2014

SUMMARY

THE STATE OF SCIENTIFIC RESEARCH IN FINLAND

ACADEMY OF FINLAND

Edited by: Anu Nuutinen and Annamaija Lehvo, Academy of Finland

Bibliometric computing: Yrjö Leino, CSC – IT Center for Science Ltd

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Further information:
www.aka.fi/tieteentila > In English

Planning and Management Support Unit
Academy of Finland
email: tieteentila(at)aka.fi

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THE STATE OF SCIENTIFIC RESEARCH IN FINLAND 2014

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Abstract

The State of Scientific Research in Finland 2014 is a compilation of material on the scope of research activities within universities and government research institutes and their scientific impact, as measured with bibliometric methods. In addition, the report reviews the recruitment of professors and the state of research infrastructures.

Based on citation indicators, the level of scientific research in Finland is stable and above the world average, but in this millennium Finland has clearly fallen behind many other OECD countries. The countries that were ahead of Finland in the early 2000s have maintained or increased their lead. In addition, many of the other countries observed have overtaken Finland.

Another clear result of the bibliometric analyses is that publications created in international cooperation have a greater scientific impact than those written in Finland alone. This applies to all disciplines for which a citation indicator could be calculated.

The results of the citation analyses for universities and government research institutes do not differ systematically from one another: there are disciplines in both organisational groups at a level clearly either above or below the international average. The results within one discipline are generally similar both in the university sector and in government research institutes.

Universities fund approximately a third of all their research expenditure with competitive funding, which, for the purposes of this report, includes funding from the Academy of Finland, Tekes – the Finnish Funding Agency for Innovation and the EU Framework Programme for Research and Innovation. The amount of competitive funding received by different disciplines is affected by the quality of research, national policies and the traditions of funding.

Universities have recruited a great many professors in recent years. In many cases, the professors had already previously worked for the university that recruited them. In open application processes, the number of applicants either from Finland or abroad was rather small. The rate of internationalisation is still somewhat sluggish. The recruitment rate of professors in government research institutes is clearly lower than in universities.

When reviewing by discipline, the university institution is still rather fragmented. Half of the 54 disciplines are represented in at least six universities. More than a third of the university discipline units employ three professors or fewer, calculated in terms of full-time equivalents. The university disciplines having the greatest scientific impact on the basis of citation indicators are represented in no more than five universities.

In most disciplines, research infrastructures have become an increasingly important precondition for high-quality research. There are many research infrastructures, but their field is also fragmented.

RECOMMENDATIONS

Key recommendation: towards higher quality research through choices, exclusions and collaboration

- Universities should quickly develop their research profiles so as to focus on their key strengths and the new initiatives emerging from these.
- Division of work and collaboration is required, along with exclusions and long-term investment in the areas of strategic value to the respective organisation.
- Opportunities for collaboration between universities and government research institutes should be leveraged better.

Specific recommendations

- Choices are put into practice in recruitment: active and open recruitment is essential.
- Systematic and long-term international collaboration is needed.
- Strategic choices and collaboration must be increased in the construction and use of research infrastructures.
- The research funding system must strongly encourage making choices.
- Evidence-based planning and decision-making must be raised to a new level in science policy.

Background and objectives

The Academy of Finland has reviewed the state of scientific research in Finland regularly since the late 1990s. The State of Scientific Research in Finland 2014 project reviewed Finnish universities and government research institutes for their teaching and research staff, research funding, publication activities and scientific impact, measured with bibliometric methods, by discipline and organisation. A special theme was the recruitment of professors in universities and government research institutes in 2010–2013. Another focus area was an overview of the research organisations' most important and strategically significant research infrastructures.

During the project, a wide range of material was compiled for further use. The goal was to produce material to support both the research organisations' own development efforts and to strengthen the knowledge base serving the Ministry of Education, Science and Culture, the Academy of Finland and other science policy actors. The discipline- and organisation-based analyses are available on this scale for the first time, and their development continues. The draft materials were presented to the future users already in the preparatory phase, and feedback was collected to further improve the analyses. The detailed material can be found on the website of the Academy of Finland by discipline and organisation (www.aka.fi/tieteentila, mainly in Finnish).

The extensive statistical material provides a specific view of the state of scientific research and the organisation of research at the research system level, both by discipline and research organisation. The resulting analyses act as a touchstone, pointing out similarities and differences. Final conclusions will require further analysis and the use of the organisations' own, supplementary materials, for example.

This summary compiles the main findings and recommendations on the research system level. The objective of the project was to provide an overall picture rather than to evaluate the quality of research in the individual disciplines. Consequently, the conclusions and recommendations do not take a stand on the state of individual disciplines.

The preparation of the State of Scientific Research in Finland 2014 report was led by a steering group chaired by the President of the Academy of Finland, Professor Heikki Mannila, and co-chaired by Academy Board member Professor Arto Mustajoki, University of Helsinki. The other members were Director Riitta Maijala, Ministry of Education, Science and Culture; Rector, Professor Kaija Holli, University of Tampere and Universities Finland UNIFI; and Research Director, Professor Per Mickwitz, Finnish Environment Institute (SYKE).

Limitations of the analyses

There are certain limitations to the analyses that should be taken into account in the interpretation of the results.[1]

The **classification of disciplines** is based on the Finnish classification of disciplines from 2010[2]. The classification is the same as that used by the Ministry of Education, Science and Culture and Statistics Finland for producing the statistics on universities' research activities. Some disciplines have for the purposes of this review been combined into larger entities. Nevertheless, the granularity of the classification varies a good deal. The problem shared by all classifications of disciplines is that the classification inevitably compartmentalises research, which has become increasingly diverse. It is also difficult to place interdisciplinary and phenomenon-based research in a traditional classification of disciplines. Material based on an alternative classification is not currently available, however.

The limitations of **bibliometric analyses** are related to the scope of the material in international citation databases as well as the processing of the material and the calculation of citation indicators. Publishing practices also vary by discipline to some degree. The publication figures for different disciplines are not comparable in all respects, as international citation databases do not cover the publications of all disciplines in the same way. The material does not, for example, include scientific articles in research books or edited scientific books (monographs). The material in international citation databases is not as appropriate for a detailed examination of publication activities in the social sciences or the humanities as in many other disciplines. The material is also incomplete in respect to peer-reviewed conference proceedings, which has a clear impact on the publication figures of computer sciences, for example.

This summary examines scientific impact as measured by bibliometric methods. The percentage of research with the greatest scientific impact can be analysed by examining the publications ranked in the top 10 per cent of the discipline in terms of the number of citations worldwide. The top 10 index selected as the citation indicator reflects how many more or fewer of the publications within the country or discipline are included in the 10 per cent of the most cited publications in the discipline in comparison to the international average. The discipline of a publication is determined by the disciplines defined for the scientific journal in which it was published.

Citation practices vary by discipline both in terms of how many earlier publications are generally cited, and how soon and for how long the publications are cited. As the material in international citation databases is updated, the citation indicator values may change accordingly. The type of publication may also affect the citation accumulation. For these reasons, the number of citations gained by a publication is normalised in the calculation of bibliometric citation indicators by discipline, publication type and publication year. For example, publications produced in Finland are compared to the international level within the same

[1] *See also www.aka.fi/tieteentila > In English > Methods and classifications*

[2] *www.stat.fi/meta/luokitukset/tieteenala/001-2010/index_en.html*

discipline, the same publication type and the same publication year. Publications are fractionalised according to country, organisation and discipline. The citation indicator is scaled so that the world average in each discipline is always one.

