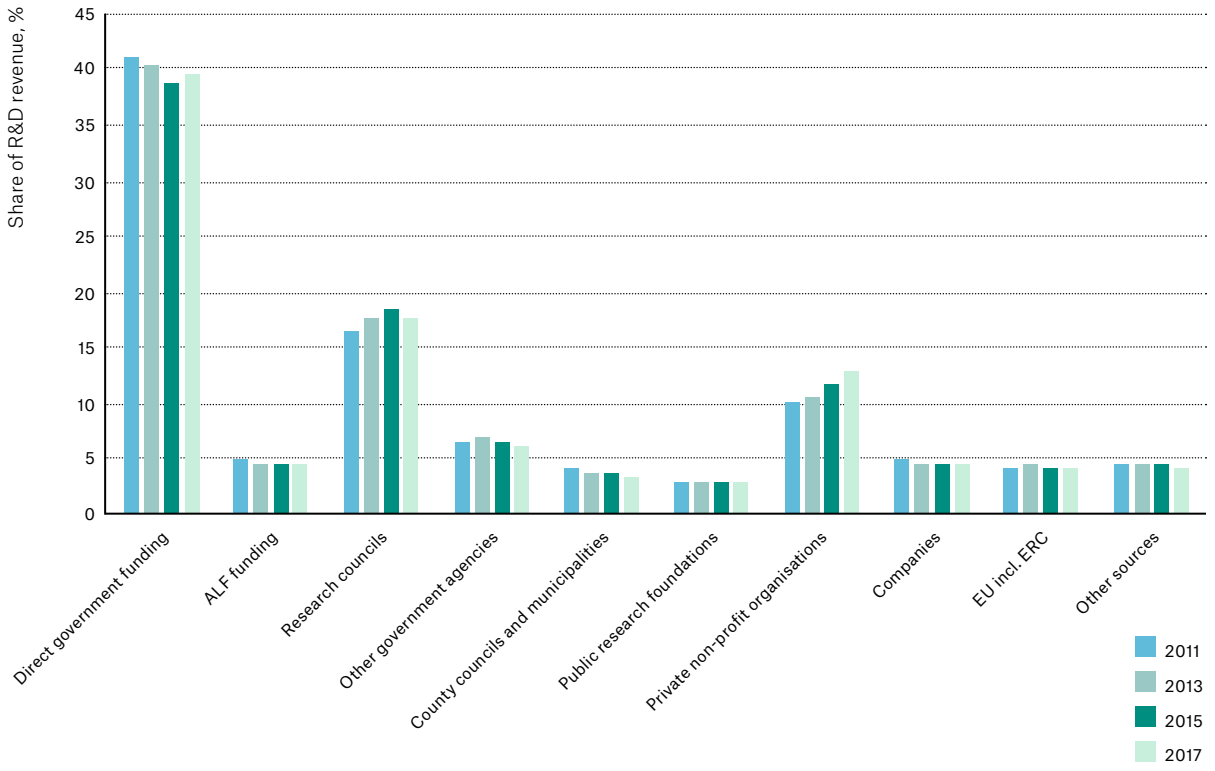


Figure 10. Development of higher education sector's R&D revenues by source of funding (percentage of overall R&D revenue). Source: Statistics Sweden.

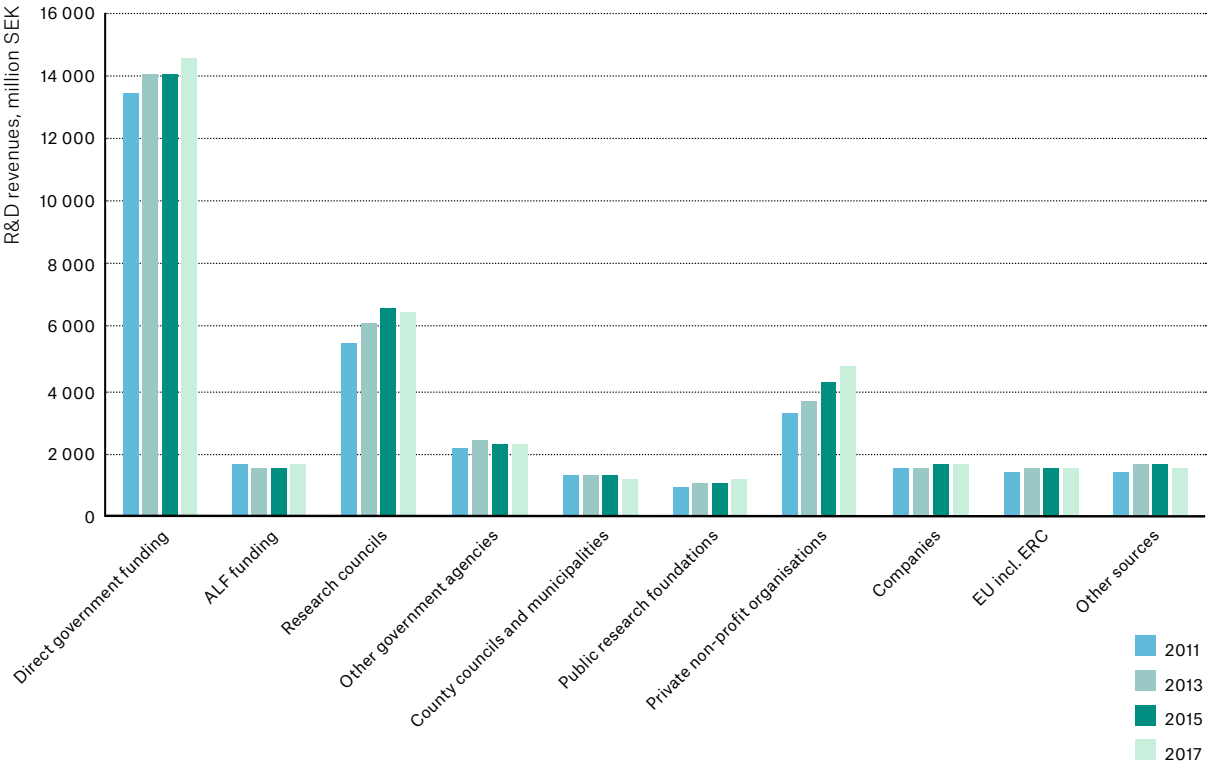


Figure 11. Development of higher education sector's R&D revenues by source of funding (million SEK, constant prices). Source: Statistics Sweden.

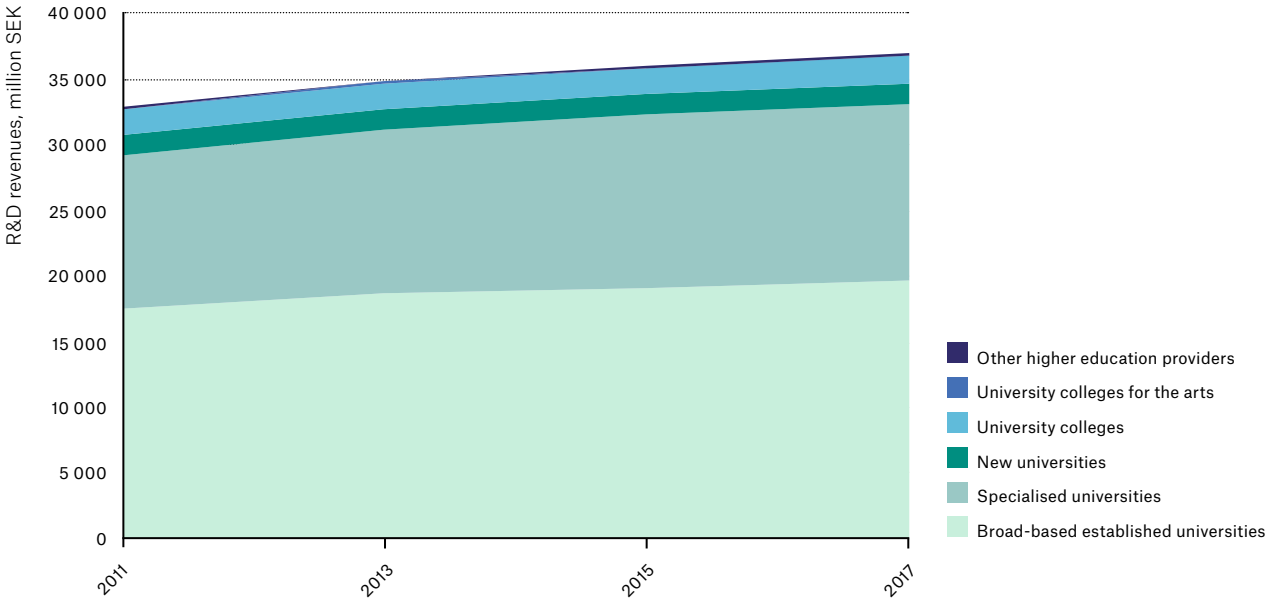


Figure 12. Development of higher education sector's R&D revenues, divided up by HEI category (million SEK, constant prices). Source: Statistics Sweden.

decreased by 19 million SEK, and revenues from county councils and municipalities decreased by 113 million SEK.

The total R&D revenues from the government sector (direct government funding, ALF funding, funding from research councils and other government agencies) increased by 2.2 billion SEK over the period. This includes in particular an increase in direct government funding of 1.1 billion SEK, and revenues from the research councils of 1.0 billion SEK. The greatest increase in both absolute and relative terms was R&D revenues from private non-profit organisations, where revenues increased by 1.4 billion SEK between 2011 and 2017.

Between 2015 and 2017, the higher education sector's total R&D revenues increased by 0.9 billion SEK. During this period, R&D revenues has increased from all sources of funding, except the research councils, other government agencies, and county councils and municipalities. The R&D revenues from the research councils decreased by 124 million SEK, while revenues from other government agencies and from county councils and municipalities decreased by 96 million SEK and 72 million SEK respectively.

Figure 10 and Figure 11 show an interesting interaction, where a change in absolute terms for an individual source of funding can impact on the percentages of R&D revenue for different sources of funding. For example, R&D revenues from direct government funding has increased in absolute terms, while the percentage of overall R&D revenues represented by these grants has decreased. This is explained by revenue from several other sources of funding, and in particular from private non-profit organisations, having increased more than revenue from direct grants.

R&D revenues divided up by HEI categories

Figure 12 shows the development of R&D revenues divided up according to different higher education institution (HEI) categories. (The division into HEI categories is described in the fact box below, and in the appendix.)

The figure shows that the higher education sector's R&D revenues primarily goes to the broad-based established universities and the specialised universities. The broad-based universities received 53 per cent of the R&D revenue in 2017,

while the specialised universities received 36 per cent, new universities 4 per cent and university colleges 6 per cent. University colleges for the arts and other private higher education providers received 0.2 per cent and 0.4 per cent respectively of the overall R&D revenue. This provides an overall picture of the scope of the research within the various HEI categories.

All HEI categories have seen an increase in their R&D revenues between the years 2011 and 2017. The broad-based established universities saw the largest increase in absolute terms (2.2 billion SEK), followed by the specialised universities (1.5 billion SEK), the new universities (0.2 billion SEK) and university colleges (0.1 billion SEK).

Figure 13 shows the development of the higher education sector's R&D revenues divided up by HEI category and field of research. Medicine and health sciences was the research subject area that received the largest R&D revenues for 2017, followed by natural sciences, engineering sciences, social sciences, humanities and art, as well as agricultural sciences and veterinary medicine. There are large differences in R&D revenues between different research subject areas. For example, the R&D revenues for medicine and health sciences was 3.5 billion SEK higher than for natural sciences in 2017. Of the higher education sector's overall R&D revenues, 34 per cent went to medicine and health, 24 per cent to natural sciences, 16 per cent to engineering sciences, 14 per cent to social sciences, 6 per cent to humanities and art, and 6 per cent to agricultural sciences and veterinary medicine.

Between the years 2015 and 2017, R&D revenues increased for medicine and health sciences, natural sciences and for humanities and the arts, while R&D revenues decreased for engineering and technology, social sciences as well as agricultural and veterinary medicine. The field of research that experienced the greatest change in absolute terms was natural sciences, where R&D revenues increased by 621 million SEK. The greatest percentage change was within the humanities and the arts, where R&D revenues rose by 13 per cent (265 million SEK).

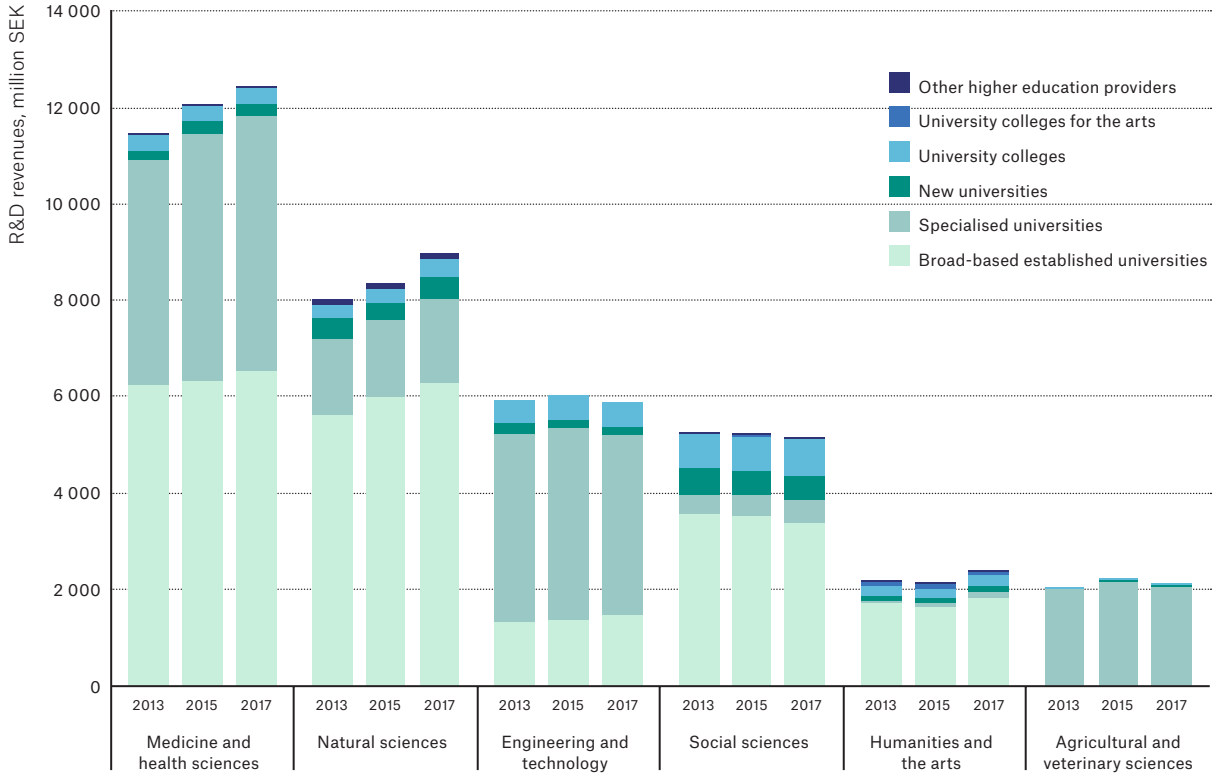


Figure 13. Development of higher education sector's R&D revenues, divided up by field of research and HEI category (million SEK, constant prices). Source: Statistics Sweden.

What are the various HEI categories?

The grouping of higher education institutions (HEIs) into categories is based on the HEIs that had R&D expenditure during the period 2011–2017 (see the appendix for further information).

- **Broad-based (comprehensive) established universities:** University of Gothenburg, Linköping University, Lund University, Stockholm University, Umeå University, and Uppsala University.
- **Specialised universities:** Chalmers University of Technology, Stockholm School of Economics, Karolinska Institutet, KTH Royal Institute of Technology, Luleå University of Technology, and the Swedish University of Agricultural Sciences.
- **New universities:** Karlstad University, Linnaeus University, Mid Sweden University, and Örebro University.
- **University colleges:** Blekinge Institute of Technology, Swedish Defence University, Swedish School of Sport and Health Sciences, Dalarna University, University of Borås, University of Gävle, Halmstad University, Jönköping University, University of Skövde, Kristianstad University, University West, Malmö University (from 1 January 2018 'new university'), Mälardalen University, and Södertörn University.
- **University colleges for the arts:** University of Arts, Crafts and Design, Royal Institute of Art, Royal College of Music, and Stockholm University of the Arts.
- **Other higher education providers:** Ersta Sköndal Bräcke University College, Swedish Red Cross University College, Sophiahemmet University, Stockholm School of Theology, and the Swedish Institute of Space Physics.

Figure 13 also describes how R&D revenues are divided up by fields of research and HEI category, and thereby shows a picture of where research is being performed within the various fields of research.

Within medicine and health, natural sciences, social sciences, as well as the humanities and the arts, R&D revenues was mainly received by the broad-based established universities. Within natural sciences and within the humanities and the arts, the broad-based established universities received around 70 and 77 per cent respectively of the R&D funds.

Within engineering, and agricultural and veterinary sciences, the specialised universities received the lion's share of R&D revenues. Around 63 per cent of the R&D revenues within engineering and technology went to the specialised universities. KTH Royal Institute of Technology and Chalmers University of Technology (both specialised universities) received 33 and 20 per cent respectively of the R&D revenues within engineering and technology. Within agricultural and veterinary sciences, 98 per cent of the R&D revenues went to the Swedish University of Agricultural Sciences, which is also a specialised university. Within medicine and health sciences, the specialised universities received a large percentage of the R&D revenues. The main recipient was Karolinska Institutet, which received 42 per cent of the R&D revenues within medicine and health.

The R&D revenues received by the new universities was divided up primarily between social sciences, humanities and the arts, and natural sciences. For example, the new universities received around 10 per cent of the R&D revenues within social sciences, and 6 per cent of the revenues within humanities and the arts. The university colleges received R&D revenues mainly within social sciences, humanities and the arts, and engineering.

What is research infrastructure?

Research infrastructure is used for conducting experiments, making observations, storing data or analysing data, for example. Examples of research infrastructure include buildings, instruments, knowledge corpora and services, aimed at being used by researchers or groups of researchers within basic research or applied research within all areas of research.[24]

Examples of research infrastructure within different research areas are: biobanks and various measuring instruments within medicine and health sciences; laboratories within physics, chemistry, materials sciences, engineering and life sciences; telescopes and other measuring equipment within astronomy, environmental and geosciences; statistics and register data within social sciences; and reality laboratories and language databases within humanities. Research infrastructure can thus take many forms, and the description above is not exhaustive.[25]

Costs for research infrastructure consists of costs for development and/or purchase, as well as current costs, such as maintenance, premises rental and personnel costs. Taken together, this means that it is difficult to estimate the overall magnitude of the infrastructure and therefore also the costs of research infrastructure.

The available statistics do not provide a full picture of the costs of research infrastructure. Statistics Sweden's figures for expenditure on R&D are divided up into current costs and investment/capital expenditures. Within the higher education sector, the investment/capital expenditures in machines and equipment amounted to 1.7 billion SEK for 2017, which corresponds to 4.4 per cent of the higher education sector's overall R&D expenditure. These figures thereby form part of the expenditure on research infrastructure, although they do not provide a complete picture. Statistics Sweden's figures for investment expenditures have been used, for example, to study changes over time, and as information for a discussion of future needs for investment in research equipment.[26]

24 Prop. 2016/17:50. Kunskap i samverkan – för samhällets utmaningar och stärkt konkurrenskraft, page 46.
25 For more information on different types of infrastructure, see Vetenskapsrådet (2018). The Swedish Research Council's Guide to Research Infrastructure 2018. Swedish Research Council.
26 Vetenskapsrådet (2010). En studie av investeringar i utrustning för forskning vid svenska universitet och högskolor, 1997–2007. Swedish Research Council.