The comparison of **input and output data** by discipline is sometimes problematic, as the work contribution of teaching and research staff may be reported to a different discipline than competitive funding or publications. To some extent, the problem lies in the combination of different datasets. This also reflects multidisciplinarity and changes in science, wherein the research and teaching discipline reported for a professor in university data collection may be different from that of the disciplines of his or her publications. The discipline for teaching and research staff and research expenditure is often determined by the administrative unit (e.g. a department) of the discipline. In some cases, the disciplines of the staff are determined by individual staff member. The discipline of a publication in the data based on the Web of Science is, on the other hand, determined on the basis of the discipline of the publication channel. It is typical in some disciplines that researchers publish via publication channels other than those of their "own discipline", and an individual researcher may well publish through the publication channels of several disciplines.

The professor survey material covers professors recruited in 2010–2013. Professors were defined to be persons working in tier IV positions in universities and as research professors and research directors in government research institutes. The survey responses did not provide sufficient information for a more detailed analysis of fixed-term tasks. Another significant limitation is that the number of applicants in open application processes was seldom stated in the responses.

The information provided by the survey of research infrastructures does not comprehensively describe the entire field, and the results are to some extent indicative. When reviewing the number of research infrastructures, the many different forms of research infrastructures should be taken into account. The different nature of research in different disciplines affects, for instance, the number of users. It proved to be difficult to evaluate replacement cost, to interpret shared use and to assess the number of users as persons in the responses.

Results

This summary compiles the key findings of the State of Scientific Research in Finland 2014 report. The methods and discipline classifications used can be found on the Academy of Finland website **www.aka.fi/tieteentila > In English.**

The level of scientific research in Finland is stable, but we have fallen behind many other countries in comparison

Finland ranks above the world average in an international comparison of scientific impact (Figure 1). Measured by bibliometric methods, Finland's position has remained practically the same throughout the 2000s. The gap between Finland and many of the top countries in science has, however, grown. In addition, compared to the situation in the early 2000s, Belgium, Australia, Germany, Ireland, Austria and Norway have overtaken Finland.

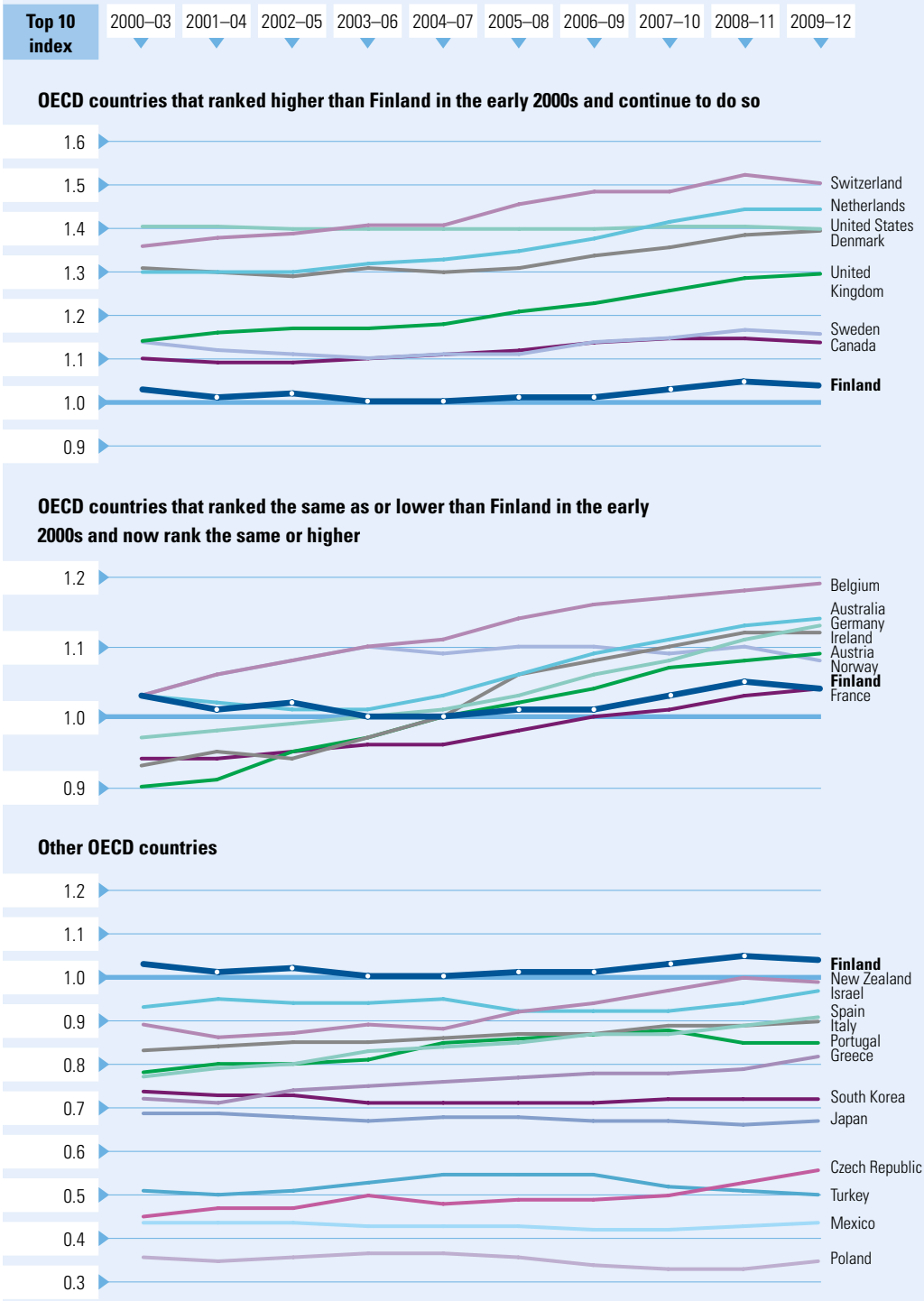
TOP 10 INDEX

- The percentage of research with the greatest scientific impact can be analysed by examining the publications ranked in the top 10 per cent of the discipline in terms of the number of citations worldwide.
- The citation indicator reflects how many more or fewer of the publications within the country or discipline are included in the 10 per cent of the most cited publications in the discipline in comparison with the world average.
- The number of citations gained by publications is normalised, that is, publications produced in Finland are compared to the international level within the same discipline, the same publication type and the same publication year.
- The discipline of a publication is determined by the disciplines defined for the scientific journal in which it was published.
- Publications are fractionalised according to country, organisation and discipline.
- The citation indicator is scaled so that the world average in each discipline is always one.
- Citations are accumulated with a delay that varies greatly between disciplines. As the material in international citation databases is updated, the citation indicator values may change accordingly.
- Further information is provided in the chapter Bibliometric analyses.

Finland's publication count has increased in the 2000s (Figure 2). Researchers working in Finland contributed to more than 28,000 publications in 2009–2012. The publication number has increased the most in universities, by 24 per cent. In the most recent review period, universities took part in 65 per cent of all Finnish publications.

FIGURE 1

Top 10 indexes of publications from the OECD countries according to WoS. The world average is 1. The countries are grouped according to their position in the early 2000s and in the years 2009–2012.



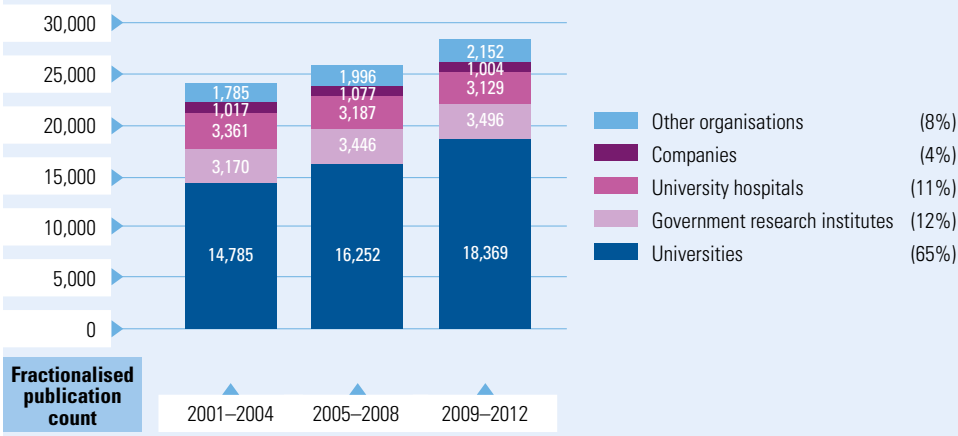
OECD countries with relatively small publication counts (approx. 15,000 publications or fewer) are not included in the figure. Measured by the top 10 index, Iceland ranked higher than Finland in the early 2000s (1.05) and continues to do so (1.15). The level of Luxembourg, Estonia, Slovenia, Hungary, Chile and Slovakia was lower than that of Finland both in the early 2000s and today.