Research personnel

2. Research personnel

Research personnel is the focus of this chapter. The chapter is divided up into two sections. The first section includes a description of Swedish researchers in international comparison, and the second section a description of research and teaching personnel within the Swedish higher education sector.

2.1 Swedish researchers in international comparison

Percentage of researchers in the population

Figure 14 below shows the percentage of the population who work as researchers in our selection of countries. In 2015, Sweden was the country that had the highest percentage of researchers in relation to its population. Sweden also saw a large increase between 2011 and 2013. This increase can partly be explained by a change in the Frascati Manual, where the category 'technical personnel' was removed and many of these persons, such as developers within the automotive industry, are now included in the category 'researchers'.

Apart from Sweden, it is primarily Denmark, Finland and Norway that have a high percentage of researchers in the population. The percentage of researchers in the population has increased in all these countries apart from Finland.

The percentage of women researchers is highest in Norway and in the United Kingdom, with around 38–39 per cent. In Sweden, women made up 34 per cent in 2015. The percentage of women researchers decreased in Sweden between 2011 and 2013, from 37 per cent to 33 per cent. This decrease can to some extent be explained by the above-mentioned change in the Frascati Manual.

How are researchers defined in the Frascati Manual?

In the Frascati Manual, researchers are defined as professionals engaged in the conception or creation of new knowledge with the help of advanced knowledge and skills. Although these skills may have been acquired through post-graduate research education, a research degree is not a necessary criterion.[27] This section accounts for persons who work with research and development within all sectors of society. The data is reported both as number of individuals and also as number of full-time equivalents occupied with research and development.

Figure 15 shows the relationship between R&D expenditure as a percentage of GDP and the number of researchers per thousand inhabitants, for our selection of countries.

27 OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris.

The sizes of the circles illustrate the magnitude of R&D expenditure in relation to the countries in the figure.

The figure shows that for our selection of countries, large R&D expenditures in relation to GDP appears to be related to a large percentage of researchers in the population. It should be noted that this measure only relates to researchers. An alternative measure is R&D personnel, which in addition to researchers also includes support personnel, such as research assisting personnel and laboratory engineers.

The figure shows that only South Korea and Switzerland have higher R&D expenditure as a percentage of GDP than Sweden, while only Denmark has a greater number of researchers per thousand inhabitants.

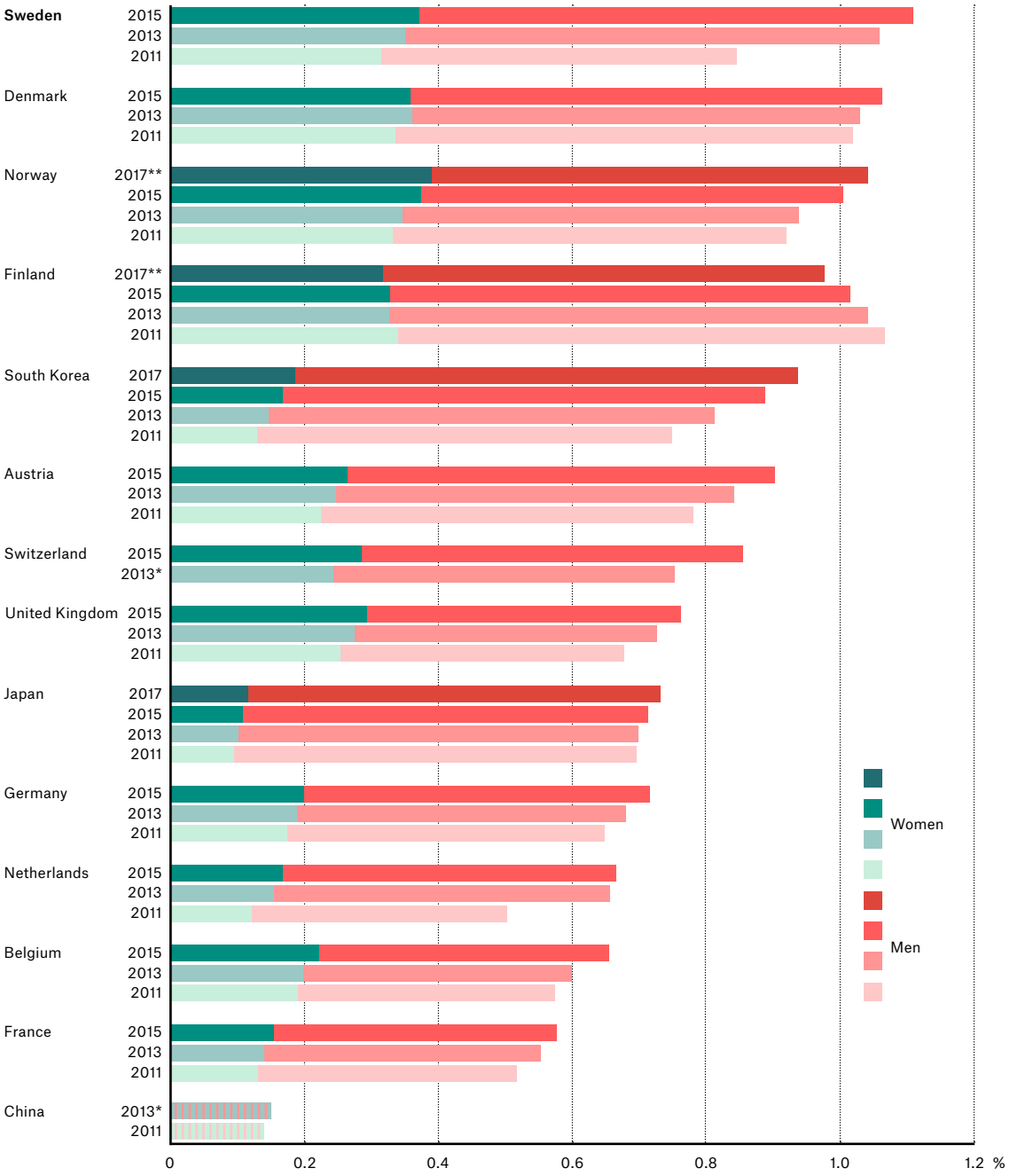


Figure 14. Percentage of the population who are researchers (individuals), over time and divided up into women and men. **Note:** * refers to 2012, ** refers to 2016. For China, figures divided up by gender are not available. No figures are available for USA, OECD and EU28. Source: OECD MSTI.

Percentage of researchers in different sectors

Figure 16 below shows how researchers are distributed between the business enterprise sector, government sector and higher education sector. The figure shows that a large percentage of researchers in South Korea work within the business enterprise sector, like in Japan and Sweden. This is because the business sector funds a lot of R&D in these countries. A considerably greater percentage of researchers work within the higher education sector in the United Kingdom, Norway and Switzerland.

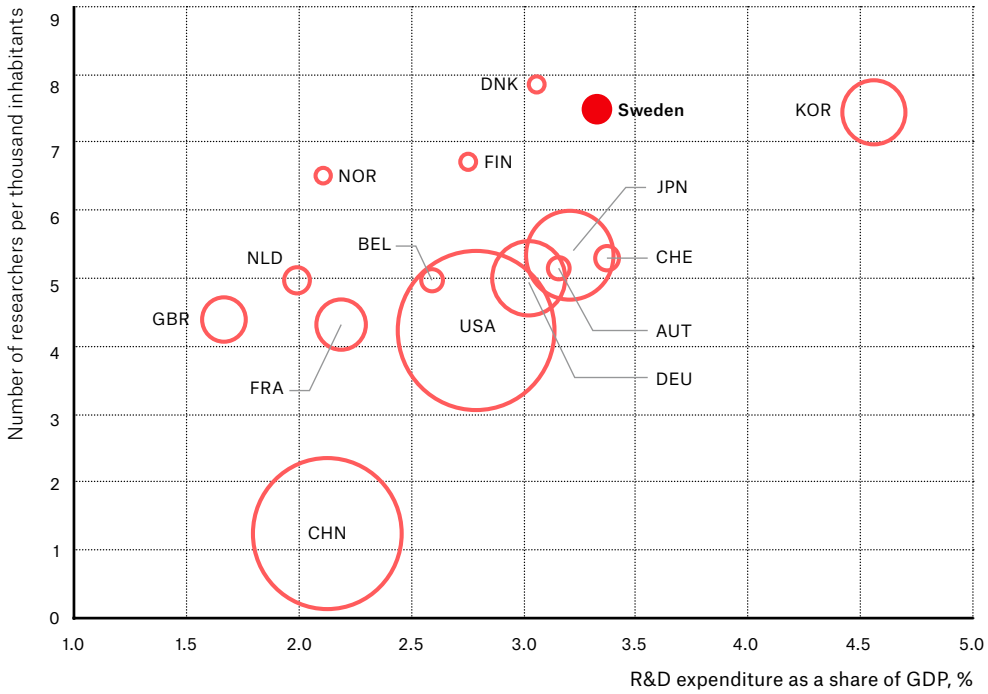


Figure 15. Gross domestic expenditure on R&D (GERD) as a percentage of GDP, in relation to the number of researchers (full-time equivalents) per thousand inhabitants, and the country's R&D expenditure in relation to the countries in the figure (size of circles), 2017. **Note:** The key to the country codes can be found in the appendix. Switzerland (CHE) with data from 2015. USA (USA) and Austria (AUT) with data for 2016 for number of researchers per thousand inhabitants. Source: OECD MSTI.

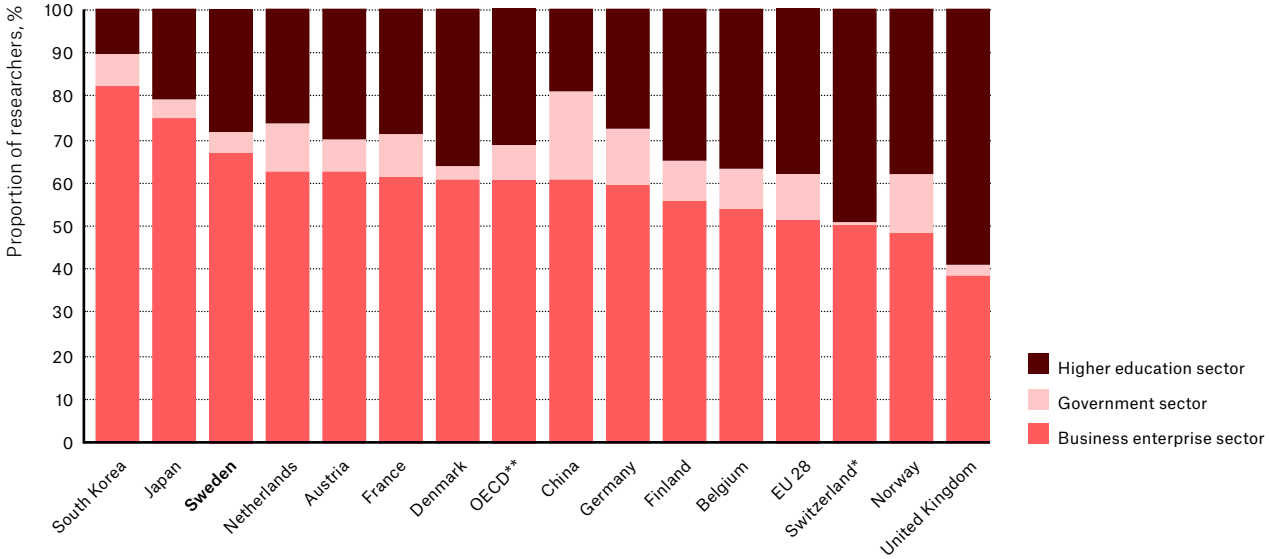


Figure 16. Distribution of researchers (full-time equivalents) between the business enterprise sector, higher education sector, and other government sector, 2017. **Note:** * refers to 2015, ** refers to 2012. Source: OECD MSTI.

China, Norway and Germany have the highest percentage of researchers active in the government sector. The R&D systems in these countries, together with a few other countries such as the Netherlands and France, are characterised by a relatively large R&D institute sector. Switzerland, the United Kingdom and Denmark have very few researchers working within the government sector and, like in Sweden, most of the publicly funded research is carried out at higher education institutions.

2.2 The higher education sector in Sweden

This section describes the higher education personnel according to career structure, gender distribution, distribution of working hours as well as internal, national and international mobility.

Research and teaching personnel and doctoral students

In 2018, the research and teaching personnel in the Swedish higher education sector amounted to around 38 000 persons. These persons correspond to just over 30 000 full-time equivalents. During the period 2008–2018, the number of research and teaching personnel at higher education institutions increased by around 10 000 employees. The doctoral students are not included in these figures, since they are not formally included in the research and teaching personnel. However, the doctoral students carry out a large proportion of the research in the HEI sector.

Figure 17 shows how the various personnel categories at HEIs with teaching and research tasks as well as doctoral student (employees) have developed over the last ten-year period.

The figure shows an increase in the number of employees within most employee categories. The number of senior lecturers and postdocs has increased throughout the period 2008–2018. The number of support personnel has also increased, while the number of employees within the category assistant senior lecturer/research fellow has only increased slightly. After a fall in the number of lecturers over a long period, the category increased slightly over the last year, primarily within social sciences.

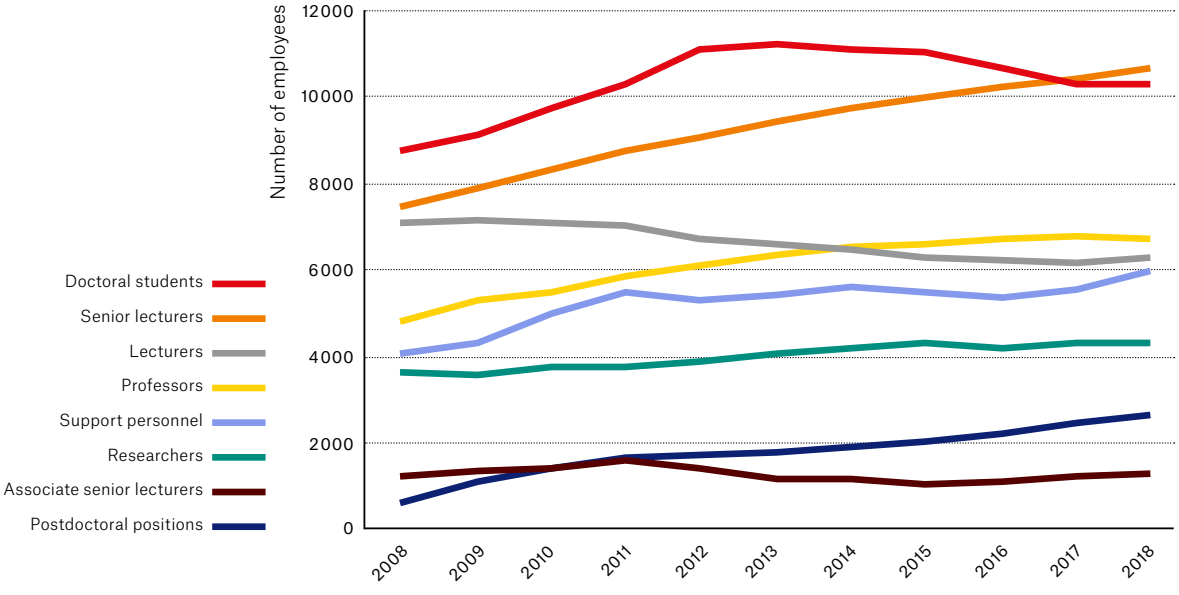


Figure 17. Development of research and teaching personnel and doctoral students in the HEI sector during the period 2008–2018. Source: Swedish Higher Education Authority.

Although most employee categories continue to increase, the increase in the number of professors has stagnated. This is partly due to a fall in the number of professors in medicine and health sciences, which in turn appears to be due to senior professors who are retiring.

The number of senior lecturers has increased in all subject areas (not shown in the figure), while the number of associate senior lecturers has fallen within research fields such as natural sciences and engineering sciences, as opposed to the number of post-docs. In medicine and health sciences, the situation is the opposite – the number of postdoctoral positions has fallen, while the number of associate senior lecturers has increased since last year.

Teaching and research personnel in the HEI sector

Employment in higher education is regulated in *Högskoleförordningen* (Higher Education Ordinance, SFS 1993:100), through agreements between the parties on the labour market or, if otherwise is not stated, in *Lagen om anställningsskydd* (Employment Protection Act, SFS 1982:80).

Employment categories regulated in Högskoleförordningen:

- **Professor:** (*Sw. professor*). There is also adjunct professor, visiting professor and combined employment with a healthcare principal.
- **Senior lecturer:** (*Sw. lektor*). There is also combined employment with a healthcare principal.
- **Associate senior lecturer:** (*Sw. biträdande lektor*). Four to six year career development employment with the right to a review for consideration of permanent appointment as senior lecturer. Eligible for appointment is a person who has been awarded a doctoral degree within five years. The employment category has been subject to several changes, and was previously designated as 'research fellow' (*Sw. forskarassistent*), with no right to a review for consideration of appointment as senior lecturer.
- **Doctoral student:** (*Sw. doktorandanställd*). Appointment for a person admitted to third-cycle education. Not all registered PhD students are employed as doctoral students. Doctoral studentships are not included in the statistics for the teaching and research personnel in the higher education sector.

Other employment categories:

- **Postdoctoral position:** (*Sw. postdoktor).* Two-year position obtained within two years of the award of doctoral degree. The position is regulated via a labour market agreement between the parties.
- **Other research and teaching personnel with doctoral degrees:** Designated as 'researchers' in the Swedish Research Barometer.
- **Other research and teaching personnel without doctoral degrees:** Designated as 'support personnel' in the Swedish Research Barometer.
- **Lecturer:** (*Sw. adjunkt*).

In 2018, there was a total of just below 17 000 active doctoral students, of which around 60 per cent were employed as doctoral students. The number of doctoral students has fallen over the last five-year period, and thereby also the number of doctoral student with an employment. The number of doctoral students is, however, expected to be relatively stable over the coming period, as the number of new doctoral students has remained relatively unchanged over the last five-year period. By far the largest number of doctoral students are within medicine and health sciences, followed by natural

sciences as well as in engineering and technology. Overall, 35 per cent of the doctoral students are from abroad, in the sense that they arrived in Sweden from other countries less than two years before starting their doctoral studies.[28] This is most common within natural sciences and engineering and technology, where 60 per cent of the doctoral students were from abroad in 2018. Just over 60 per cent of the foreign doctoral students leave Sweden within three years of being awarded their doctoral degrees.

Research and teaching personnel by HEI category

Sweden's higher education sector consists of around 40 higher education institutions of varying sizes, different subject specialisations, and with a large variation in the proportion between research and teaching carried out. In the Research barometer, the HEIs are divided up into six categories: broad-based established universities, specialised universities, new universities, university colleges, university colleges for the arts, and other higher education providers (see the fact box in Section 1.2 and the appendix for which HEIs are included in the different groups).

Figure 18 shows the personnel composition and the total number of employees in the research and teaching personnel, at the different HEI categories. Doctoral students are not included in the research and teaching personnel, and are therefore not included in the figure.

The largest number of research and teaching personnel are employed at the broad-based established universities, followed by the specialised universities, the university colleges and the new universities.

The share of professors is higher at the broad-based established universities, as well as the specialised universities, while senior lecturers and lecturers form the dominant employment categories at the university colleges and at the new universities. The spe-

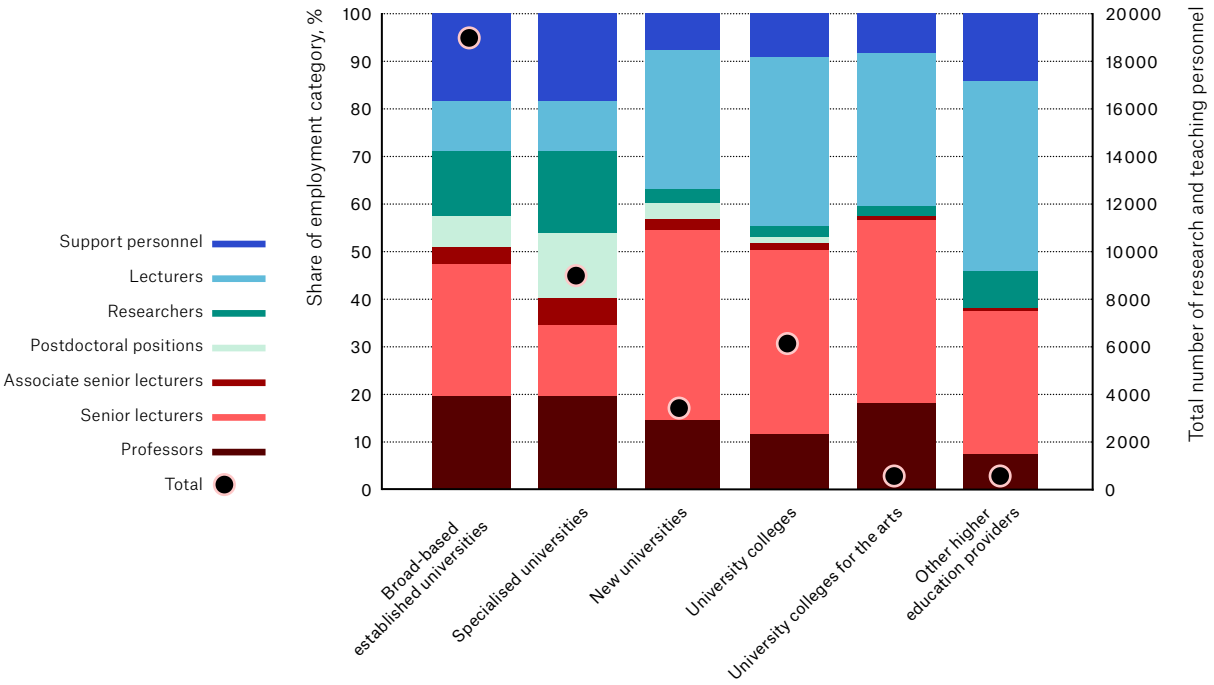


Figure 18. Research and teaching personnel at Swedish HEIs 2018. The left axis shows the relative distribution between employment categories (bars) and the right axis the number of individuals (dots).
Note: 'Support personnel' refers to other research and teaching personnel without doctoral degrees.
Source: Swedish Higher Education Authority.

28 UKÄ (2019). Statistisk analys: Många utländska doktorander lämnar Sverige efter examen.

cialised universities have a lower percentage of senior lecturers and a higher percentage of researchers, postdoctoral positions and associate senior lecturers, which reflects the higher percentage of research conducted in relation to teaching at these HEIs.

The fact that research activities are concentrated to the broad-based established universities and the specialised universities, is shown by the personnel categories that are mainly occupied in research being more common there, such as postdocs and researchers. This is also reflected in the number of doctoral students, which is highest in relation to the number of employees at the specialised universities and lowest at the university colleges.

The regional teaching responsibility is an important component. The new universities and university colleges are responsible for 40 per cent of the educational volume measured as registered students during autumn term 2018. In comparison, the specialised universities had 13 per cent, and the broad-based established universities around 45 per cent of the registered students.[29]

Women and men in the HEI sector

Gender equality means that women and men have the same opportunities, rights and obligations within all areas of life. Gender equality has both quantitative and qualitative aspects, where quantitative gender equality means equal percentages of women and men in all areas of society, for example within different professions. When the gender distribution falls within the interval 40 to 60 per cent, it is usually consider that the gender distribution is even. Qualitative gender equality means that the knowledge, experiences and opinions of both women and men are taken into account, which enrich and influence the development within all areas of society.[30] An equal gender distribution does not automatically imply that an organisation is gender equal qualitatively.[31]

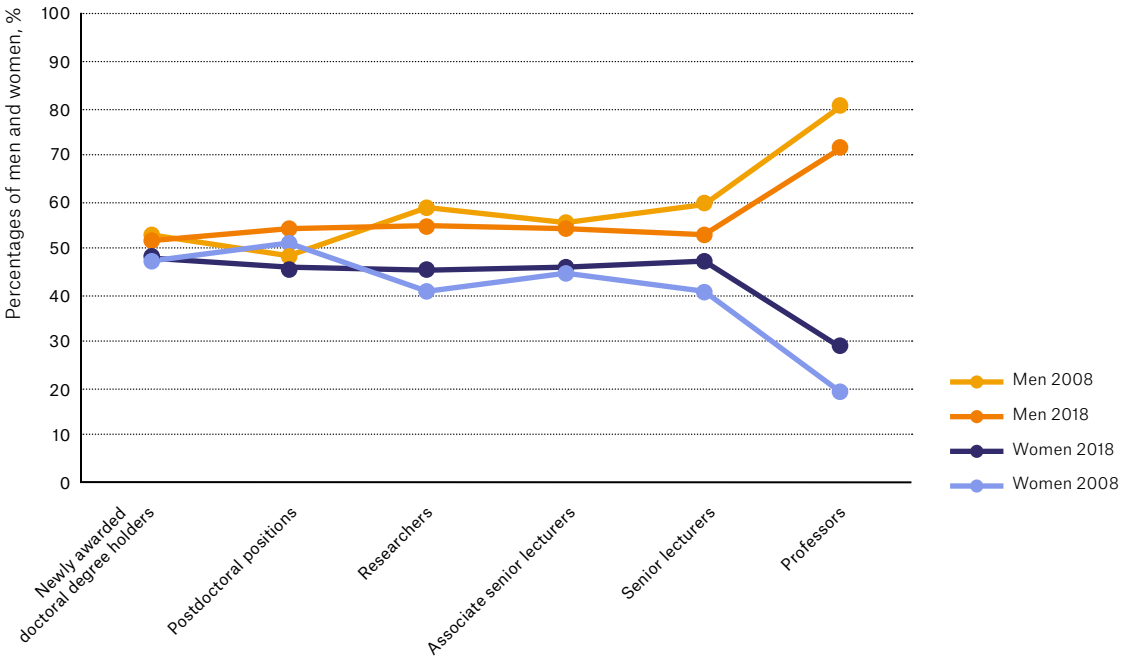


Figure 19. Percentages of women and men among different employment categories as well as among newly awarded doctoral degree holders, in 2008 and in 2018. Source: Swedish Higher Education Authority and Statistics Sweden.

29 Swedish Higher Education Authority.

30 SCB (2016). På tal om kvinnor och män – Lathund om jämställdhet 2016., Vetenskapsrådet (2018). Redovisning av regeringsuppdrag att utveckla uppföljning av svensk forskning.

31 Universitets- och högskolerådet (2014). Jämställdhet i högskolan – ska den nu ordnas en gång för alla?

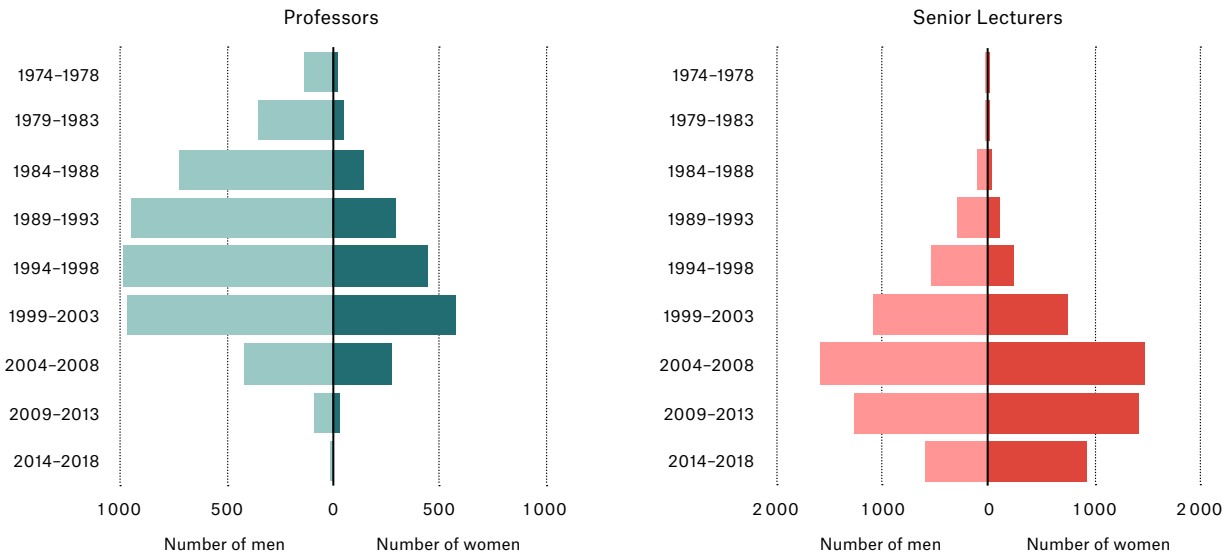


Figure 20. Number of professors and senior lecturers distributed by gender and year of doctoral degree award, 2018. Source: Statistics Sweden.

Nevertheless, it is important to track the gender distribution within various career stages in the HEI sector.

Figure 19 shows how the percentages of women and men respectively have developed over the last ten-year period.

In 2018, all career stages up to and including senior lecturer had roughly the same percentages of women and men. The percentage of women varies between 45 and 48 per cent, and that for men between 52 and 55 per cent. The development is also towards a higher percentage of women among professors, and over the ten-year period, the percentage of women increased by around ten percentage points. This means that the gender distribution among professor currently is about 30 per cent women and 70 per cent men.

Over the last few decades, the number of women active in the higher education sector has grown strongly. Figure 20 shows the number of men and women among professors and senior lecturers, distributed by the year the person was awarded the doctoral degree.

Of the professors who were awarded their doctoral degrees relatively recently, during 2009–2013, the proportion of women is 26 per cent. For those with doctoral degree award years 2004–2008, that is to say professors who received their PhD between 10 and 15 years ago, women represent 40 per cent, and in the interval 1999–2003 women make up 37 per cent. For doctoral degree award years before 1999, the proportion of women is between 31 and 12 per cent.

Approximately the same percentage of women (47 per cent) as men (53 per cent) have been awarded the doctoral degree since 2000, so the explanation for the slightly lower percentage of women than men obtaining employment as professors must be sought elsewhere. Of those who obtained employment as professors relatively soon after becoming a PhD, that is to say with doctoral award years 2009–2013, there are considerably more men than women, also when compared to the average for all professors. Why this is so is difficult to say, and the total number of individuals is small. It should be noted that the description in the figure is based only on year of doctoral degree award. To make a description based on career age, parental leave and other factors also need to be taken into account.

Among senior lecturers, the career age structure is more similar for men and women, although there are considerably more men among those who received their doctoral

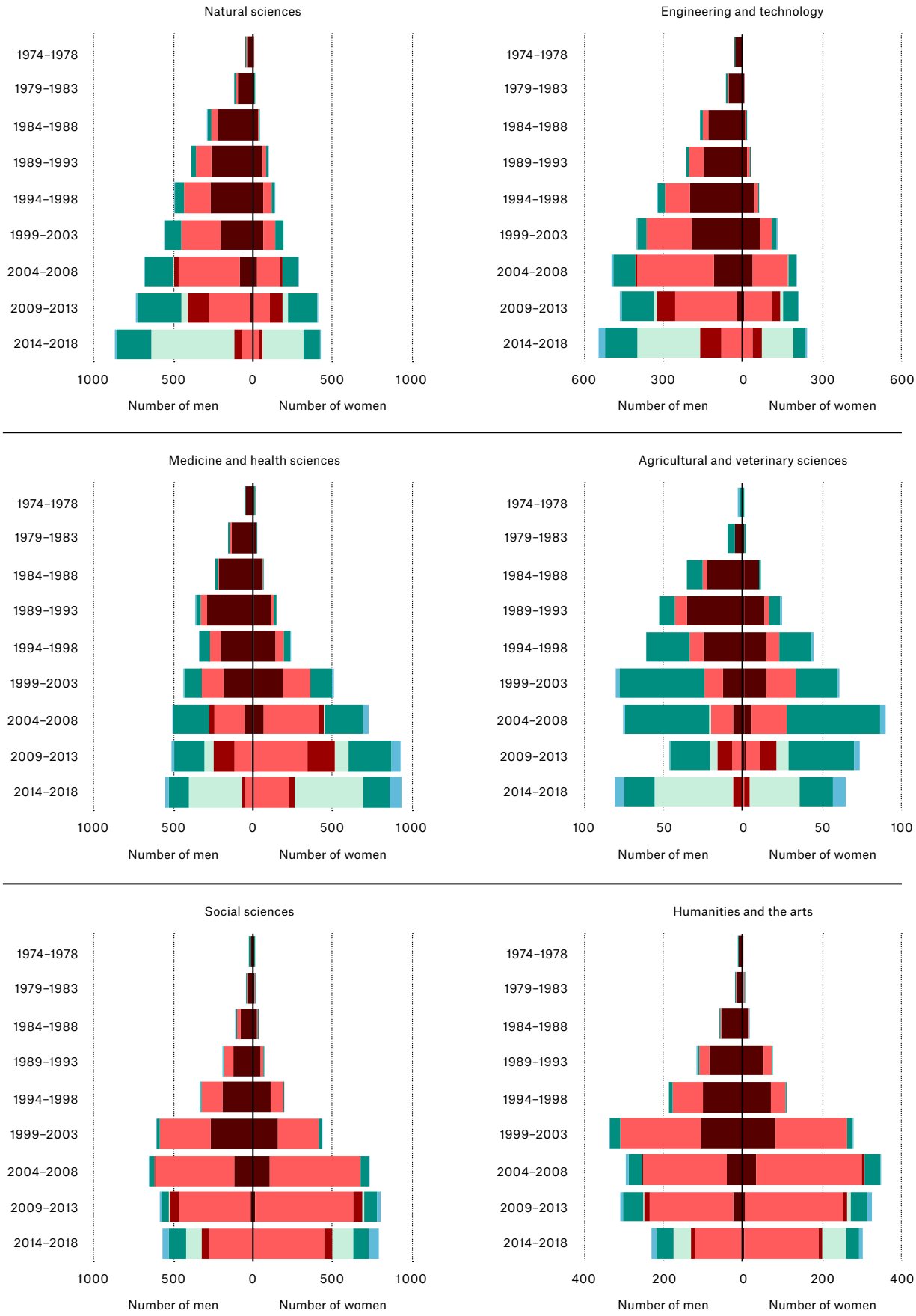


Figure 21. Research and teaching personnel with doctoral degrees, according to doctoral degree award year, employment category, gender, and field of research, in 2018. **Note:** See the appendix for further information. Source: Statistics Sweden.

degrees more than 15 years ago. Among those awarded doctoral degrees 2009–2013, there are more women senior lecturers than there are men. This is due to a number of different factors, such as the historical distribution between men and women regarding third-cycle education as well as variations in employment structure between different fields of research.

Figure 21 shows the number of men and women in the research and teaching personnel with a doctoral degree, according to field of research, gender and doctoral degree award year.

All fields of research apart from the humanities and the arts have a large number of employees with doctoral degree award year in the periods 2014–2018 and 2009–2013. This shows once again that the research and teaching personnel has expanded much during the 2000s. The variation between fields of research is large, however, and the increase has primarily occurred within natural sciences and within medicine and health sciences. These fields of research are characterised to a greater extent by many researchers and teachers who relatively recently was awarded the doctoral degree.

Within all fields or research, the more senior personnel in career terms consists of men to a larger extent, but there is also an increasing proportion of women among those with the more recent doctoral degree award yeras. However, within both natural sciences as well as engineering and technology, men dominate all award years, while the proportion of women and men is even (within the 40/60 per cent interval) for doctoral degree award years 2009–2013 and later, within both social sciences as well as the humanities and the arts. Within medicine and health sciences, the gender distribution has changed from being dominated by men in the earlier degree award intervals to consisting of more than 60 per cent women in the later degree award intervals. Within agricultural sciences, the development is also towards an increasing proportion of women.

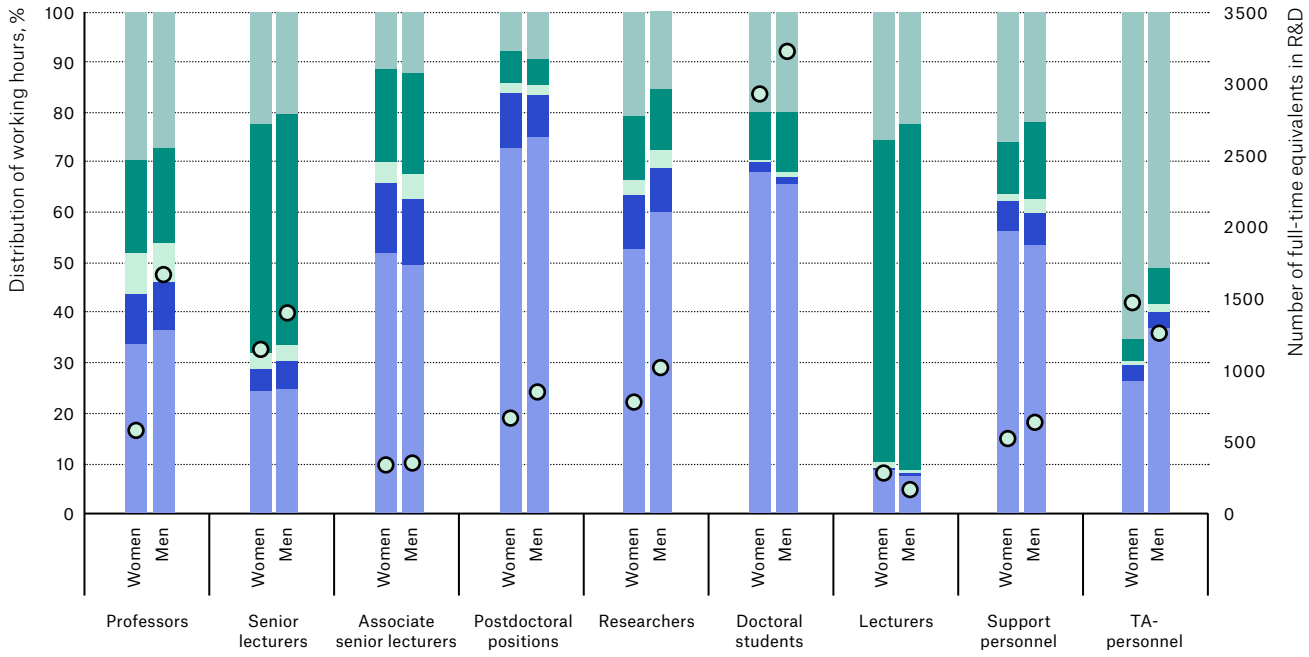


Figure 22. Relative distribution of working hours spent on different tasks for different employment categories and genders (left axis) and total number of R&D full-time equivalents (right axis), 2017.
Note: TA personnel means technical and administrative personnel. These are not counted as research and teaching personnel, and are therefore not included in the other figures relating to personnel in this section. Working hours spent on R&D is calculated as the sum of 'R&D' and 'of which applying for R&D funds'. Source: Statistics Sweden.