The fractionalised publication counts of the countries featured in the figures range from approximately 19,000 in Ireland to 1.2 million in the United States in 2009–2012. Finland's fractionalised publication count was approximately 28,000.

Source: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

FIGURE 2

Finland's fractionalised publication count by sector according to WoS. The proportion of each sector (%) in 2009–2012 is indicated after the sector name in parentheses.



Publications have been fractionalised between countries, organisations and disciplines. "Other organisations" includes the hospitals of hospital districts, their publications being distinguished from university hospital publications, publications of polytechnics and other organisations that conduct research.

Source: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

In Finland, universities report annually on their publication output to the Ministry of Education, Science and Culture. Figure 3 shows the number of peer-reviewed scientific publications reported by the universities in all disciplines. The publication count has not been fractionalised, so it differs from the publication count of the Web of Science data. Furthermore, the WoS data do not cover all peer-reviewed publications. The publication count by discipline presented in the figure includes some of the publications several times over, if researchers from several Finnish universities have contributed to the publication. There are differences between disciplines in the publishing practices, for instance, with regard to whether results are mainly published as journal articles, as book sections or chapters in research books, in conference proceedings or as edited scientific books (monographs). International co-publishing is not as common in all disciplines. The proportion of international co-publications was 37 per cent on average, varying between 5 and 88 per cent in the review period 2012–2013.

Scientific publishing in polytechnics has been on the increase in recent years, especially the publication of journal articles in scientific journals.[3]

A qualitative classification of scientific publication channels based on evaluation by national expert panels (the Publication Forum) has been in use in Finland since 2011.[4] The qualitative classification is updated regularly. Researchers can also propose new publication channels for evaluation. The use of material based on the current classification of publication channels is problematic, in particular when all disciplines are to be reviewed together; hence, this material is not included in this summary.

The core funding of universities was previously directly affected by the number of publications produced by the university. In the new university funding model, the emphasis is on the quality of publications, measured by their rating in the Publication Forum classification, in addition to their number. The funding model additionally takes into account the greater work effort required for scientific books (monographs) compared to individual articles.

[3] The publication data reported by polytechnics are available in the Vipunen statistical portal of the Ministry of Education, Science and Culture and the National Board of Education in Finland (vipunen.csc.fi).

[4] More information about the Publication Forum: www.tsv.fi/julkaisufoorumi/english.php?lang=en.

FIGURE 3 (OPPOSITE PAGE)

Peer-reviewed scientific publications – domestic publications and international co-publications – by discipline in 2012–2013 as reported by Finnish universities, according to publication data collected by the Ministry of Education, Science and Culture. The total non-fractionalised publication count of the discipline is indicated in parentheses after the name of the discipline.

The data include the publications reported in the data collected by the Ministry of Education, Science and Culture in the following publication types:

A1 *Journal article in a scientific journal*
A2 *Review article in a scientific journal*
A3 *Book section, chapters in research books*
A4 *Article in a conference proceeding*
C1 *Edited scientific book (monograph).*

Publication as a book section, chapters in research books or as an edited scientific book (monograph) is especially common in the social sciences and humanities.

The publication counts by discipline contain some of the publications several times over, if researchers from several Finnish universities have contributed to the publication. The total publication count of different disciplines cannot directly be compared to Figure 2 with respect to universities, as Figure 2 is based on fractionalised publication counts over four-year periods.

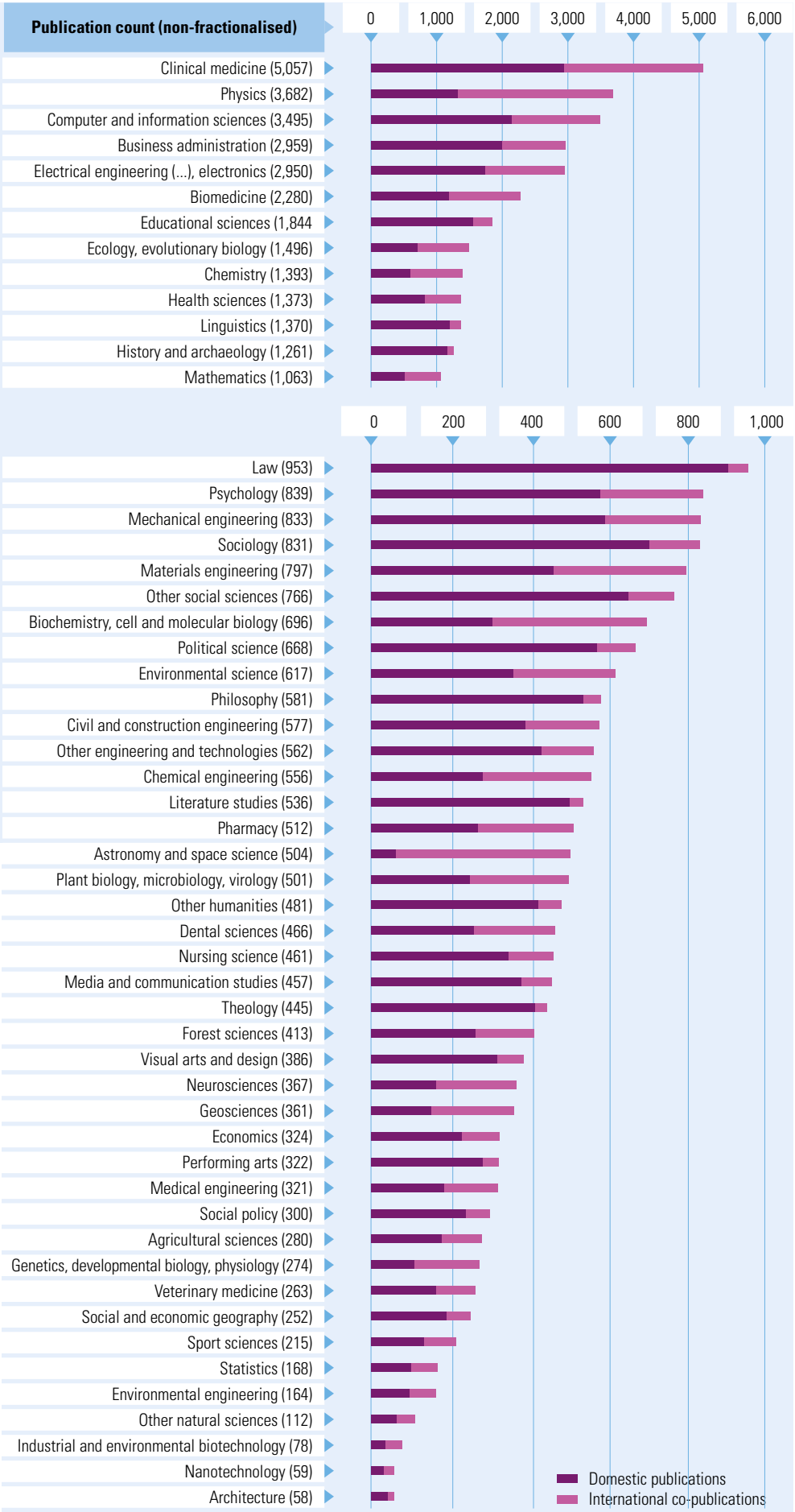
The abbreviated discipline Electrical engineering (...), electronics refers to Electrical, automation and communications engineering, electronics, and Performing arts refers to Theatre, dance, music, other performing arts.