The gender distribution for different employment categories described in Figure 21, corresponds to the gender distribution for persons with doctoral degrees in total, divided up by field of research and year of doctoral degree award. Within medicine and health sciences, for example, the number of doctoral degree holders has shifted from being dominated by men to more recently being dominated by women.

In terms of different employment categories, professors form an ever-increasing percentage of employees among persons awarded doctoral degrees 1999–2003, and in the degree award interval 1993–1998 they form the entirely dominant employment category within all subject areas.

During the first five years following the doctoral degree award, senior lecturer is the most common employment category within social sciences and within humanities and the arts. For the other fields of research, a postdoctoral position is the most common employment category during the first five years. This largely reflects the relationship between research and teaching. There are more senior lecturers within research fields with large teaching obligations, and it is more common to be employed as a senior lecturer relatively soon after the doctoral degree award, while in areas with relatively more research, employment as a postdoc or a researcher is more common.

Distribution of working hours

Figure 22 shows the relative distribution of working hours within the various employment categories in terms of: research and development (including time for applying for R&D funds), teaching at various levels, as well as 'other activities.' The figure also shows the total number of full-time equivalents spent on R&D conducted by the various employment categories.

Postdocs spend the highest proportion of their working hours on R&D, followed by researchers and doctoral students. Professors, associate senior lecturers and research fellows, as well as researchers, all spend around 10 per cent of their working hours on applications for R&D grants. Among the higher education personnel with doctoral degrees, senior lecturers spend the smallest proportion of their working hours on research, around 30 per cent; simultaneously they teach the most, spending around 50 per cent of their working hours on this. Professors spend the largest percentage of their working hours, around 30 per cent, on other work which may consist of both administration and various expert and elected assignments. Postdocs are the employees who spend the least time on 'other work,' less than 10 per cent.

Doctoral students are the employment category that conducts the highest number of full-time equivalents in R&D in the HEI sector, followed by TA personnel, senior lecturers and professors. The largest number of full-time equivalents are carried out by men in all personnel categories that require a doctoral degree, and among doctoral students. Only relatively small changes have occurred since the last measurement, which referred to 2015.

Internal, national and international recruitment

The mobility of researchers and teachers, that is to say short or long periods of activity at different higher education institutions or other R&D institutions nationally or internationally, is often perceived as an important element for scientific exchange and revitalisation. There are many ways of achieving mobility; everything from short visits, e.g. conferences, sabbaticals and postdoc visits, to longer, more-or-less permanent changes. One way of measuring the mobility of researchers and teachers is to investigate the recruitment carried out by HEIs, whether they recruit mostly from within the own organisation (that is to say persons who have been awarded a doctoral degree at the same HEI), from other Swedish HEIs, or by recruiting persons with doctoral

degrees from HEIs outside of Sweden. Figure 23 shows the percentage of teachers and researchers according to internal, national and international recruitment.

Looking at all HEI categories, just over half of the researchers and teachers in higher education with a doctoral degree got this from the same HEI they are now employed at. Around 30 per cent had a doctoral degree from another Swedish HEI, and around 14 per cent had a doctoral degree from a HEI outside of Sweden.

The broad-based established universities and specialised universities recruit largely in-house. Around 64 per cent of the personnel at the broad-based established universities, and around 58 per cent of the personnel at the specialised universities have a doctoral degree from the same HEI that they are now working at. The broad-based established universities and specialised universities also recruit persons with a foreign doctoral degree to a greater extent than the new universities and university colleges do.

The new universities and university colleges primarily recruit personnel with doctoral degrees from another Swedish HEI. At the university colleges, around 80 per cent of the personnel with doctoral degrees were awarded this at another Swedish HEI than the one they were employed at in 2018. This result was expected however, as the university colleges have limited opportunities to conduct third cycle higher education by themselves.

For all four HEI categories, the percentage of personnel with foreign doctoral degrees has increased, while the percentage of personnel with doctoral degrees from the own HEI has decreased slightly. Mobility varies according to doctoral degree award year. The highest percentage of personnel with foreign doctoral degrees is found among those whose degree was awarded between 5 and 10 years ago, that is to say in the interval 2008–2014.

The percentage of internally, nationally or internationally recruited persons also varies between field of research and gender, which is shown in Figure 24.

Natural sciences has by far the highest proportion of employees with a doctoral degrees from a foreign HEI, at around 25 per cent, while humanities and the arts, and social sciences show the highest national mobility, where between 40 and 42 per cent have a doctoral degree from another Swedish HEI. Overall, the least mobility is shown within agricultural and veterinary sciences, followed by medicine and health sciences, where 57 per cent had a doctoral degree awarded by the same HEI the person is employed at.

The differences between men and women are small, except within agricultural and veterinary sciences. There are, however, relatively few persons in agricultural and veterinary sciences, which imply that any further analysis should be done with caution.

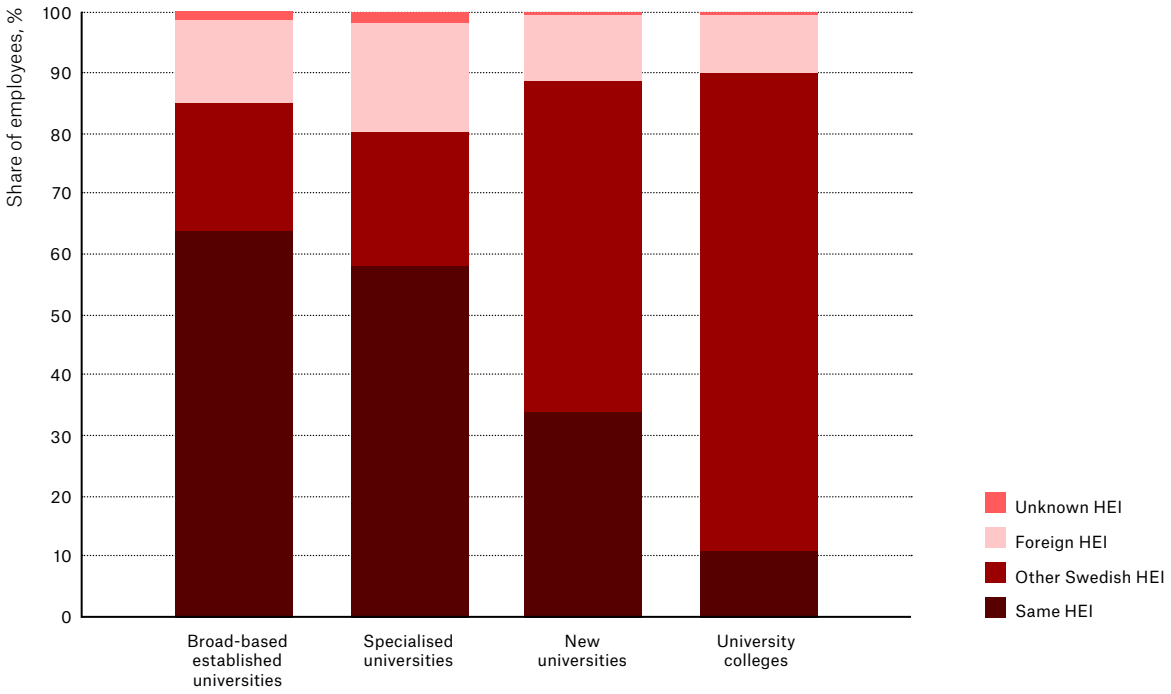


Figure 23. Recruitment of higher education personnel with doctoral degrees, by HEI category, year 2018. The percentage of persons with doctoral degrees from the same HEI (i.e. doctoral degree from the same HEI the person in question was employed at in 2018), other Swedish HEI, foreign HEI and unknown HEI respectively. Source: Statistics Sweden.

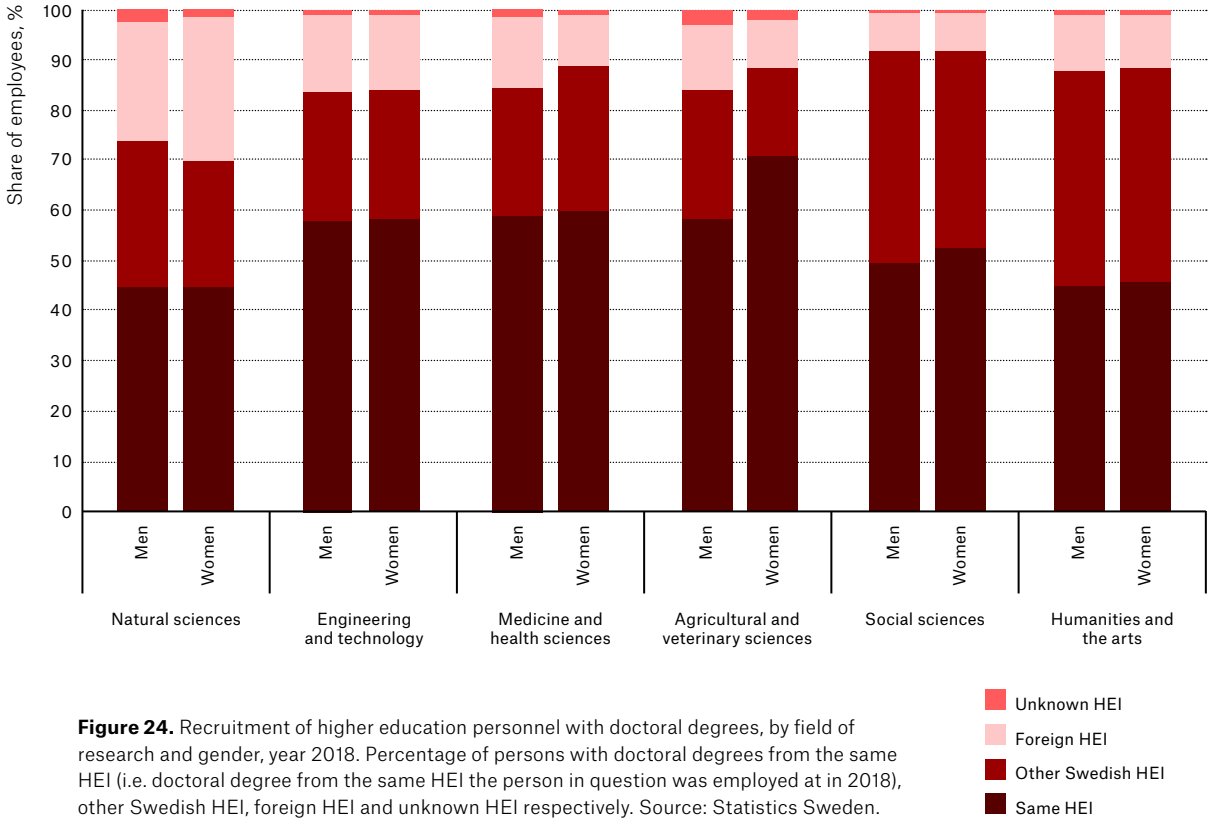


Figure 24. Recruitment of higher education personnel with doctoral degrees, by field of research and gender, year 2018. Percentage of persons with doctoral degrees from the same HEI (i.e. doctoral degree from the same HEI the person in question was employed at in 2018), other Swedish HEI, foreign HEI and unknown HEI respectively. Source: Statistics Sweden.

Scientific publication

3. Scientific publication

Scientific publication is the focus of this chapter. The chapter is divided up into two sections. The first section includes a description of Sweden's scientific publications in international comparison, and the second section a description of the Swedish higher education institutions' publications.

3.1 Scientific publications in international comparison

Number of scientific publications

Figure 25 shows the development of the number of scientific publications, for different continents and for different research areas. The overall number of scientific publications has increased significantly since the early 2000s. Over a ten-year period (2007–2017), all continents have seen a large increase in the number of publications, although Asia stands out with the largest increase in both relative and absolute terms. During the period 2007–2017, Asia increased its volume by 130 percent, which can be compared to Europe and North America, which increased by 30 and 20 per cent respectively over the same period.

Asia, Europe and North America produce around 90 per cent of the total num-

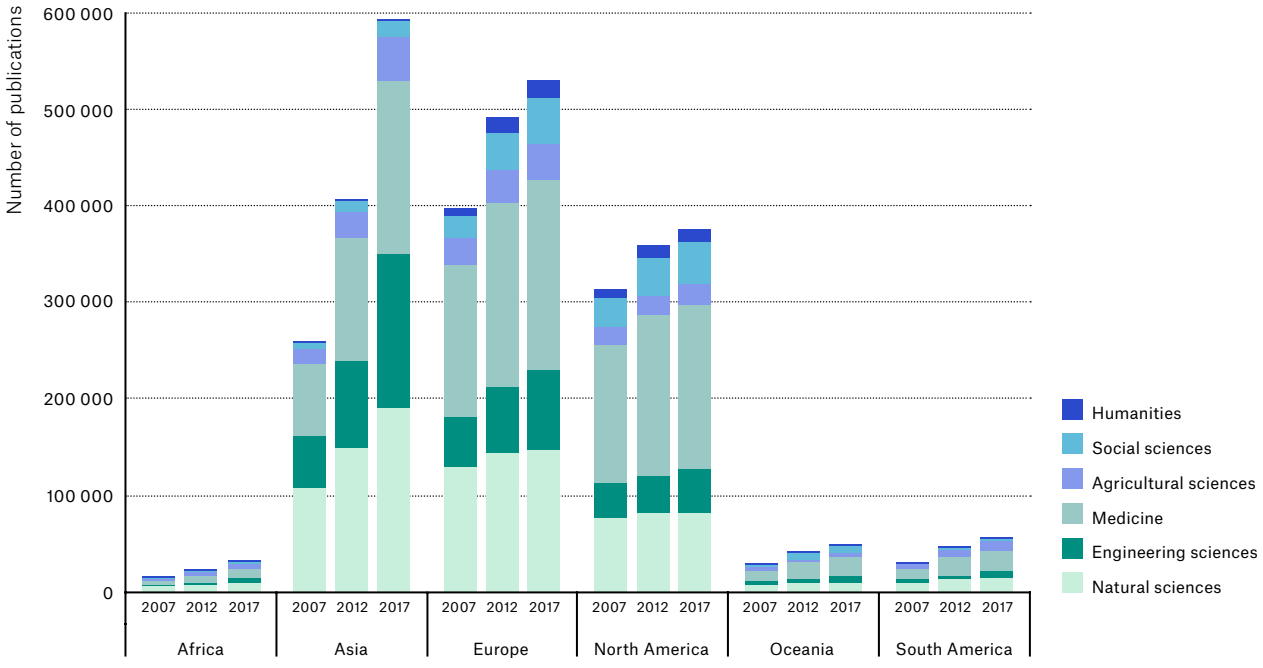


Figure 25. Number of publications per continent, year and research area. Source: Clarivate Analytics.

ber of scientific publications. Europe is the largest producer within three research areas: humanities, medicine and social sciences. Within humanities, Europe produces almost half of all scientific publications. Asia is largest within agricultural sciences, natural sciences and engineering sciences.

The differences in the number of articles within different research areas can also be interpreted as differences in research profile. For both Europe and North America, medicine is by far the largest research area (37 and 45 per cent respectively), followed by natural sciences (28 and 22 per cent respectively). For Asia, natural sciences is largest, but only marginally larger than the research areas medicine and engineering sciences.

When the global article volume is divided up by research areas, it emerges that medicine and natural sciences represented around 65 per cent of the overall number of articles in 2017.

How is the number of publications calculated?

The number of publications can be calculated using either 'full counts' or 'fractioned' counting. Full counts means that authors A and B of a co-publication are each credited with one publication. This means that the total number of publications for all individual authors is greater than the actual volume. In fractioned counting, authors A and B are instead awarded half a publication each, and the author total ends up the same as the actual number of publications. Unless otherwise is stated, the fractioned counting is used in this report.

The publication statistics are based on data from the Swedish Research Council's publication database, which is based on the same material as Web of Science. The publication database covers around 18 000 international scientific periodicals. Each periodical in the database is classified by Clarivate Analytics into one or several of around 250 subject classifications, where individual articles receive the periodical's subject classification. In the report, the 250 subjects have been aggregated to two classifications, one with 6 research areas and one with 16 subject areas.

When reference is made to percentage of articles in the world or citation impact in relation to the world average, it is in relation to the publication database. The database's coverage of different subject areas varies. See the appendix for further description.

The number of publications a country publishes is strongly correlated to the number of inhabitants in the country. Instead of expressing publication volume in absolute terms, volume can be expressed relative to the number of inhabitants, which can also be seen as a form of productivity measure. Figure 26 compares the number of publications per 1 000 inhabitants with the percentage of highly cited publications. The figure also shows the country's relative publication volume in relation to the countries in the figure, which are illustrated using circles.

During the period 2015–2017, Switzerland (CHE) and Denmark (DNK) published the greatest number of articles per inhabitant. Australia (AUS) and Sweden followed as the third and fourth most productive countries. It is worth noting that all five Nordic countries are among the top seven in terms of article production in relation to population. Major research countries, such as USA, China (CHN) and United Kingdom (GBR), which produce a great volume in absolute terms, do less well in such a comparison, while small countries, such as the Nordic countries, the Netherlands (NLD) and Singapore (SGP) have greater production in relative terms.

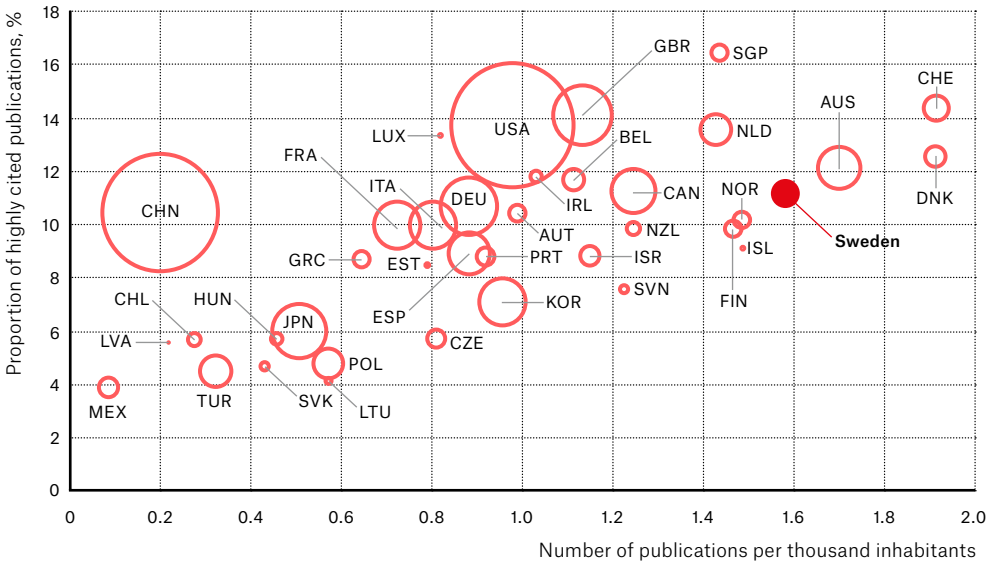


Figure 26. Number of publications per thousand inhabitants in relation to the proportion of highly cited publications, and the country's relative publication volume (size of circles), for OECD, Singapore and China, 2015–2017. **Note:** The key to the country codes can be found in the appendix. Source: Clarivate Analytics and UN.