"An international co-publication means that the authors include at least one person employed by a non-Finnish organisation. If a person has an employment relationship with both a Finnish and an international organisation, and he or she has entered both as his or her affiliation, the publication will be considered an international co-publication." (Ministry of Education, Science and Culture Publication Data Collection Manual 2012)

The scientific impact of research can be measured with bibliometric citation indicators. There are a number of problems involved in the interpretation of the results of citation indicators (see also the chapters Limitations of the analyses and Bibliometric analyses). Citation indicators alone do not provide a reliable overall picture of the level of research. However, they do add a useful perspective to the analysis of scientific impact.

The top 10 index values calculated on the basis of universities' publication data by discipline are presented in Figure 4. The values vary widely both between disciplines and in the different four-year periods of individual disciplines. Disciplines with large publication counts include disciplines that are clearly above the world average, as well as others that are almost as clearly below the average.

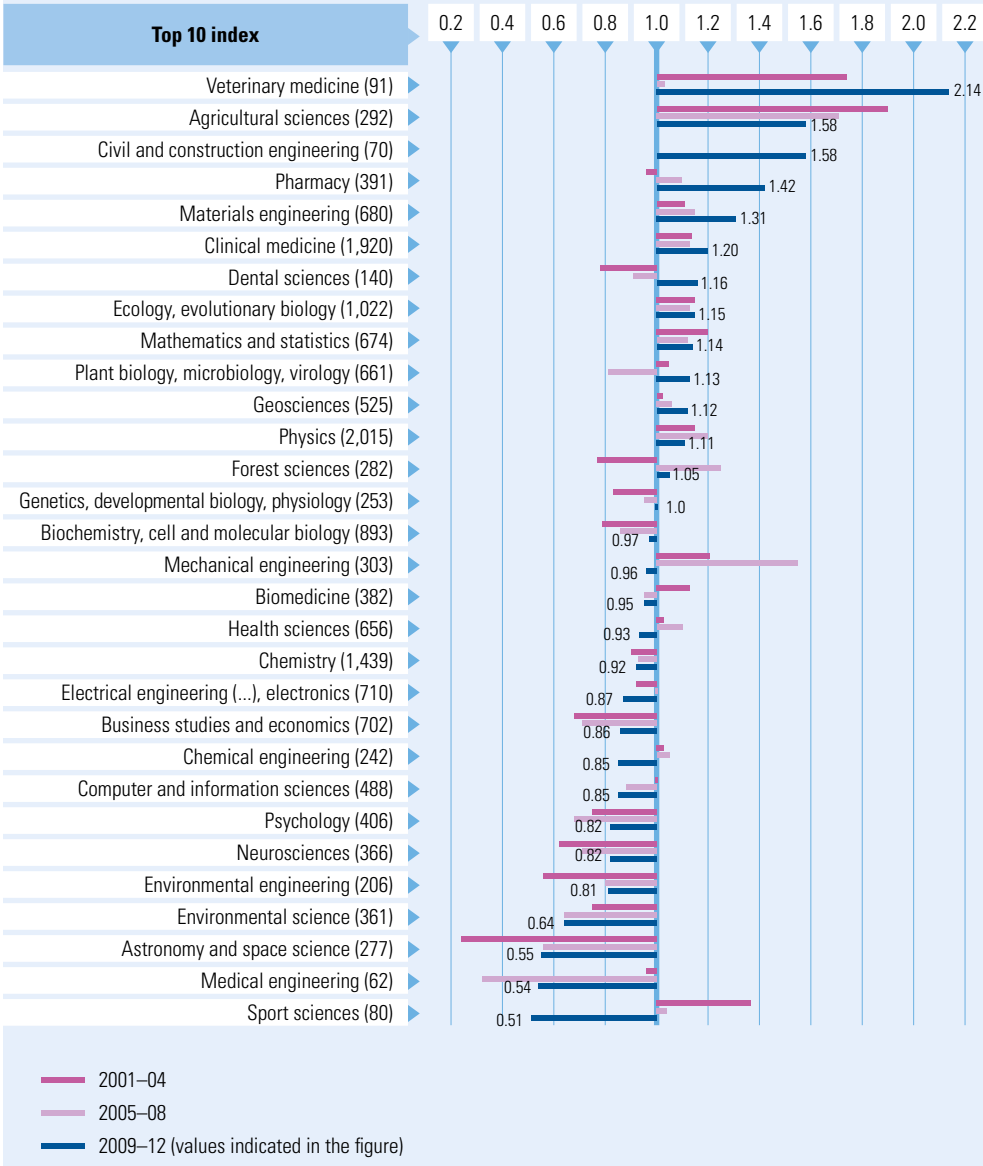
The variation in the top 10 index values should be taken into account especially in disciplines with large publication counts. In smaller disciplines, there is great variation between different four-year periods, even if no significant change has occurred in the level of research. A similar variation caused by small publication counts between four-year periods can be seen especially in the reviews of citation indicators by organisation.



Source: Publication data collection by the Ministry of Education, Science and Culture in 2013 and 2014.

FIGURE 4

Top 10 index of publications from universities by discipline according to WoS. The world average in the discipline is 1. The fractionalised publication count in the years 2009–2012 is indicated in parentheses after the name of the discipline and the top 10 index value in the figure.



The top 10 index reflects how many more or fewer of the publications within the discipline are included in the 10 per cent of the most cited publications in comparison with the international average. The world average in the discipline is 1. The top 10 index values of disciplines with smaller publication counts may vary a great deal between review periods. This does not mean, however, that the level of research in the discipline changes considerably over a few years.

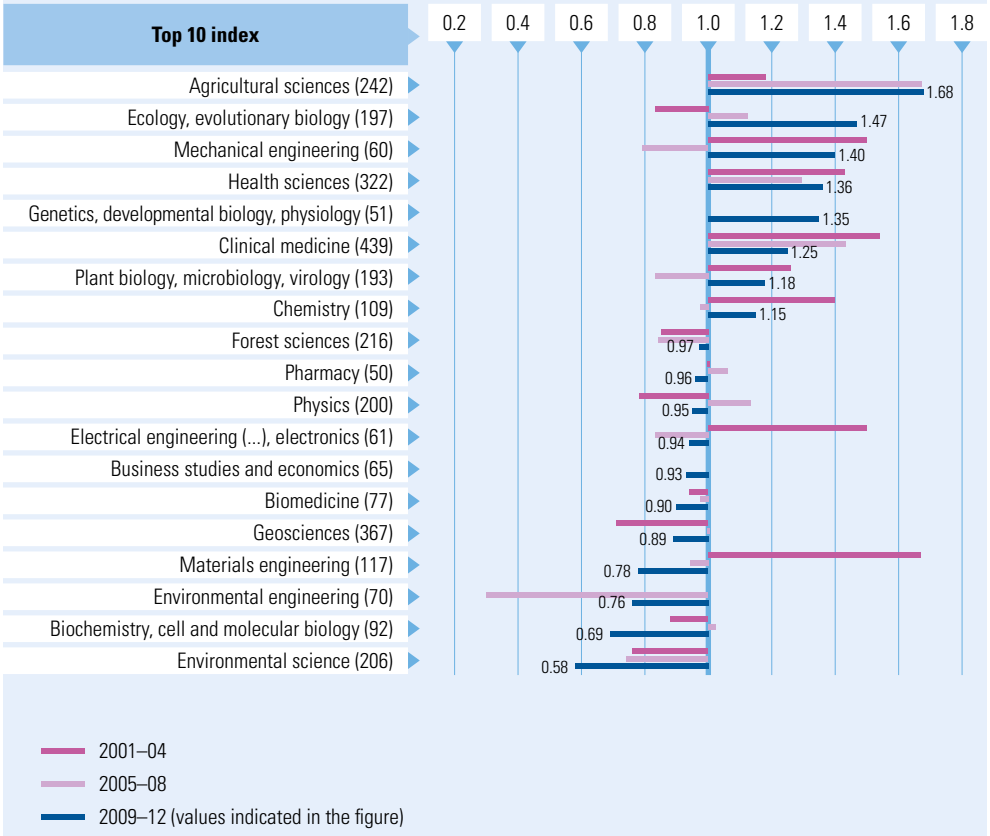
If the fractionalised publication count in a review period is less than 50, the bar indicating the top 10 index is missing for the review period in question. Publications in the social sciences and humanities are inadequately represented in the data.