If we look at the number of publications instead, USA and China together produced around 45 per cent of the overall number of articles for the countries in Figure 26, as illustrated by the circle size. During the period 2015–2017, USA and China produced almost 40 per cent of the world's article volume. If we add the volumes from the United Kingdom, Germany, and Japan, these countries together produced more than 50 per cent of the total world volume. Over the same period, Sweden produced 1 per cent of the total volume.

How is the proportion of highly cited publications calculated?

To study the scientific impact, the Swedish Research Barometer uses the citation impact indicator, which refers to the proportion of highly cited publications. The citation impact shows how large a percentage of a continent's, a country's or an organisation's article volume is in the 10 per cent most cited publications in the world. The global average for this indicator is 10 per cent.

The proportion of highly cited publications is a more stable measure than average number of citations, for example, as the measure proportion of highly cited publications is not as sensitive to extreme values.

The world average is calculated based on articles available in the publication database, and is therefore dependent on the coverage of various subject areas. The number of citations is counted during a three-year window, which means that the citations are counted as from the year the article is published and for the two following years. All citation values are field-normalised, and self-citations are excluded. The division into subject areas is based on a classification of journals in the publication database. For further details, please see the appendix.

Citation impact

In addition to the number of publications per inhabitant, Figure 26 also shows the different countries' citation impact. The citation impact shows how large a percentage of the country's article volume are in the 10 per cent most cited publications in the world. The global average for this indicator is 10 per cent.

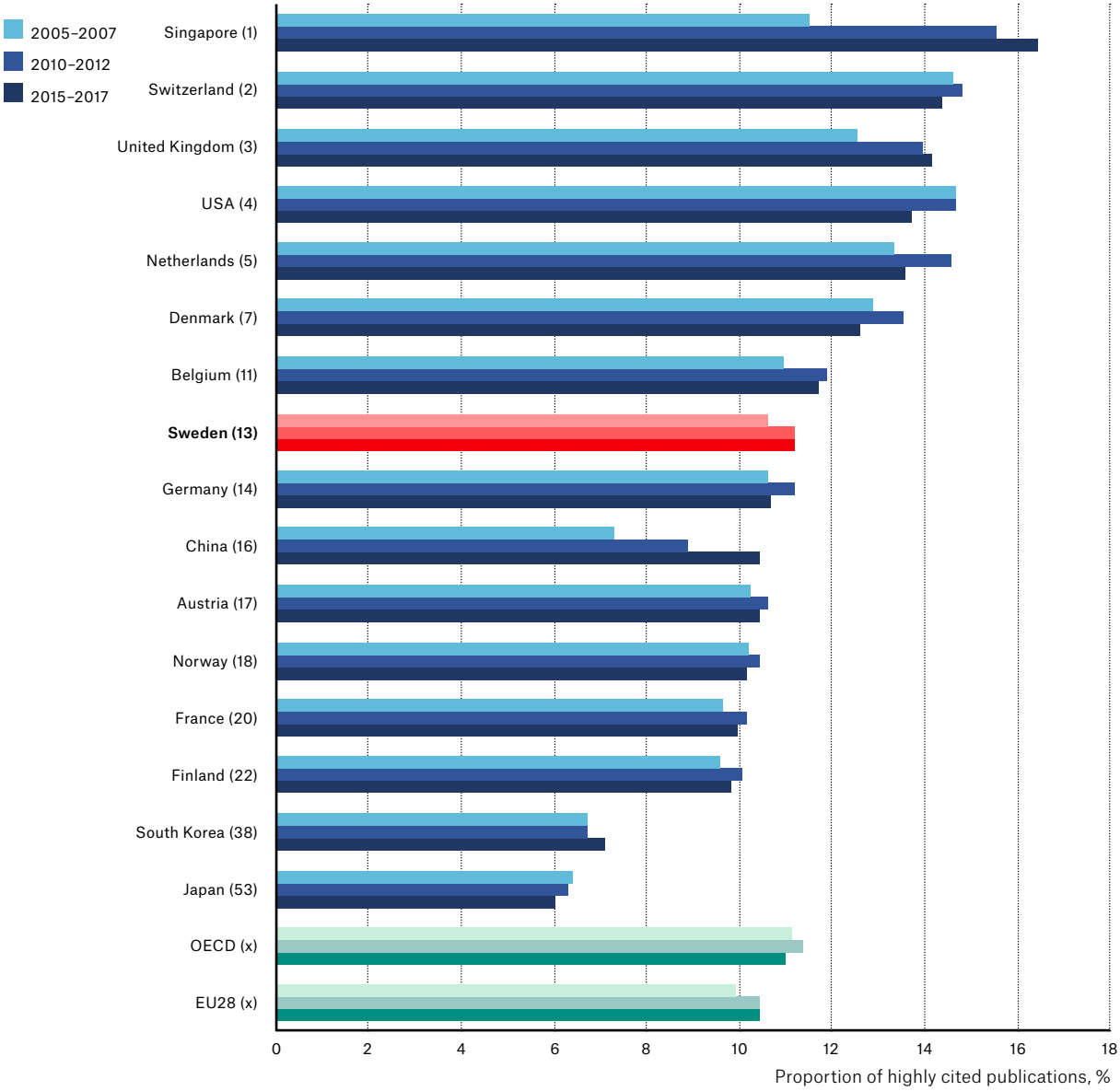


Figure 27. Development of citation impact (proportion of highly cited publications) and world ranking (in brackets). **Note:** The proportion of highly cited publications is calculated for a three-year period. The figure in brackets shows the country's ranking 2015–2017, out of all the countries in the Swedish Research Council's publication database.[32] Source: Clarivate Analytics.

Figure 26 shows that Switzerland (CHE) and Denmark (DNK) are the countries that produce the most article in relation to their populations, but that Switzerland has a higher citation impact. Norway (NOR), Finland (FIN) and Sweden all produce around the same amount in relation to their populations, but Sweden has a slightly higher citation impact.

Figure 27 shows the citation impact during three time periods for Sweden and our selection of countries. The figures in brackets shows each country's ranking in terms of highly cited publications of all the countries in the world during the period 2015–2017.

Sweden's percentage of highly cited publications is just over 11 per cent, which is above the global average of 10 per cent. On this measure, Sweden is ranked 13th, and therefore comes after Denmark (which has almost 13 percent), but before the other Nordic countries.

32 For countries with at least 300 publications.

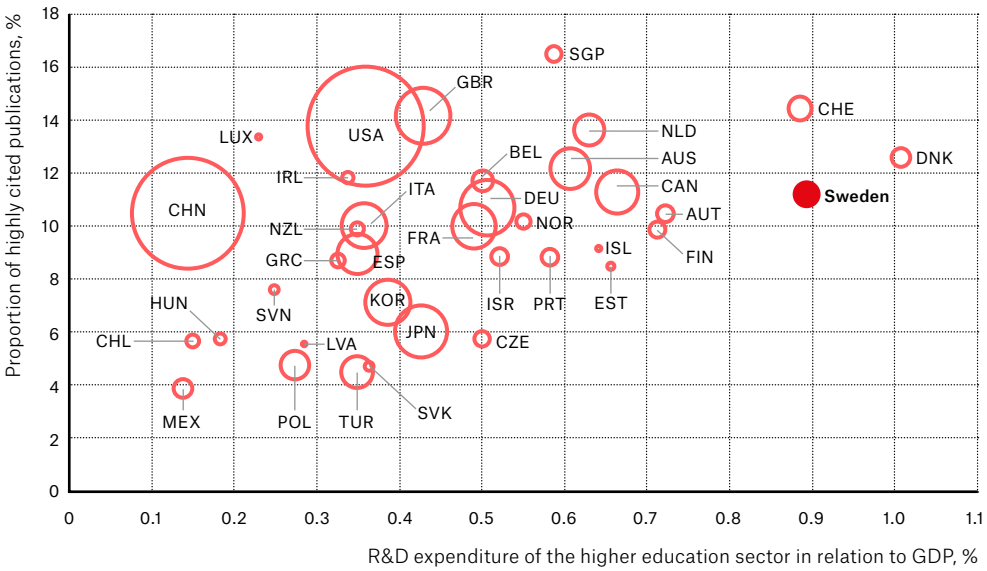


Figure 28. Higher education expenditure on R&D (HERD) as a percentage of GDP 2013–2015, in relation to the proportion of highly cited publications 2015–2017, and relative scientific production (circle size), for OECD, China and Singapore. Source: Clarivate Analytics and OECD MSTI.

Two countries stand out with a large increase in the citation impact during the periods investigated: Singapore and China. During the period, both these countries have increased their citation impact by more than 40 per cent.

During the period, Sweden increased its proportion of highly cited publications from 10.6 per cent to 11.2 per cent. During the same period, Japan, Norway, Denmark and Switzerland have seen a negative development of their citation impacts.

It should also be noted that the differences in citation impact is relatively small between Sweden and the countries immediately before and after in the ranking. Marginal changes in citation impact can therefore cause major rearrangement of the ranking list.

Countries with a large percentage of highly cited publications often have a large percentage of publications in relation to their population (Figure 28), or a large percentage of R&D expenditure in relation to GDP. However, the correlation is far from perfectly linear, which means that the variation in citation impact cannot easily be explained by the variation in R&D expenditure. Moreover, correlation does not necessarily imply causation.

Figure 28 depicts the higher education sector's R&D expenditure as a percentage of GDP, in relation to the percentage of highly cited publications. To take into account the time lag that exists between research being financed and the resulting research being published, the citation impact is calculated for the period 2015–2017 and the percentage of R&D expenditure for the period 2013–2015. The figure shows that the higher education sector's R&D expenditure in relation to GDP is about the same in Switzerland (CHE) and in Sweden, but that Switzerland has considerably higher citation impact. The figure also shows that countries such as the Netherlands (NLD), Belgium (BEL) and the United Kingdom (GBR) all have higher citation impacts than Sweden, while having lower R&D expenditure in the higher education sector in relation to GDP. The differences in citation impact can therefore not simply be explained by the amount of resources invested in R&D, but probably has more complicated explanations to do with factors such as the organisation and functioning of the research systems. One such factor is the size of the higher education sector in relation to the business and institute sectors.

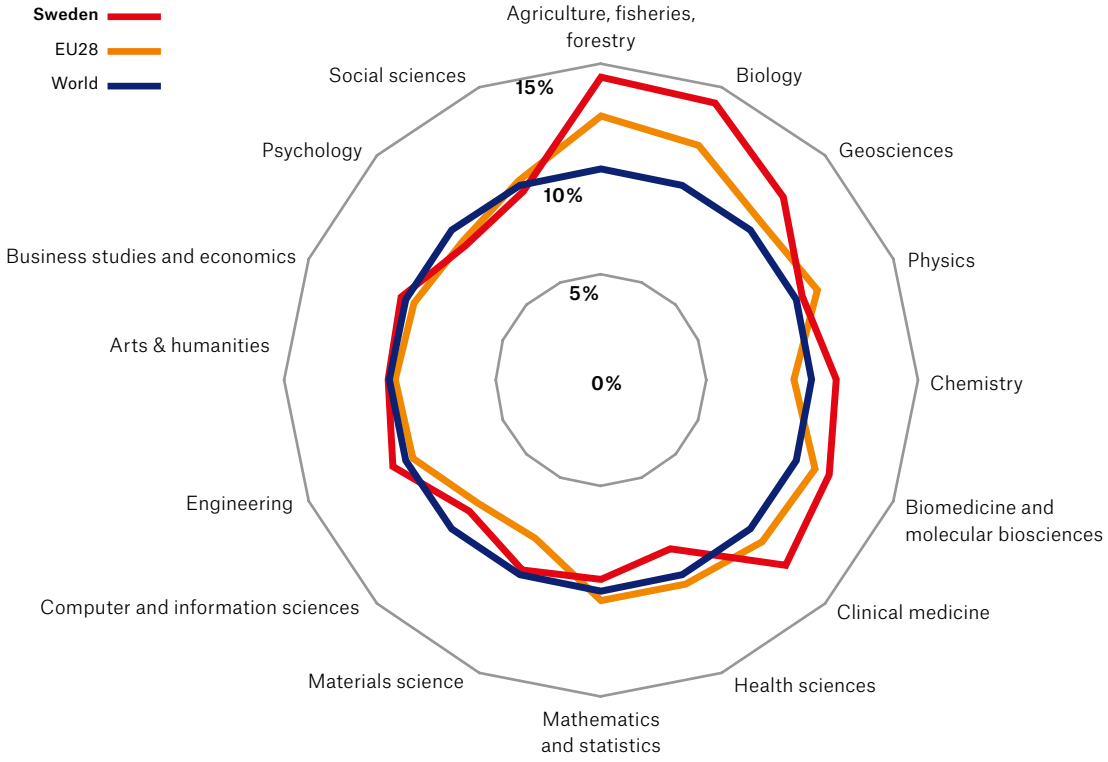


Figure 29. Proportion of highly cited publications within different subject areas, for Sweden, EU28 and the world, 2015–2017. Source: Clarivate Analytics.

Citation impact for different subject areas

Figure 29 shows the citation impact (proportion of highly cited publications) for Sweden, EU28 and the world, divided up into different subject areas.

Sweden is above or just below the world average for a majority of subject areas. Agriculture, biology, clinical medicine, geosciences, biomedicine and chemistry are Sweden's strongest subjects, as these are well above both the world average and the citation impact for the EU28 countries. Agriculture and biology, which the subject areas where Sweden has the greatest impact, are also the subject areas where the EU28 have their greatest citation impact.

Sweden is below the world average for six of the subject areas (materials science, social sciences, mathematics, psychology, computer and information science, and health sciences), even if the difference compared to the world average in general is quite small, and less than 5 per cent. The greatest differences are within health sciences and computer and information sciences, where the difference in citation impact compared to the world average is more than 10 per cent. Within computer and information sciences, materials science and psychology, both Sweden and the EU28 are below the world average.

Figure 30 shows the subject profile for Sweden, USA and China for the 16 subject areas. The figure should be interpreted as follows: If a subject area (a bubble) is to the right in the figure (where the specialisation index is positive), the country has published more than the world average within this subject area, and is therefore specialised in the subject area. If a subject area (a bubble) is in the upper half of the figure (where the citation impact is above 0.1), the subject area has a higher citation impact than the world average, and vice versa. The area of the bubble is proportional to the country's article volume within each subject area.

When the three countries are compared in this way, it is noticeable that the bub-

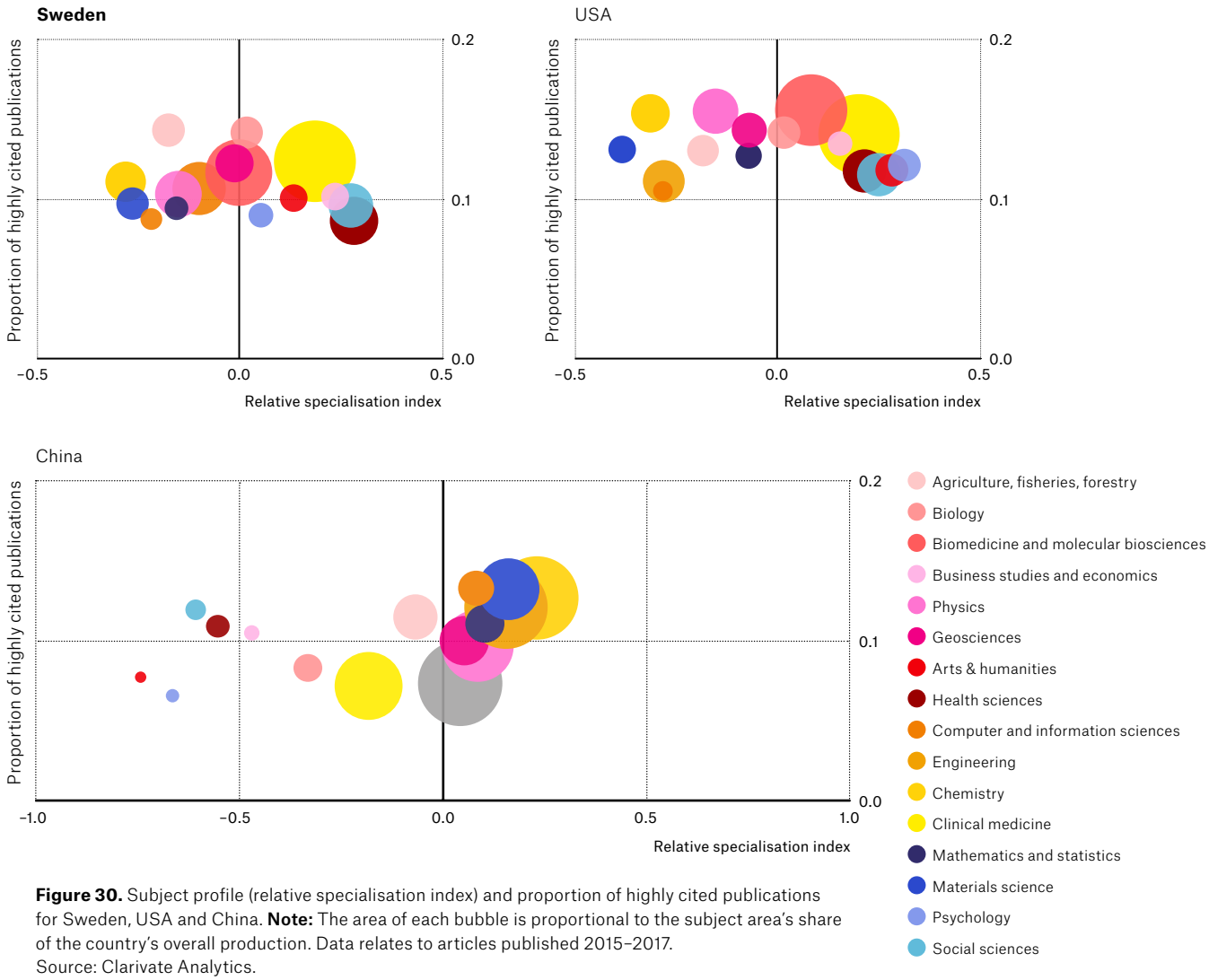


Figure 30. Subject profile (relative specialisation index) and proportion of highly cited publications for Sweden, USA and China. **Note:** The area of each bubble is proportional to the subject area's share of the country's overall production. Data relates to articles published 2015–2017.
Source: Clarivate Analytics.

bles for Sweden are more clustered together in the middle of the figure compared to China and the USA. This means that Sweden's subject profile is more similar to the world average than the subject profiles of China and the USA.

The subject areas with the highest citation impact in Sweden are agriculture and biology, which we also saw in Figure 29. Compared to the rest of the world, Sweden produces more publications within health sciences and social sciences, but produces fewer than the world average within chemistry and materials science. Sweden thus publishes more than the world average within health sciences and social sciences, while the citation impact for these subjects are below the world average.

For USA, the citation impact for all subject areas is above the world average of 10 per cent. Overall, USA is the world's largest individual producer of scientific articles. On the other hand, USA produces less than the rest of the world in relative terms within materials science, chemistry and engineering, but more within psychology, humanities and social sciences.

The subject profile for China is slightly different. 10 of the 16 subject areas have a citation impact above the world average. Materials science have the highest citation impact, followed by chemistry and engineering. Within biomedicine, molecular bioscience and clinical medicine, the citation impact is a bit lower than the

world average. In terms of specialisation, China produces considerably below the world average within a number of subject areas (humanities, psychology, social sciences, health sciences and economics), while the number of articles within areas such chemistry, materials science and mathematics is above the world average.

International co-publications

International collaboration within R&D is important, as international collaboration is assumed to raise the quality of the research and to strengthen the country's competitiveness and attraction. One way of measuring international research collaboration is to measure the percentage of Swedish researchers' publications that are co-authored with researchers from other countries. (Swedish researchers are here defined as researchers with an affiliation in Sweden.)