The fractionalised publication count indicated after the discipline cannot be compared to the non-fractionalised publication count of the discipline shown in Figure 3. The length of the review period is also different.

Source: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

FIGURE 5

Top 10 index of publications from government research institutes by discipline according to WoS. The world average in the discipline is 1. The fractionalised publication count in the years 2009–2012 is indicated in parentheses after the name of the discipline and the top 10 index value in the figure.



Only disciplines with a fractionalised publication count from government research institutes of 50 or more in the years 2009–2012 are shown in the figure. The top 10 index values of disciplines with smaller publication counts may vary a great deal between review periods. This does not mean, however, that the level of research in the discipline changes considerably over a few years. If the fractionalised publication count in a review period is less than 50, the bar indicating the top 10 index is missing for the review period in question. Publications in the social sciences and humanities are inadequately represented in the data.

Source: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

Significant variation is also found in the top 10 index values of disciplines in government research institutes (Figure 5). Systematic differences cannot be observed between the level of scientific research in government research institutes and universities as measured by bibliometric methods. Analysis by discipline is quite problematic with respect to government research institutes, as their research approach is often primarily phenomenon-based. Researchers publish in the publication series of several different disciplines, resulting in a low discipline-specific publication count.

EXAMPLE OF THE EFFECT OF A SMALL PUBLICATION COUNT ON THE TOP 10 INDEX

- Let us assume that Finnish universities produce 80 publications in a particular discipline over a four-year period.
- The world average, that is, a top 10 index value of 1, is achieved by 8 publications that are positioned in the 10 per cent of the most cited publications in the discipline.
- If there are 7 such publications, the top 10 index value is 0.88, that is, the publications produced by Finnish universities rank below the world average in this discipline.
- If there are 12 such publications, the top 10 index value is 1.50, that is, the publications produced by Finnish universities rank above the world average in this discipline.
- Thus, small variations in the number of frequently cited publications have a considerable impact on the results.
- Because the calculation of the top 10 index is based on a publication count fractionalised among countries, organisations and disciplines, in reality a higher number of publications is required than indicated above.

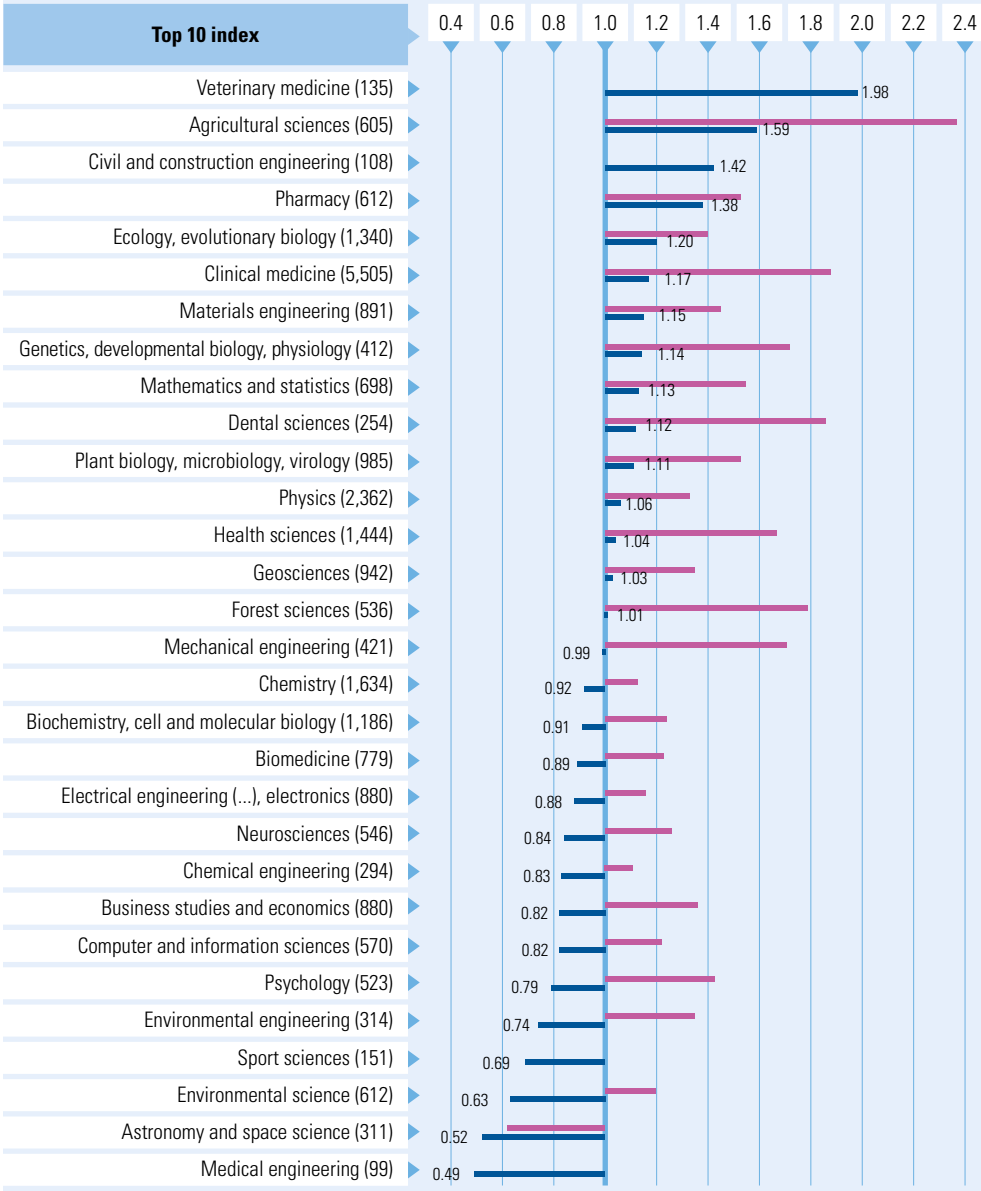
According to bibliometric analyses, scientific impact is significantly increased by international collaboration. In all disciplines, a greater proportion of publications produced in international collaboration is in the 10 per cent of the most cited publications in the discipline compared to all publications in the discipline produced within Finland (Figure 6). In practically all disciplines (23 out of 26), the top 10 index of international co-publications is also clearly higher than the world average, when the threshold is defined as a top 10 index value of ≥ 1.15. For all publications, seven disciplines are clearly above the world average.

In the bibliometric classification of disciplines, the general scientific journals *Nature, PLOS ONE, PNAS*[5] and *Science* as well as many lesser-known publication forums are grouped into the category of multidisciplinary journals. The publications of researchers working in Finland in multidisciplinary journals are more often cited than Finnish publications on average (Figure 7). Publications in multidisciplinary journals are generally produced in collaboration with researchers in foreign organisations. International co-publications count for 76 per cent of this group. There has been a particularly large increase in publication in the *PLOS ONE* online journal.

[5] *Proceedings of the National Academy of Sciences of the United States of America (PNAS).*

FIGURE 6

Top 10 index of publications produced in Finland by discipline for all publications and international co-publications in the years 2009–2012 according to WoS. The world average in the discipline is 1. The fractionalised publication count in the years 2009–2012 is indicated in parentheses after the name of the discipline and the top 10 index value in the figure for all Finnish publications.