The percentage of Swedish researchers' international co-publications has increased markedly over a long period. In 2006, the percentage of international co-publications was around 50 per cent, but by 2017 it was close to 70 per cent. One reason put forward for this increase is that a growing number of publications are the result of large-scale collaboration, where a large number of authors and countries are involved. This cannot explain the entire increase, however, as one third of Sweden's overall publication volume in 2017 consisted of co-publications with only one other country, and 60 per cent consisted of collaboration with one to four other countries. Only 3 per cent of Sweden's articles in 2017 had authors from ten countries or more.

Figure 31 shows Swedish researchers' international co-publications divided up by different groups of countries.

The number of co-authored publications by Swedish researchers has increased for most groups of countries, except for the OECD, which has decreased slightly. Co-publication with researchers from the EU28 countries has increased from 63 to

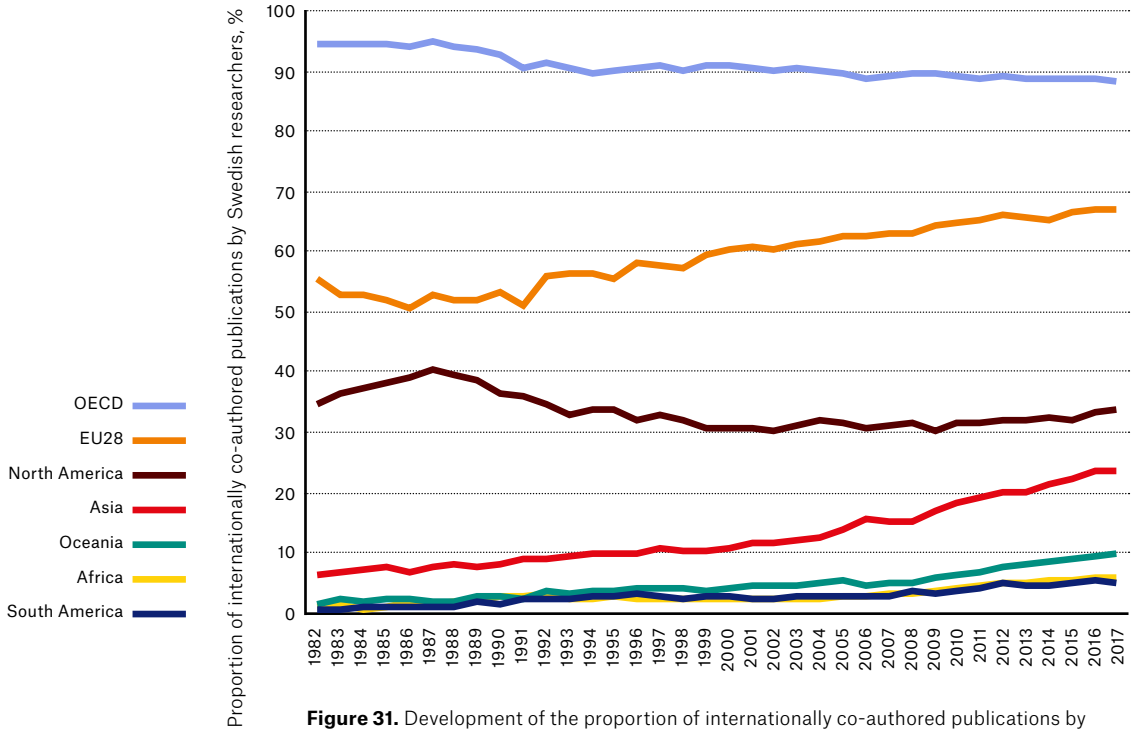


Figure 31. Development of the proportion of internationally co-authored publications by Swedish researchers, in terms of the location of the collaborating researchers.
Note: The publications are in full counts, which means that the sum of all co-publications is greater than 100 per cent. Source: Clarivate Analytics.

67 per cent over the last ten-year period. Over the same period, co-publication with researchers from the USA has increased from 31 to 34 per cent. The most marked increase is in co-publications with researchers from Asia, which increased from 11 to 24 per cent between 1997 and 2017, which is an increase of 124 per cent.

Figure 32 shows the countries that Swedish researchers collaborate with the most, measured as the number of internationally co-authored scientific publications per year and collaborating country.

Swedish researchers have mostly collaborated with researchers residing in the USA. This is not entirely unexpected, as the USA is the world's largest producer of scientific publications. During the period 2013–2017, just over 5 000 articles had at least one author from both Sweden and the USA. This corresponds to around 30 per cent of all Swedish international co-publications. During this period, USA produced just over 20 per cent of all publications in the world. Swedish researchers also collaborate to a large extent with the United Kingdom, Germany and France, which are also major research nations in terms of number of articles.

Denmark is the Nordic country that Sweden collaborates with most often. Sweden collaborates with China to roughly the same extent as it collaborates with Norway and Finland. On the assumption that Sweden's collaboration with other countries should be equal to these countries' percentage of the world production, Sweden's collaboration with China is lower than expected. Swedish researchers' percentage of international co-publications with researchers in China was around 10 per cent, while China's percentage of the world's production was just over 16 per cent.

International co-publication within different subject areas

Figure 33 shows the international co-publication within different subject areas for Swedish researchers with respect to 2007 and 2017.

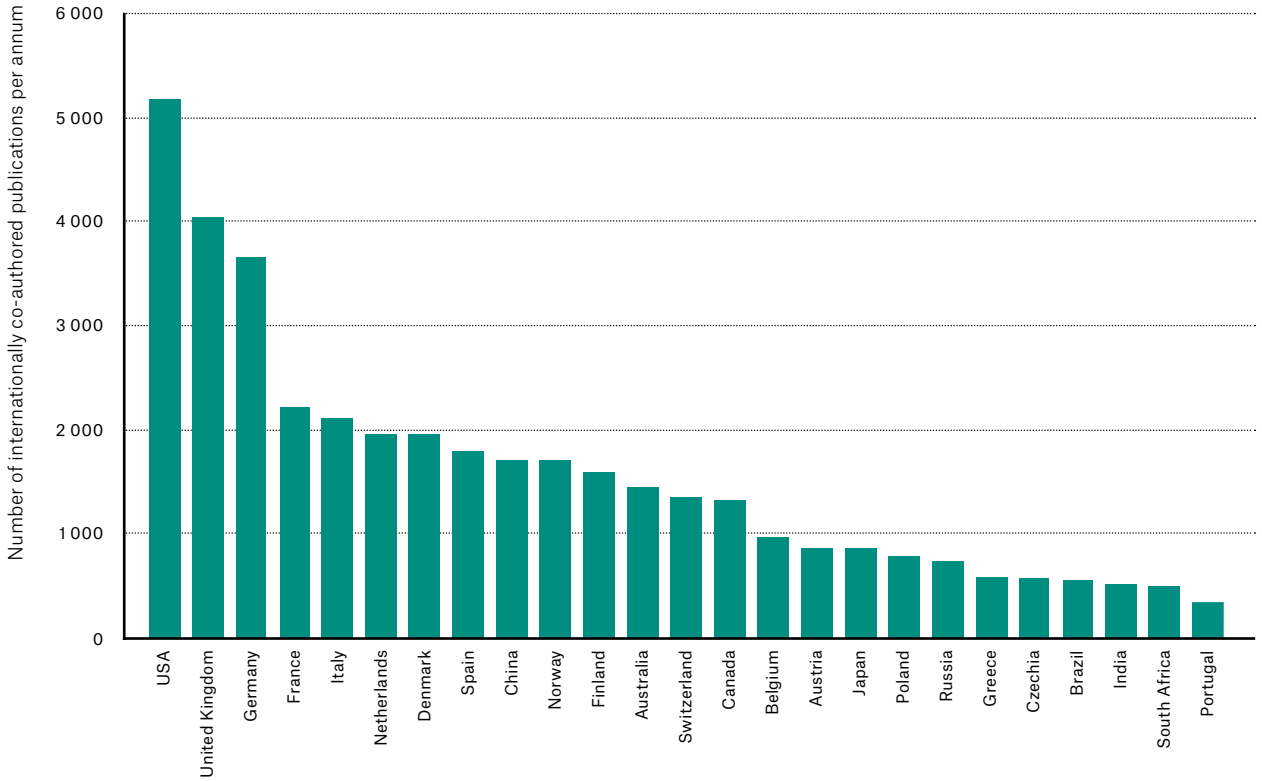


Figure 32. Number of internationally co-authored publications for Swedish researchers per collaboration country (number of publications in full counts, average for the years 2013–2017). Source: Clarivate Analytics.

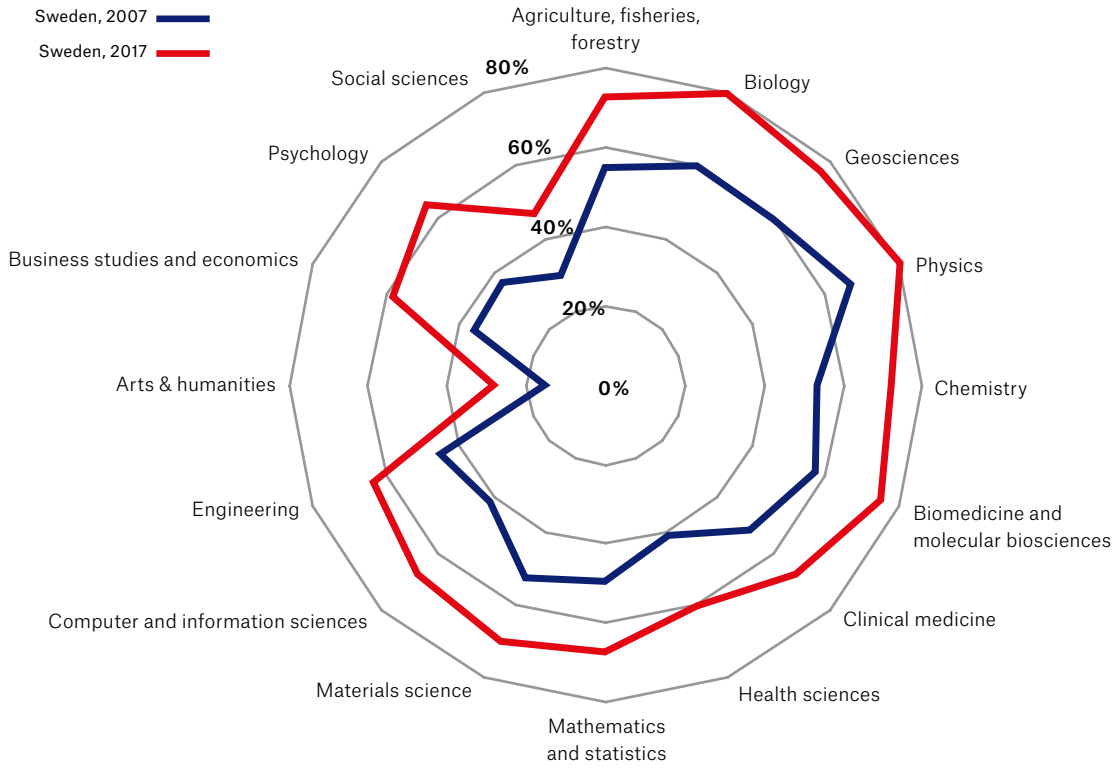


Figure 33. Swedish researchers' international co-publications as a percentage of the total number of publications, for different subject areas in 2007 and 2017. Source: Clarivate Analytics.

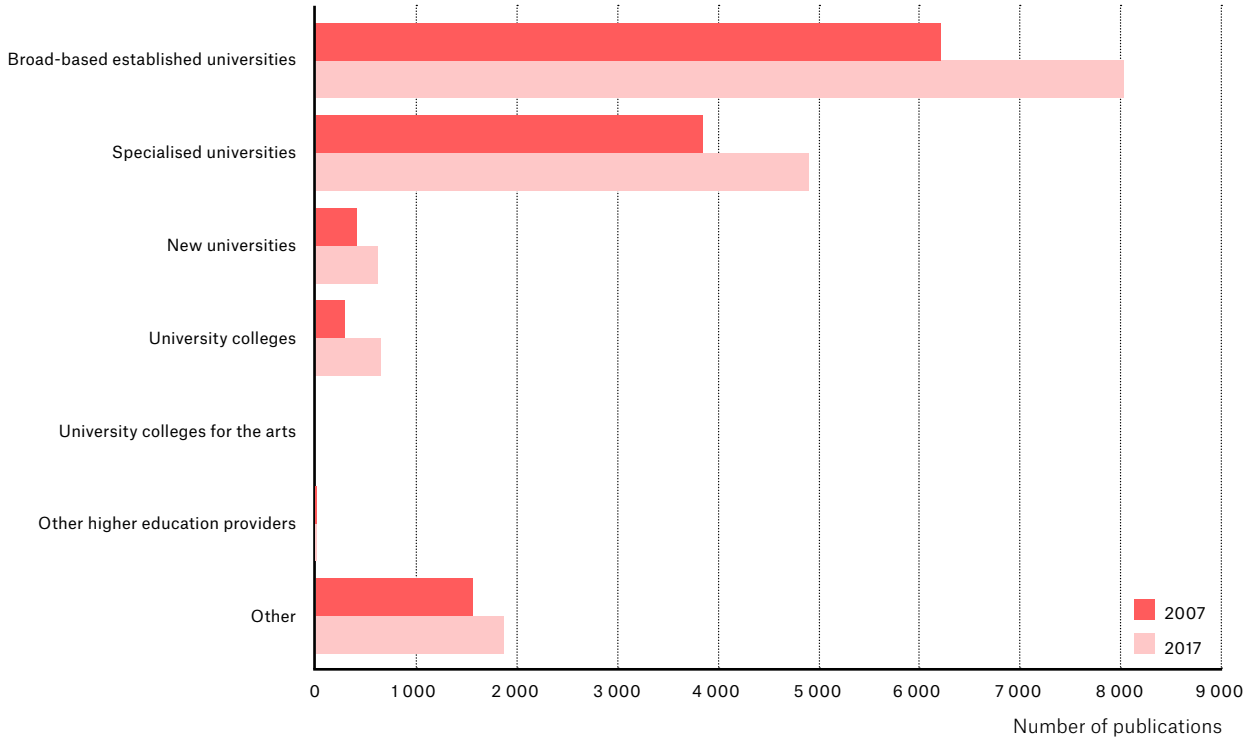


Figure 34. Number of scientific publications for different higher education institution categories including other organisations, 2007 and 2017. **Note:** The category 'Other' includes mainly businesses, research institutes, hospitals (not university hospitals) and public agencies outside the higher education sector. Source: Clarivate Analytics.

The figure shows that co-publication increased over the ten-year period within all subject areas. However, there is great variation in international co-publication intensity between the different subject areas. Co-publication occurs most frequently within physics, biology, geosciences and biomedicine. Publication traditions and access to joint infrastructures are assumed to be two causes of differences between the subject areas in the level of collaboration. In physics, for example, it is common to collaborate with research teams from other countries. Major international infrastructures, such as the particle physics laboratory CERN, are also assumed to have caused international co-publication within physics to have become even more common.

Humanities and social sciences are the subjects where Swedish researchers have the smallest percentage of co-publication with international researchers. Psychology, computer and information sciences, as well as business studies and economics are the subjects that have seen the greatest increase in the percentage of co-publications during the period 2007–2017.

3.2 The higher education sector in Sweden

This section provides an overall description of the scientific publication for the higher education sector in Sweden.

Scientific publications

Figure 34 shows the number of scientific publications for different higher education institution categories for the years 2007 and 2017. It is the broad-based established universities and the specialised universities that produce by far the most articles. In 2017, these organisations produced 80 per cent of the entire Swedish publication volume.

In 2017, the broad-based established universities produced half of the published articles in Sweden, while the specialised universities produced almost one third. The university colleges and new universities produced 4 per cent each of the Swedish published articles overall. The organisations classified as "other", such as businesses, research institutes and public agencies, produced 12 per cent of the overall number of articles in 2017.

University colleges for the arts and the other higher education providers have very few scientific articles included in the publication database Web of Science. This is partly because their primary focus is on teaching, and partly because the university colleges for the arts publish their research results via channels other than those included in the database.

During the period, the university colleges have seen the largest increase in the number of scientific publications. From 2007 to 2017, their volume increased by 9 per cent per year. During the same period, the broad-based established universities and the specialist universities increased by around 3 and 2 per cent respectively per year.

Citation impact

Figure 35 shows the citation impact of the higher education institutions. The citation impact is measured as the proportion of highly cited publications, which measures how large a percentage of the country's article volume are in the 10 per cent most cited publications in the world.

Karolinska Institutet was the HEI with the highest citation impact during the period 2015–2017. Karolinska Institutet also increased its citation impact from 12

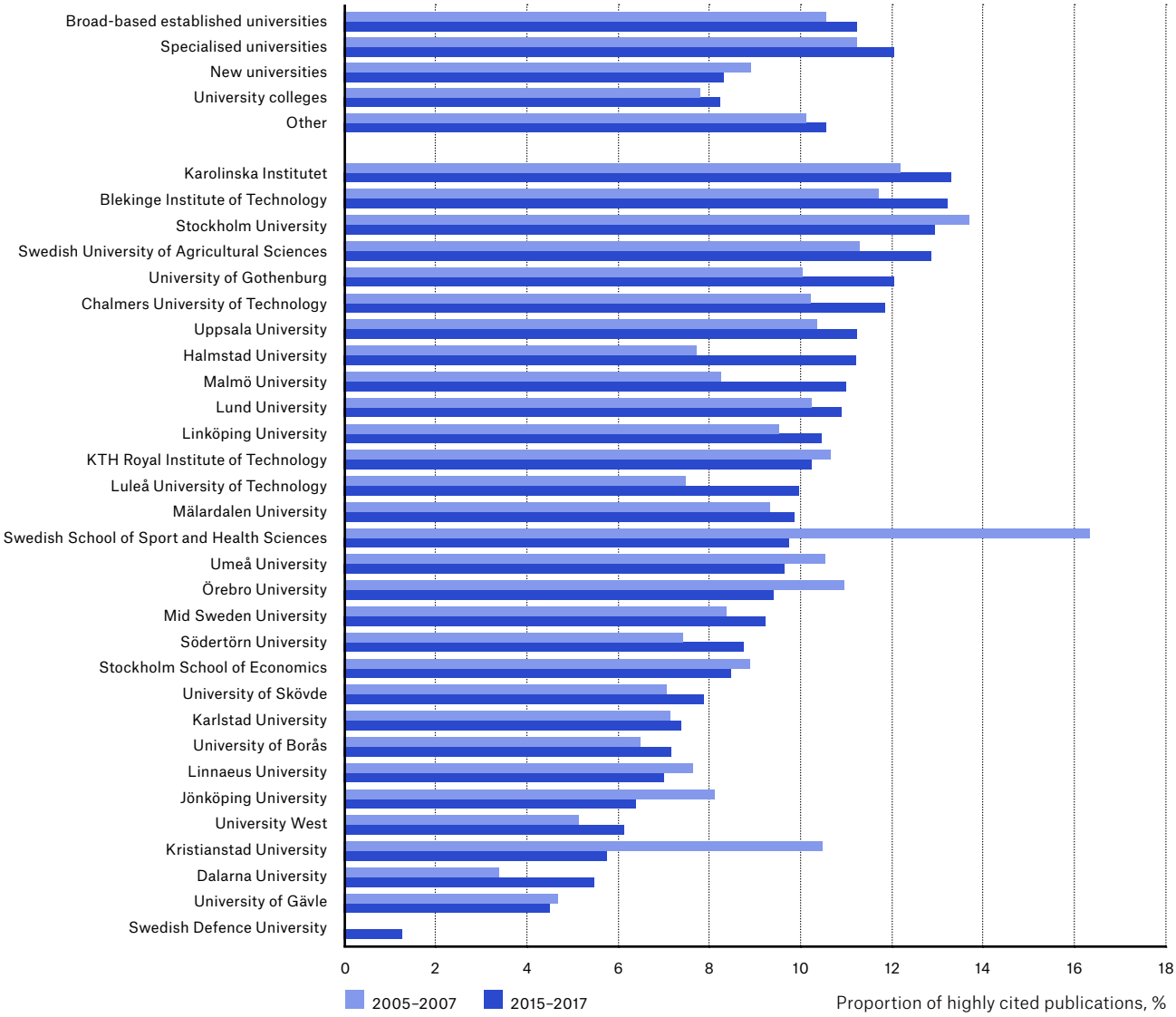


Figure 35. Development of the citation impact (proportion of highly cited publications) for different HEIs and HEI categories in Sweden. **Note:** The category 'Other' includes mainly businesses, research institutes, hospitals (not university hospitals) and public agencies outside the higher education sector. University colleges for the arts and other providers of education are not shown due to having too small a number of publications. Source: Clarivate Analytics.

to 13 per cent between the two comparison periods. The highest citation impact after Karolinska Institutet was achieved by (in falling order) Blekinge Institute of Technology, Stockholm University, Swedish University of Agricultural Sciences and University of Gothenburg. Four of the five top HEIs are thus 'broad-based established universities'. It should be noted that Blekinge Institute of Technology has a small publication volume compared to the other top producing HEIs, which means the result is considerably more uncertain, as the choice of year to be included becomes a critical factor.