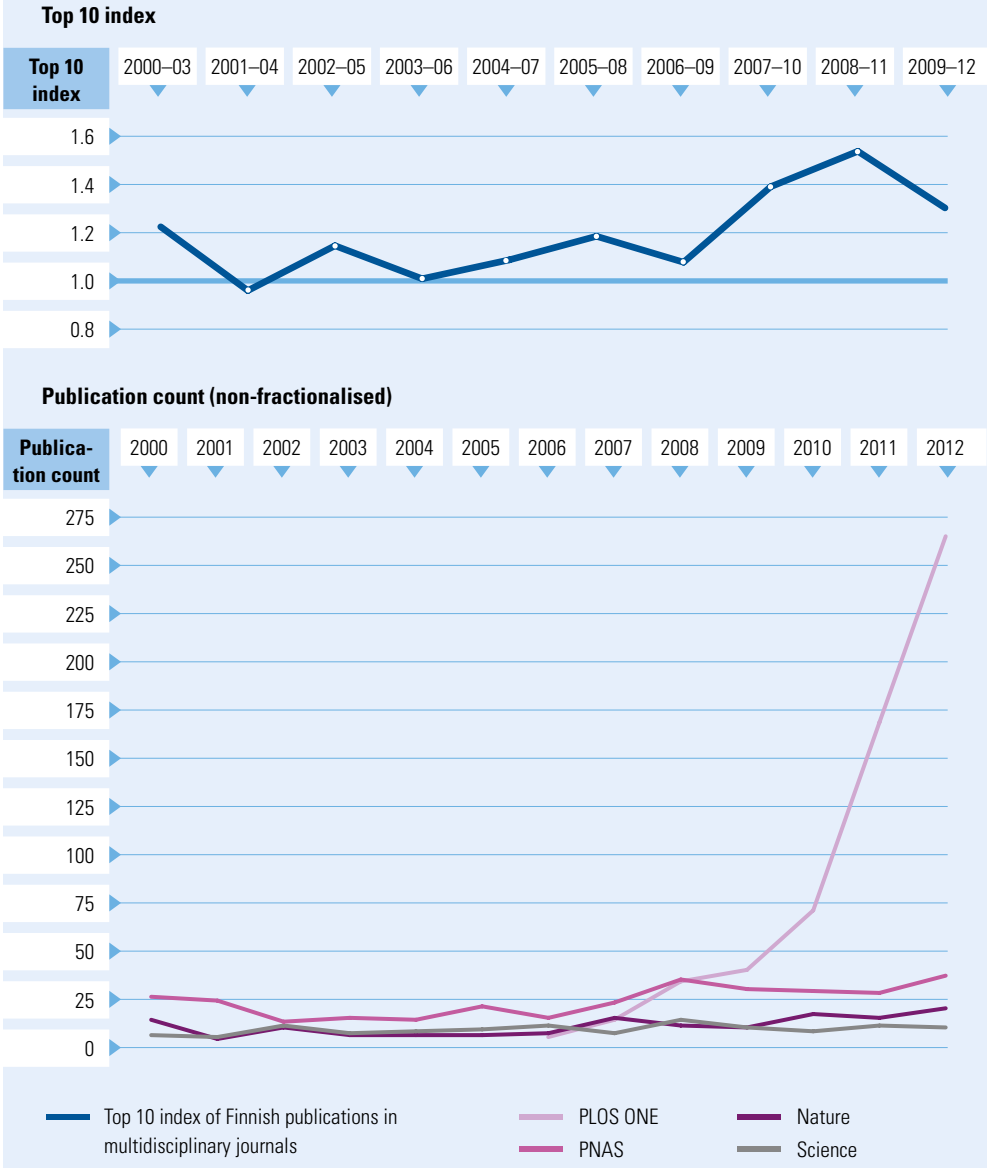


International collaboration means that at least one author with an address in a country other than Finland has contributed to the publication. If the fractionalised international co-publication count is less than 50, the bar indicating the top 10 index is missing for the discipline in question. Publications in the social sciences and humanities are inadequately represented in the data.

Source: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

FIGURE 7

Top 10 index of Finnish publications published in multidisciplinary journals (such as *Nature, PLOS ONE, PNAS* and *Science*) according to WoS. The world average in the multidisciplinary journal group is 1. The figure also shows the number of publications produced in Finland in the four above-mentioned journals in the years 2000–2012, according to the WoS online database.



Articles in multidisciplinary journals have not been relocated into different disciplines. They belong to the category of "multidisciplinary journals". The group of multidisciplinary journals includes 59 journals, including the general science journals Nature, PLOS ONE, PNAS and Science and several lesser-known scientific journals. The list of journals is available at: http://science.thomsonreuters.com/cgi-bin/jrnlst/jlresults.cgi?PC=D&SC=RO.
Finland's fractionalised publication count in multidisciplinary journals was 311 in the years 2009–2012.

The annual publication count in the Nature, PLOS ONE, PNAS and Science journals was retrieved from the WoS online database (country Finland, publication types article, letter and review). The data in the online database differ to some extent from the data used for the calculation of the top 10 indexes. In the latter, the addresses of publications by Finnish research organisations have been checked, for example.

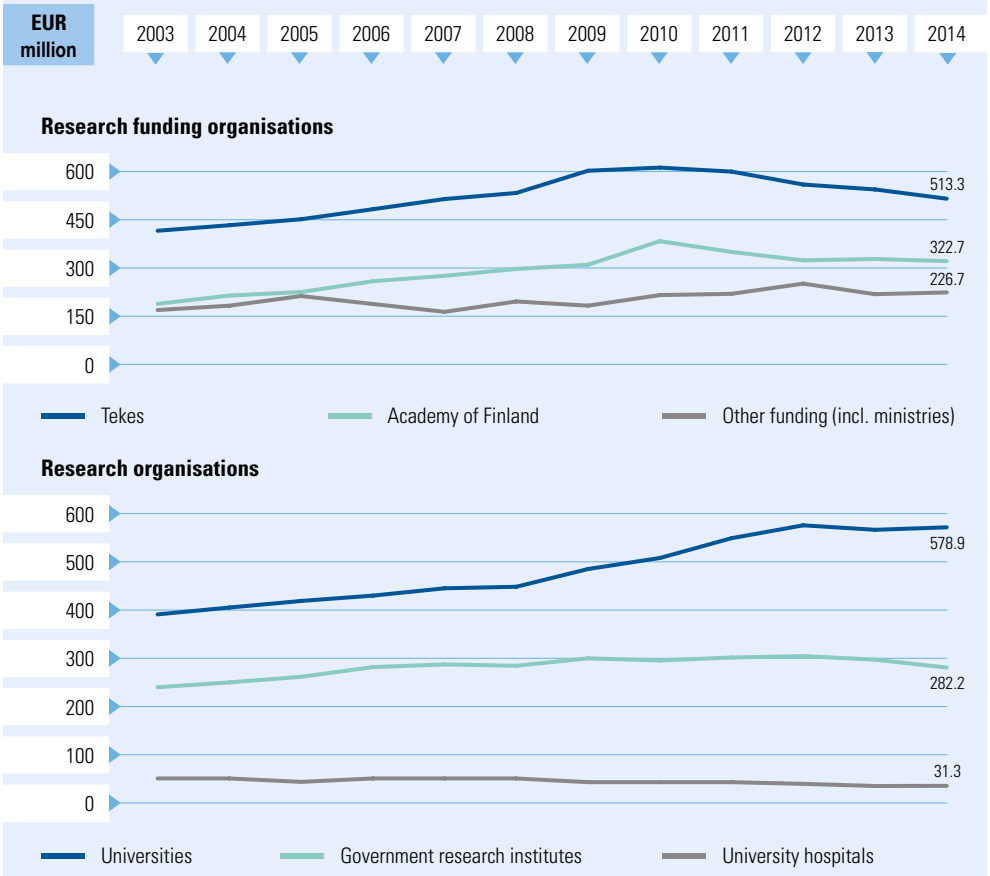
Sources: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric calculation CSC, 2014; Academy of Finland WoS online database (data retrieved on 19 Sep 2014).

The success of different disciplines in obtaining competitive funding varies

The real value of public funding for research and development increased from 2003 to 2010, after which funding has decreased.[6] The budget funding for universities and the amount of funding granted by the Academy of Finland and Tekes are now significantly higher than in 2003, however (Figure 8). The public research funding for university hospitals has decreased in the review period.

FIGURE 8

Government R&D funding in current prices, according to research funding organisations and research organisations in the years 2003–2014. The funding volume in 2014 (EUR million) is indicated in the figure.



The budget funding for the R&D activities of universities and government research institutes has been derived by computation. Universities, government research institutes and university hospitals fund their research activities to a considerable extent with supplementary funding. Funding from the Academy of Finland and Tekes is awarded through competition. Other funding primarily refers to funding for R&D activities allocated via ministries.

In the 2010 budget, a so-called technical addition of 90 million euros was allocated in order to finance the change of the Academy of Finland's research posts into employment relationships and for the tasks of the new Academy Professors and Academy Research Fellows.

Source: Official Statistics of Finland (OSF): Government R&D funding in the state budget 2014 [e-publication, Appendix Table 9]. Statistics Finland 2014.

Access method: http://tilastokeskus.fi/til/tkker/2014/tkker_2014_2014-02-20_tau_009_fi.html [referred: 15 Sep 2014]

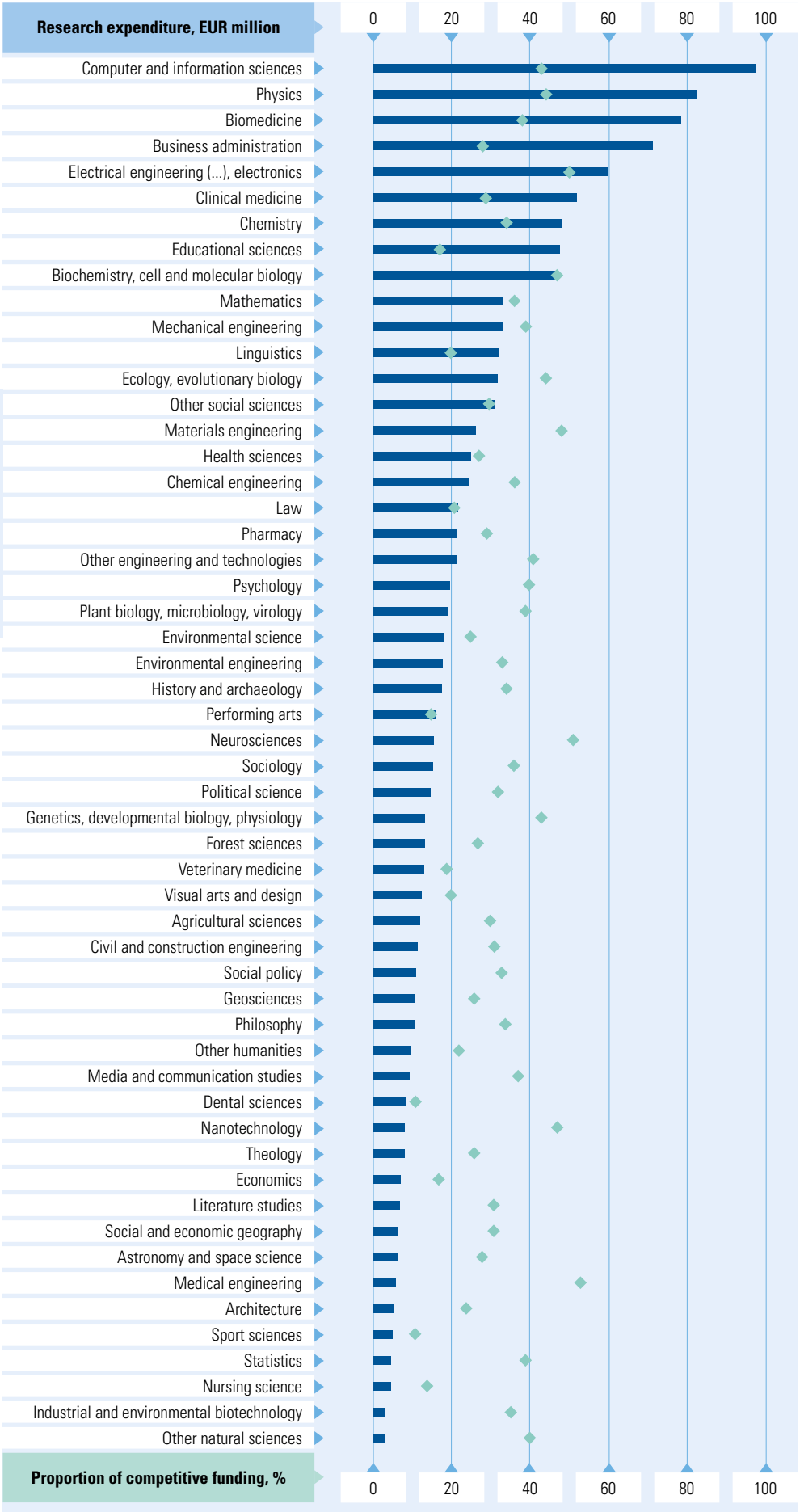
[6] *Government R&D funding in the state budget 2014. Statistics Finland 2014. (Available only in Finnish.)*

In the largest disciplines, total university research funding is approximately 80–100 million euros a year, while the funding for the smallest disciplines is less than 10 million euros per year (Figure 9). In 2012, universities financed approximately 35 per cent (EUR 431.7 million) of their total research expenditure through competitive funding, which, for the purposes of this report, includes funding from the Academy of Finland, Tekes and the EU Framework Programme for Research and Innovation. Funding from foundations is important for certain disciplines, but it is difficult to obtain comprehensive and comparable discipline-specific information on this, as personal research grants are not always included in the research funding reported by the universities. The importance of competitive funding in the funding structure of different disciplines varies. At its lowest, competitive funding accounted for 11 per cent of the discipline's research expenditure; at its highest, the figure was 53 per cent.

FIGURE 9 (OPPOSITE PAGE)

University research expenditure (EUR million) and the proportion of research expenditure covered by competitive funding (%) by discipline in 2012.

Competitive funding means university research expenditure covered by funding from the Academy of Finland, Tekes and the EU Framework Programme for Research and Innovation. In 2012, the proportion of competitive funding of university research expenditure was on average 35 per cent.



Source: Statistics Finland 2013.

The following figure (Figure 10) compares the proportion of competitive funding of the discipline to the proportion of the discipline of full-time equivalents (FTEs) in tier IV positions[7] so that the competitive funding of universities and the FTEs of the above-mentioned positions in all disciplines amount to 100 per cent. Significant differences can be observed between disciplines.