During the period 2015–2017, the broad-based established universities and specialised universities had citation impacts of 11–12 per cent. All HEIs in these categories are close to or above the world average of 10 per cent. The new universities and the university colleges, on the other hand, had citation impacts of just over 8 per cent. This means that the citation impact for the new universities and the university colleges is around 20 per cent below the world average.

Subject profiles and citation impacts

Figure 36 shows various HEIs' subject profile for the 16 subject areas. The figure should be interpreted as follows: if a subject area (a bubble) is to the right in the figure (where the relative specialisation index is positive), the HEI has published more than the world average within this subject area. It is therefore classified as specialised within that particular subject area. If a subject area (a bubble) is in the upper half of the figure (where the citation impact is above 0.1), the subject area has a higher citation impact than the world average, and vice versa. The size of each bubble is proportional to each subject's share of the HEI's overall article volume.

Figure 36 shows that there is no obvious link between the specialisation index and citation impact. The HEIs with a high citation impact, often have a high citation impact in several subjects.

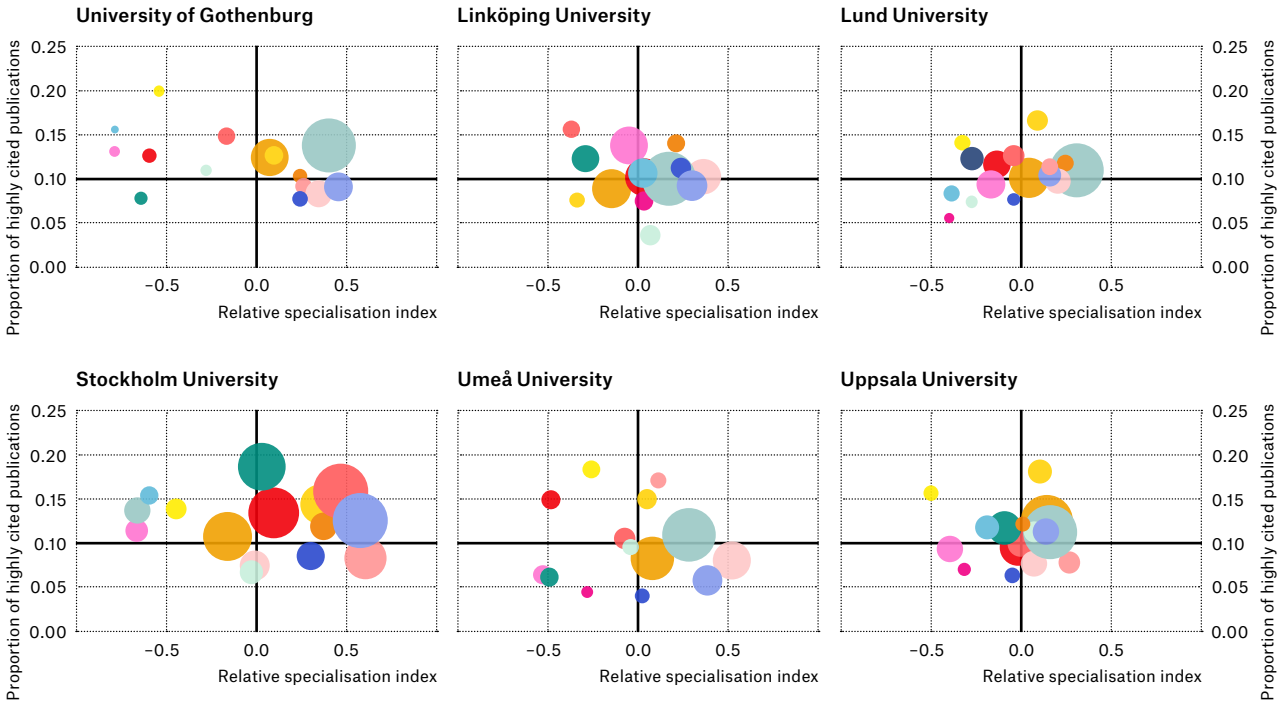
The specialised universities are generally much more specialised than other HEIs, as expected. For example, almost all of the publications of the Stockholm School of Economics are within business studies and economics, the Swedish University of Agricultural Sciences has its largest volume within agriculture, fisheries, forestry and biology, while the technology universities – KTH Royal Institute of Technology, Chalmers University of Technology and Luleå University of Technology – produce most within engineering. Karolinska Institutet has a considerably higher percentage of clinical medicine and health sciences than in general.

With a few exceptions, the broad-based established universities have production within all subject areas (that is to say, at least 30 publications within a subject area). On the other hand, the broad-based established universities do show a wide range in their specialisation. Stockholm University and University of Gothenburg, which do not have engineering faculties, have a low percentage of articles within the technology subjects engineering and materials science, while they are big within social sciences. The remaining broad-based established universities, for which publications at the university hospital have been included, have their largest percentage of publications within medicine and health (clinical medicine or health sciences).

Among the broad-based established universities, Stockholm University is the HEI with the greatest range in its specialisation index, but it is also the HEI with the largest number of subject areas with a citation impact above the world average. Lund University has the smallest range in its specialisation index, and therefore has the publication profile that most resembles that of the database Web of Science.

The new universities only have a few subject areas where they produced more than 30 publications during the period. A common denominator for the new universities is that all have a specialisation index above zero for the subject areas social sciences and health sciences.

Broad-based established universities



New universities

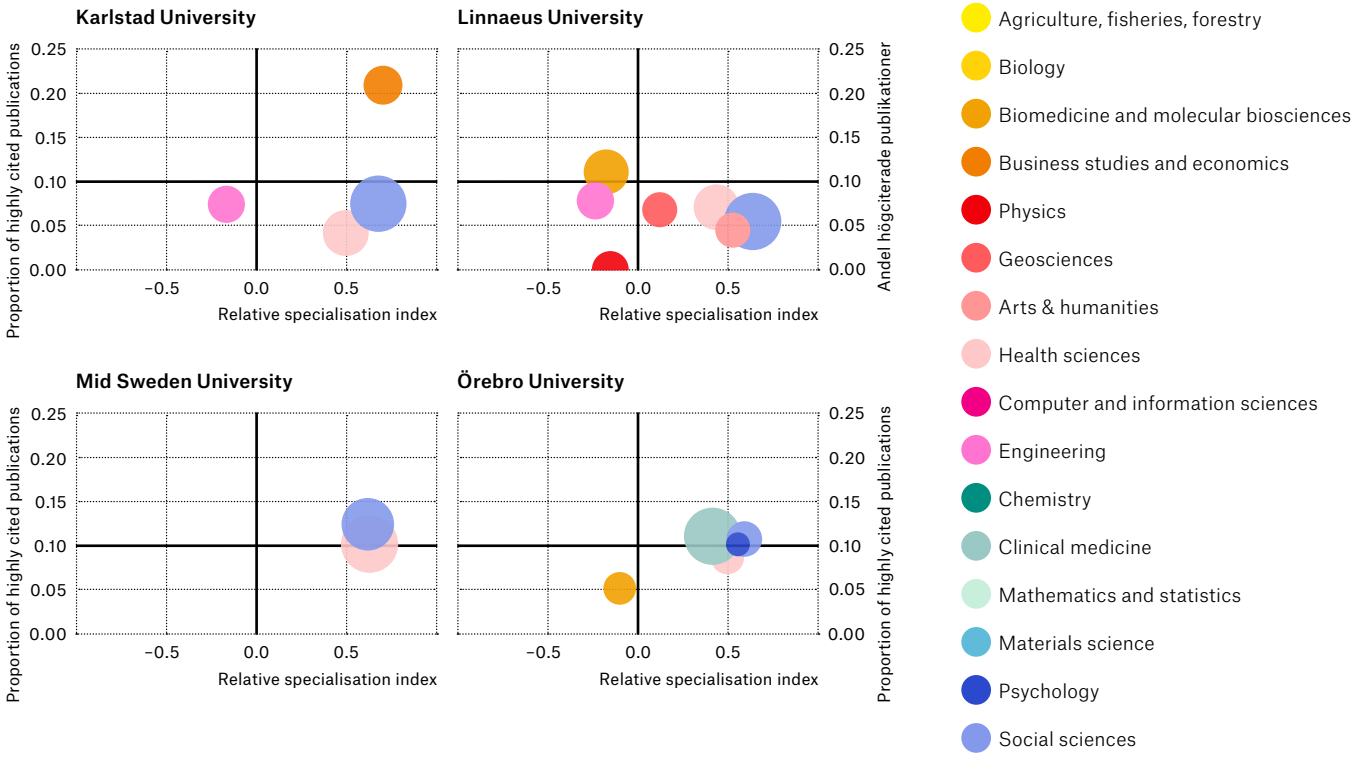
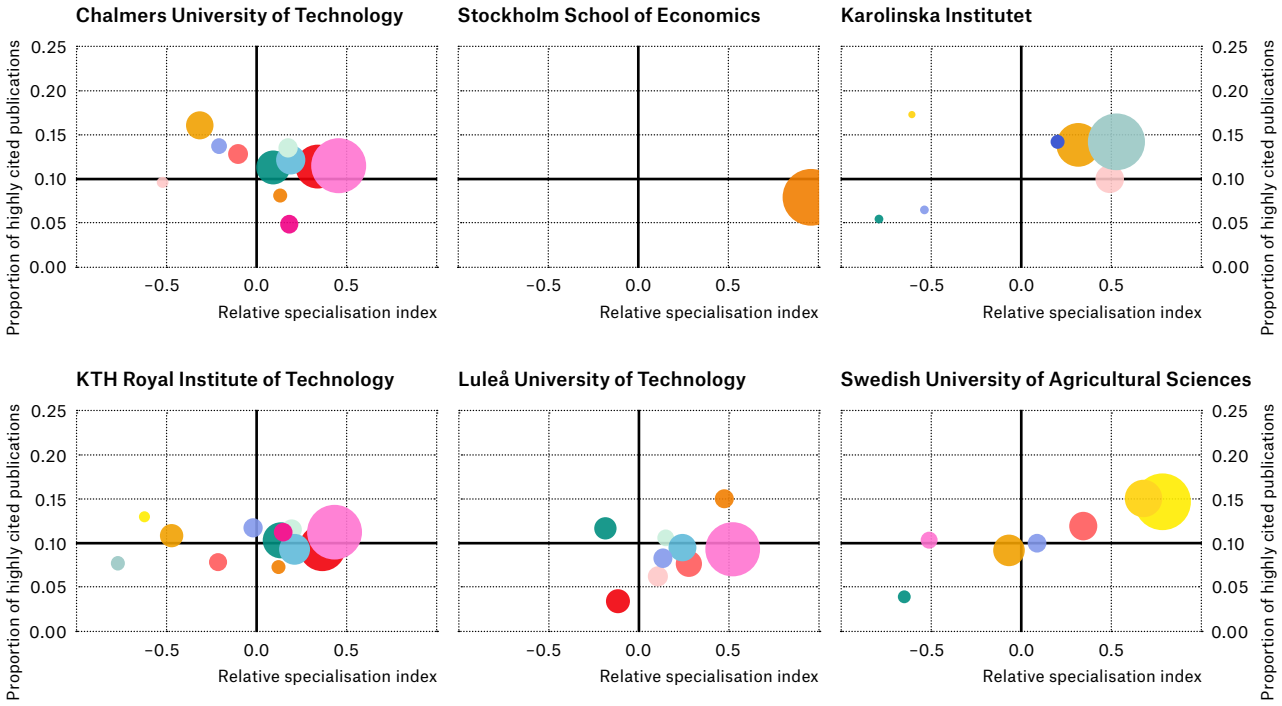
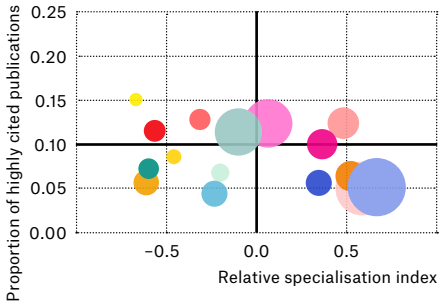


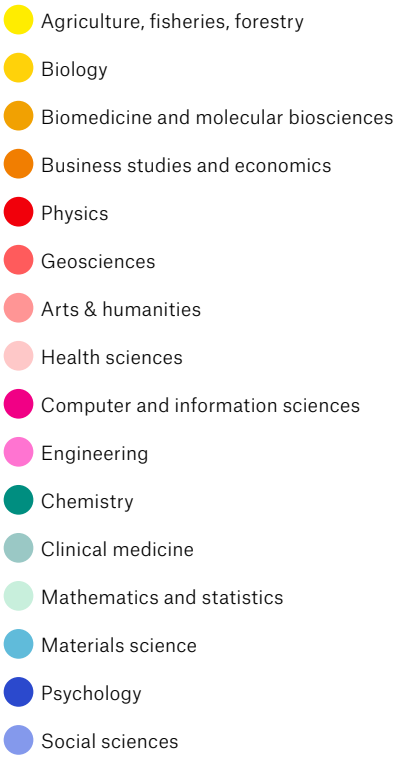
Figure 36. Subject profile (relative specialisation index) and proportion of highly cited publications for Swedish HEIs.
Note: The area of each bubble is proportional to the subject area's share of the HEI's overall production. Only subject areas where the HEI published at least 30 articles during 2015–2017 are included in the figure. Source: Clarivate Analytics.

Specialised universities



University colleges





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Appendix: Method, data and clarifications

The purpose and focus of the Swedish Research Barometer

The purpose of the Swedish Research Barometer is to describe the status and development of Swedish R&D. The report therefore includes an international comparison of the Swedish R&D system, with a particular focus on the Swedish higher education sector. As the Swedish Research Barometer is a recurrent report, the choice of indicators and figures is repeated year by year as far as possible, and the description focuses on development in recent years. The report takes only a descriptive approach.

International comparisons

As the purpose of the Swedish Research Barometer is to describe the Swedish research system in international comparison, the selection of countries and groups of countries to compare Sweden with is of great importance. International comparison of the R&D in different countries is not simple, as countries differ with regard to e.g. organisation and funding.

To provide as nuanced and fair a picture as possible of how Sweden compares as a research nation with other countries, Sweden is compared both with the EU28, OECD and "the world" (in terms of publications), and also with three different groups of countries: comparable countries, large established research countries and fast-growing research countries. The countries included in the various comparison groups are:

- *Comparable countries:* Belgium, Denmark, Finland, Netherlands, Norway, Switzerland and Austria.
- *Large established research countries:* France, Japan, United Kingdom, Germany and USA.
- *Fast-growing research countries:* China and South Korea.

These countries are referred to in the report as the "selected countries". Comparable countries to Sweden are countries where the conditions for research and development are similar to those that apply for Sweden, and the countries are also comparable in terms of number of publications in relation to population and in terms of citation impact. The large established research countries are countries that are often perceived as major actors and are characterised by large publication volumes and a high citation impact. The fast-growing research countries are countries whose research systems have expanded rapidly over the last ten-year period.

As the report also aims to describe how Sweden compares with the international research frontier, Sweden is also compared with the following groups of countries: EU28 (the EU's 28 member states), OECD (member countries of the OECD),

OECD including Singapore and China, and the world as a whole. These comparison groups have been selected as they constitute interesting and often used comparison groups, but also because of limitations in the statistics available. For statistics on R&D expenditure and number of researchers, the report is limited to the statistics available from OECD MSTI. The OECD database consists primarily of the member countries of the OECD, but also includes statistics for a few other countries, including totals for the EU28. In some figures, the comparison group 'OECD including China and Singapore' has been used, as China is part of the group 'fast-growing research countries', and as Singapore is the country with the highest citation impact in the world. The comparison group 'the world' is only used in descriptions of number of publications and of citation impact, and is based on the countries included in the Swedish Research Council's publication database.

Data sources

Funding and personnel statistics in the international comparisons were taken from the OECD database Main Science and Technology Indicators (OECD MSTI version 2018-2, February 2019). The statistics are based on individual countries' reporting to the OECD. The most recent more-or-less comprehensive data for R&D expenditure date from 2017, and for personnel from 2015. The figures based on data from the OECD do not always include data for all years. This means that data for individual countries and years are sometimes lacking, and have therefore not been presented in the report. For a number of figures, values from the nearest available year have been used instead, which is also explained in the figure and in the figure text.

Data on Sweden's participation in Horizon 2020 are taken from eCORDA (extraction date 13 Mar 2019). Table 1 refers to awarded and contracted funds ('signed grants'), while Table 2 refers to funds awarded ('retained applications'). To calculate 'funds awarded per capita', the population numbers for 2018 from Eurostat have been used (updated 28 Mar 2019). However, Eurostat does not have population data for Israel, Tunisia or the Faroes, for which population numbers were taken from the UN (UN 2017. World Population Prospects: The 2017 Revision).

Figures for R&D expenditure for the higher education sector in Sweden are taken from Statistics Sweden. The R&D statistics are updated every two years, and the latest available figures are from 2017. R&D expenditure that includes comparisons over time have been calculated at constant prices (year 2017). Constant price calculations are used to adjust price levels for inflation and clearing away any price effects that may impact on the interpretation of the development of "real" expenditure levels. The constant price calculation is done using the GDP deflator, which is the method for constant price calculation used by Statistics Sweden when describing R&D expenditure over time.[33] The GDP deflator is calculated as GDP at constant prices in relation to GDP at current prices. The GDP deflator is based on data from the Swedish National Institute of Economic Research (updated 19 Dec 2018).

Statistics about the research and teaching personnel in the Swedish higher education sector are taken from Statistics Sweden (SCB) and the Swedish Higher Education Authority (UKÄ). Personnel statistics are collected annually by Statistics Sweden on behalf of the Swedish Higher Education Authority. The statistics are based on personnel data from the HEIs' salary reporting system for October. The statistics on the distribution of working hours for different employment categories, is based on a survey.[34]

The data in the report is sometimes based on additional processing carried out

33 SCB (2019). Forskning och utveckling i Sverige 2017.
34 SCB (2018). Statistikens framställning – Forskning och utveckling i Sverige. UF0301.

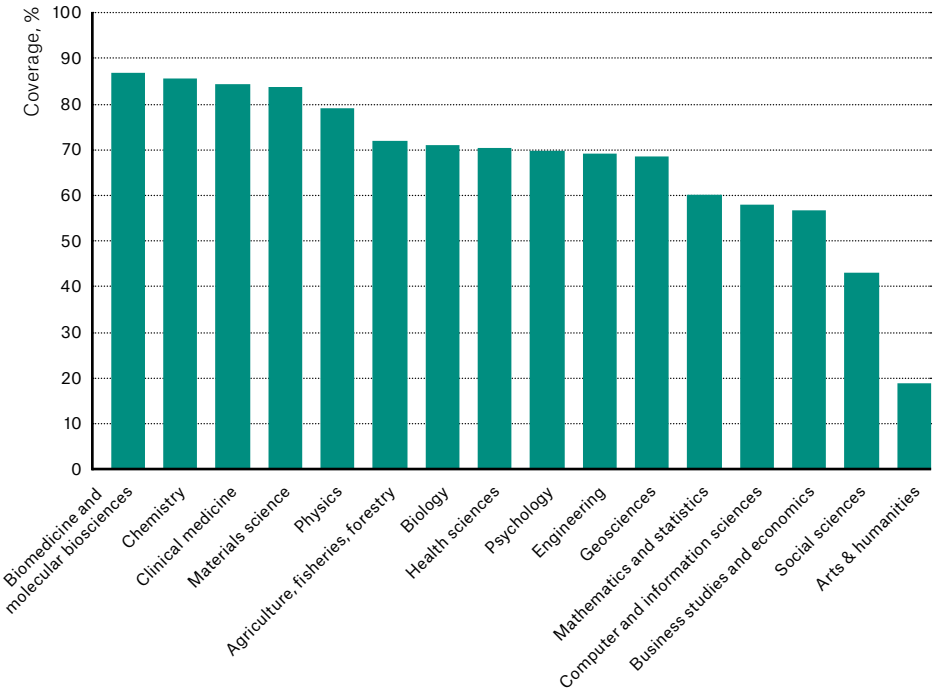

Figure 37. Coverage (percentage of references to other publications in the Swedish Research Council's publication database) for different subject areas.

by Statistics Sweden, e.g. the indicator doctoral degree award year (figures 20 and 21) as well as doctoral degree and employment divided by HEI (figures 23 and 24) in the section on higher education personnel. This data has a certain amount of missing data, partly due to unknown degree award year, and partly due to lack of information on doctoral degree. The extent of missing data concerning doctoral degree award year is 4 per cent for professors, 1 per cent for senior lectures, researchers and postdocs, 2 per cent for associate senior lectures, and 0 per cent for lecturers.

There is also missing data concerning doctoral degree award. The extent of missing data concerning doctoral degree award is 10 per cent for professors and senior lecturers, 17 per cent for associate senior lecturers, and 30 per cent for postdocs. In the figures 20 and 21 showing doctoral degree award year, we have assumed that these have the same relative distribution of degree award year as those with data on doctoral degree award year, and have therefore allocated them proportionally across the various doctoral degree award year intervals. Regarding lectures and other reseach and teaching personnel, only persons with a doctoral degree are included.

In figures 23 and 24 (relating to mobility) we have information on doctoral degrees, but not always information on higher education institution (i.e. unknown HEI). Observations with unknown HEI are most often foreign doctoral degrees.

Data on the number of publications, citation impact and international co-publications are based on the Swedish Research Council's publication database, which in turn is based on the same background material as Web of Science. The data in the report corresponds to the contents of Web of Science on 1 November 2018 (for further information, please see "Bibliometric analysis" below).

Classification into fields of research, research areas and subject areas

The Swedish Research Barometer uses three classifications of research areas. For data on R&D expenditure and R&D personnel within the higher education sector in Sweden, we use the Standard för svensk indelning av forskningsämnen, supplied by the Swedish Higher Education Authority.[35] The classification is in line with the OECD classification 'Field of Research and Development (FORD).' In the Research barometer, this classification is referred to as 'fields of research.'

For data on number of publications and citation impact, we use two classifications, one with 6 research areas and one with 16 subject areas. These two classifications are based on the classifications of different scientific periodicals included in the Swedish Research Council's publication database, and is called 'research areas' and 'subject areas' in the report.

Bibliometric analysis

This section summarises how the bibliometric indicators have been calculated and used in the report. For a more detailed description of how bibliometrics are used at the Swedish Research Council, please see *Riktlinjer för användning av bibliometri vid Vetenskapsrådet* and *The bibliometric database at the Swedish Research Council – contents, methods and indicators*[36].

The Swedish Research Council's database for bibliometrics

The Swedish Research Council's database for bibliometrics comes from Clarivate Analytics and the contents correspond to the material of Web of Science (WoS).[37] The publication database covers around 18 000 international scientific periodicals. These periodicals are classified by Clarivate Analytics into one or several of around 250 subject classifications, where individual articles receive the periodical's subject classification. The 250 subjects have been aggregated into two classifications, one with 6 research areas and one with 16 subject areas. The Swedish Research Council reclassifies the periodicals classified by WoS as Other/Multidisciplinary. Following reclassification of multi-disciplinary periodicals, very few publications remain in this category, and they have been excluded from the statistics in the report.

Every publication in WoS is also classified as one of 39 different document types. The Swedish Research Council's statistics are based on publications of the types Article or Review, which are added together into a joint document type.

Figure 37 shows the percentage of the references within the various subject areas that refer to other publications in database. For example, 87 per cent of all references in biomedicine and molecular biosciences are to publications in the database. We can therefore assume that a major part of the research that is relevant within biomedicine is represented in the database. For arts and humanities, on the other hand, only 19 per cent of the references can be found in the database, that

35 UKÄ (2016). Standard för svensk indelning av forskningsämnen 2011.

36 Vetenskapsrådet (2014). Riktlinjer för användning av bibliometri vid Vetenskapsrådet. 2014-12-15. Dnr 113-2014-7357., Vetenskapsrådet (2015). The bibliometric database at the Swedish Research Council – contents, methods and indicators 2015, 2015-09-18. Dnr 113-2010-6148.

37 The Swedish Research Council buys raw data from Clarivate Analytics and the contents correspond largely to the contents of Web of Science. When Web of Science is stated, this means the Swedish Research Council's database (consisting of the following products: Science Citation Index Expanded®, Social Science Citation Index® och Arts and Humanities Citation Index®. These products have been compiled by Clarivate Analytics®, Philadelphia, Pennsylvania, USA© Copyright Clarivate Analytics® 2018. All rights reserved.)

is to say 81 per cent of the articles found relevant by researchers within arts and humanities are not included in the database.

The calculations of the number of publications and of citation impact in the report, is based on the publications included in the publication database. In the report, these indicators are interpreted as the number of publications or citations in relation to the world or the world average. Such a description is therefore based on the assumption that the selection of periodicals in the publication database can be used to provide a representative picture of the world's publications and citations. This is an assumption that appears to correspond well to subjects such as biomedicine, which has a high coverage rate in the database, but less well for subjects such as the arts and humanities, which has a low coverage rate.

Publication volume and fractioning

Several figures in the report show indicators based on the number of publications. One challenge of counting the number of publications is that a publication can have authors from different countries. The sum of the number of publications from the different countries is then larger than the total number of publications. The same difficulty arises in comparisons that include the number of publications within different subject areas, as a publication may be classified as belonging to several subject classifications. This means that the sum of the number of publications within the individual subjects is larger than the total number of publications.

The number of publications can be calculated using either 'full counts' or 'fractioned' counting. Full counts means that authors A and B of a co-publication are each credited with one publication. This means that the total for all individual authors is greater than the actual volume. In fractioned counting, authors A and B are instead award half a publication each, and the author total ends up the same as the actual number of publications. Unless otherwise is stated, the indicators used in the barometer uses fractioned counting.

Swedish researchers are defined as researchers with an affiliation (address) in Sweden.

Proportion of highly cited publications

The proportion of highly cited scientific publications is a measure of citation impact that, contrary to the citation average, is not significantly impacted on by one-off extremely highly cited publications. To study the impact of publications, an indicator is used that states how large a percentage of a country's or an HEI's publications is among the 10 per cent most cited scientific publications in the world (in the publication database).

In other words, the fact that a publication is among the 10 per cent most cited means that it is one of the 10 per cent most cited scientific publications published within the same subject in one specific year. If a publication is classified in two subjects, half the publication is compared to one subject, and the other half to the other subject. If the publication only has author addresses in Sweden and is among the 10 per cent most highly cited within one of the subjects, the publication will contribute the weighting 0.5 to the number of Swedish publications that are among the 10 per cent most highly cited. The percentage of publications among the 10 per cent most highly cited is then calculated by dividing the sum of all weightings for a country's publication fractions that are among the 10 per cent most highly cited with the sum of the country's total publication fractions.

Relative specialisation index

To specify the subject specialisation of a country's (or an organisation's) publications, a relative specialisation index (RSI) is used. This is a symmetrical indicator that varies between -1 and +1 and is based on a country's (or an organisation's) activity index (AI). The activity index for a specific country is calculated by dividing the percentage of publications it has within a specific subject by the percentage that the subject constitutes in the publication database as a whole. If 50 per cent of Sweden's publications were classified as physics, while the corresponding figure for the whole of the database is 25 per cent, then Sweden's activity index for physics will be 2. In this example, Sweden therefore has double the amount of physics publications compared to the database. The activity index is an unsymmetrical measure that can assume values between 0 and infinity. To make the figures easier to compare, we use RSI instead, which is calculated as follows:

$RSI = (AI - 1)/(AI + 1)$.

If $RSI < 0$, the country (or the organisation) has a lower percentage of publications within the subject than the world average. If $RSI > 0$, the percentage is higher than the world average.

Higher education institution categories

The higher education institutions (HEIs) listed below are those that have data on R&D expenditure for the period 2011–2017, and are thus the HEIs included in the description in the report.

Broad-based (comprehensive) established universities
University of Gothenburg[38]
Linköping University[39]
Lund University[40]
Stockholm University
Umeå University[41]
Uppsala University[42]

Specialised universities
Chalmers University of Technology
Stockholm School of Economics
Karolinska Institutet[43]
KTH Royal Institute of Technology
Luleå University of Technology
Swedish University of Agricultural Sciences

New universities
Karlstad University
Linnaeus University
Mid Sweden University
Örebro University[44]

38 for the measures 'number of publications' and 'citation impact' including Sahlgrenska University Hospital
39 for the measures 'number of publications' and 'citation impact' including Linköping University Hospital
40 for the measures 'number of publications' and 'citation impact' including Skåne University Hospital
41 for the measures 'number of publications' and 'citation impact' including University Hospital of Umeå
42 for the measures 'number of publications' and 'citation impact' including Uppsala University Hospital
43 for the measures 'number of publications' and 'citation impact' including Karolinska University Hospital
44 for the measures 'number of publications' and 'citation impact' including Örebro University Hospital

University colleges
Blekinge Institute of Technology
Swedish Defence University
Swedish School of Sport and Health Sciences
Dalarna University
University of Borås
University of Gävle
Halmstad University
Jönköping University
University of Skövde
Kristianstad University
Gotland University[45]
University West
Malmö University[46]
Mälardalen University
Södertörn University

University colleges for the arts
University of Arts, Crafts and Design
Royal Institute of Art
Royal College of Music
Stockholm University of the Arts[47]

Other education providers
Ersta Sköndal Bräcke University College
Swedish Red Cross University College
Sophiahemmet University
Stockholm School of Theology
Swedish Institute of Space Physics

45 From 1 January 2013 Uppsala University Campus Gotland
46 From 1 January 2018 Malmö University is a university (move into HEI category 'new universities')
47 Until 31 December 2013, the School of Dance and Circus, the University College of Opera, and the Stockholm Academy of Dramatic Arts

Country codes

Country codes for OECD member countries including China and Singapore (according to ISO 3166-1 alpha-3).

AUS	Australia	FRA	France	MEX	Mexiko
AUT	Austria	GBR	United Kingdom	NLD	Netherlands
BEL	Belgium	GRC	Greece	NOR	Norway
CAN	Canada	HUN	Hungary	NZL	New Zealand
CHE	Switzerland	IRL	Ireland	POL	Poland
CHL	Chile	ISL	Iceland	PRT	Portugal
CHN	China	ISR	Israel	SGP	Singapore
CZE	Czechia	ITA	Italien	SWE	Sweden
DEU	Germany	JPN	Japan	SVK	Slovakia
DNK	Denmark	KOR	South Korea	SVN	Slovenia
ESP	Spain	LTU	Lithuania	TUR	Turkey
EST	Estonia	LUX	Luxembourg	USA	United States of America
FIN	Finland	LVA	Latvia		

List of tables and figures

Explanations of abbreviations and concepts

BERD: Business Enterprise Expenditure on (intramural) R&D, during a given period.

Citation impact: The number of citations of a country's or organisation's scientific publications. See also Proportion of highly cited publications.

Clarivate Analytics: A company that publishes Web of Science, a publication database with citation indices. When Clarivate Analytics is referenced in the report, this refers to the Swedish Research Council's database for bibliometrics, which is based on the same material as Web of Science.

Comparable countries: A classification of countries used in the Swedish Research Barometer to represent countries comparable to Sweden in terms of conditions for R&D, as well as number of publications in relation to population and citation impact. Consists of: Belgium, Denmark, Finland, Netherlands, Norway, Switzerland, and Austria.

Constant prices: Constant prices are prices from a specific (constant) time period. Constant prices are used to take account of any price effects that may impact on "real" expenditure levels. When studying the development of R&D expenditure over time at constant prices, we are studying the "real" development of expenditures disregarding changes in price levels (i.e. inflation and deflation). See also the section on Data sources.

Current prices: Current prices are the actual (current) prices for the time period in question. Studying R&D expenditure at current prices over time would entail also studying changes in price levels (i.e. inflation and deflation). See also Constant prices.

eCORDA: external COmmon Research DAta warehouse, data source on participation in the EU's framework programme for research and innovation.

EU15: The member states of the European Union before the expansion with ten new countries on 1 May 2004 (15 countries): Belgium, Denmark, Finland, France,

Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, United Kingdom and Austria.

EU28: The countries that were part of the European Union on 1 July 2013 (28 countries): Belgium, Bulgaria, Cyprus, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Croatia, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, United Kingdom, Sweden, Czech Republic, Germany, Hungary and Austria.

Fast-growing research countries: A classification of countries used in the Swedish Research Barometer to represent countries that have had a rapid expansion of their research systems over the last ten-year period. Consists of China and South Korea.

Fields of research: Classification of Swedish R&D according to the Standard för svensk indelning av forskningsämnen.[48] The classification is in line with the OECD classification 'Field of Research and Development (FORD).' In the Swedish Research Barometer, this classification is referred to as 'fields of research.' The classification consists of three levels. Fields of research at the one-digit level (highest level) are: Natural sciences, Engineering and technology, Medicine and health sciences, Agricultural and veterinary medicine, Social sciences and Humanities and the arts.

Formas: a Swedish Research Council for Sustainable Development.

Forte: Swedish Research Council for Health, Working Life and Welfare.

Frascati Manual: OECD's guidelines for statistics on R&D.[49]

Full time equivalent (FTE): A full time equivalent is the work carried out by one full-time employee during one year. A full-time employee who spends half their time on R&D has carried out 0.5 FTEs on R&D.

GDP (Gross domestic product): The value of all goods and services produced in a country during a given period.

GERD: Gross Domestic Expenditure on (intramural) R&D. Describes the total national expenditure on R&D carried out within a country over a specified period.

HEI: Higher education institution.

HERD: Higher Education Expenditure on (intramural) R&D, during a given period.

Large established research countries: The classification of countries used in the Swedish Research Barometer to describe countries that are often perceived as important countries in international comparisons and are characterised by large publication volumes and a high citation impact. Consists of: France, Japan, United Kingdom, Germany, and USA.

OECD: Organisation for Economic Cooperation and Development. For a list of OECD member countries, see the section on Country codes.

OECD MSTI: OECD's database Main Science and Technology Indicators.

PPP$ (Purchasing power-parity US dollars): Purchasing power adjustment is a way of taking into account price differences in different countries, and thereby expressing R&D expenditure or GDP for different countries in a common currency

48 UKÄ (2016). Standard för svensk indelning av forskningsämnen 2011.

49 OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris.

and at the same price levels. In simple terms, purchasing power adjustments takes into account that 100 SEK buys you different amounts of goods and services in different countries, due to differences in the countries' price levels.

Proportion of highly cited publications: The proportion of a country's or organisation's publications that are among the 10 per cent most cited scientific publications in the world (in the Swedish Research Council's publication database). See also the section on Bibliometric analysis.

Publication volume: Number of scientific publications over a specified period.

Relative specialisation index (RSI): RSI shows whether a country publishes more or less than the world average within a specific subject area. See the section Relative specialisation index for a more detailed explanation.

Research area: Classification of different research subject areas used in the description of scientific publication and citations (six research areas). The research areas are based on the classification of scientific periodicals in the Swedish Research Council's publication database.

R&D (Research and experimental development): Defined in the Frascati Manual as: "Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge."[50] R&D includes basic research, applied research and experimental development. See the fact box in Section 1.1.

R&D expenditure: Refers most often to Gross domestic expenditure on (intramural) R&D, unless otherwise stated. Consists of current costs and investment/capital expenditure. See the fact box in Section 1.2.

R&D intensity: R&D expenditure as a percentage of GDP or R&D expenditures per capita.

R&D system: Refers to all actors, organisations etc. that either perform and/or fund R&D within a country, that is to say the business enterprise sector, the higher education sector, the other government sector and the private non-profit sector.

Researcher: The Frascati Manual definition is: "Researchers are professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods."[51] Researchers can be found in the higher education sector, business enterprise sector and the rest of society, see Section 2.1.

SCB: Statistics Sweden (Sw. Statistiska centralbyrån).

Scientific publication: In the bibliometric analyses, the publication types 'article' and 'review' are added together into a common document type, which in the report are designates as 'scientific publication'. Monographs or other types of scientific publications are not included.

SEK: Swedish krona.

Subject area: Classification of different research subject areas used in the description of scientific publication and citations. The subject areas are based on the

50 OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris, page 44.

51 OECD (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris, page 162.

classification of scientific periodicals in the Swedish Research Council's publication database.

Subject profile: Subject profile refers to a country's (or organisation's) specialisation of its scientific production within different subject areas. For further information, see Relative specialisation index.

Swedish Higher Education Authority: Sw. Universitetskanslersämbetet, UKÄ.

UKÄ: Swedish Higher Education Authority.

Vinnova: Sweden's Innovation Agency.

The Swedish Research Barometer provides an overall description of research and development (R&D) in Sweden, and highlights how Sweden compares internationally as a research nation. In addition, the Swedish Research Barometer places particular focus on the research conducted within the higher education sector in Sweden.

The report consists of three chapters:
- Research funding
- Research personnel
- Scientific publication

The Swedish Research Council publish the Swedish Research Barometer every two years. This is the third report.

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The Swedish Research Council has a leading role in developing Swedish research of the highest scientific quality, thereby contributing to the development of society. Besides funding research, the agency advises the Government on research-related issues and participates actively in the discussions to create understanding of the long-term benefits of research.