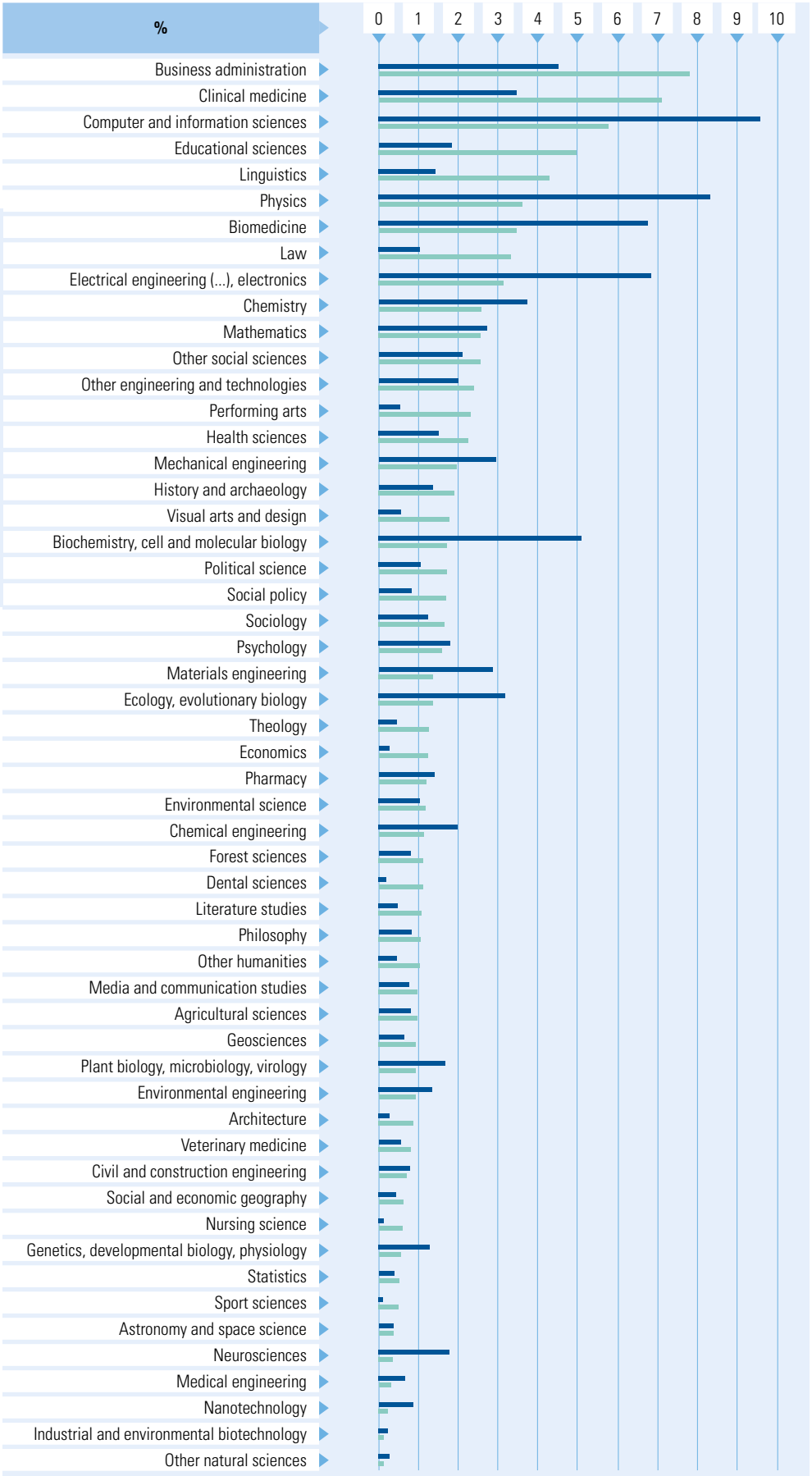
FIGURE 10 (OPPOSITE PAGE)

The proportion of the discipline (%) of full-time equivalents in tier IV positions and of competitive funding in universities in 2012. All disciplines in total equal 100 per cent.

Tier IV positions in the university research career model include those of professor, Academy Professor, research professor and research director.

The comparison of full-time equivalents (FTEs) and competitive funding is sometimes problematic, as the work contribution of teaching and research staff may be reported to a different discipline than competitive funding. For example, the FTEs of departments that include several disciplines have not always been reported by discipline; instead, they may have been allocated to just one. For this reason, in the discipline of philosophy, more FTEs have been reported than is actually the case.

[7] *Tier IV positions in the university research career model include those of professor, Academy Professor, research professor and research director.*



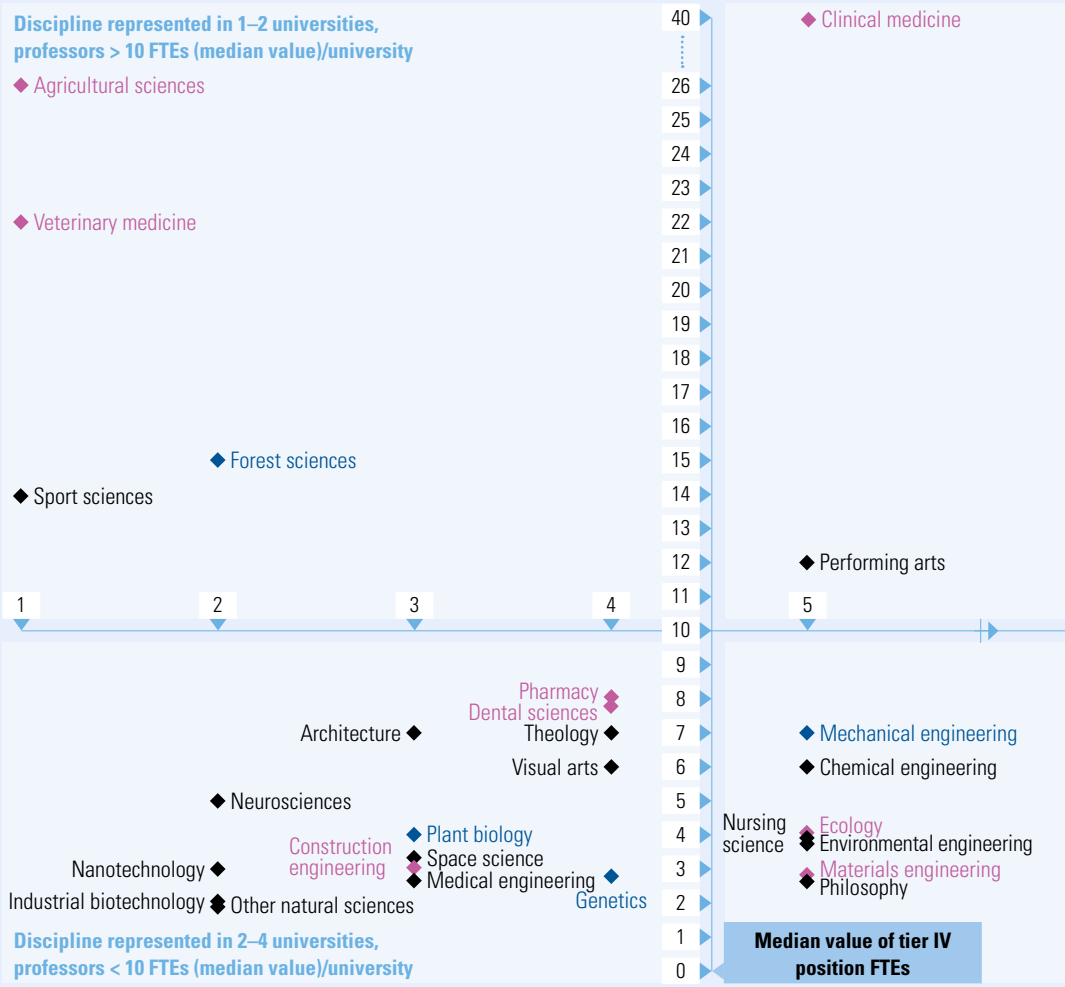
Sources: University data collection by the Ministry of Education, Science and Culture 2013; Statistics Finland 2013.

The university institution is fragmented

The discipline units[8] of Finnish universities are typically small. More than a third of the university disciplines employ three professors or fewer, calculated in terms of full-time equivalents. This analysis is naturally affected by the granularity of the classification of disciplines. Reviewed against the top 10 index, the university disciplines with the greatest scientific impact were represented in no more than five Finnish universities (Figure 11).

FIGURE 11

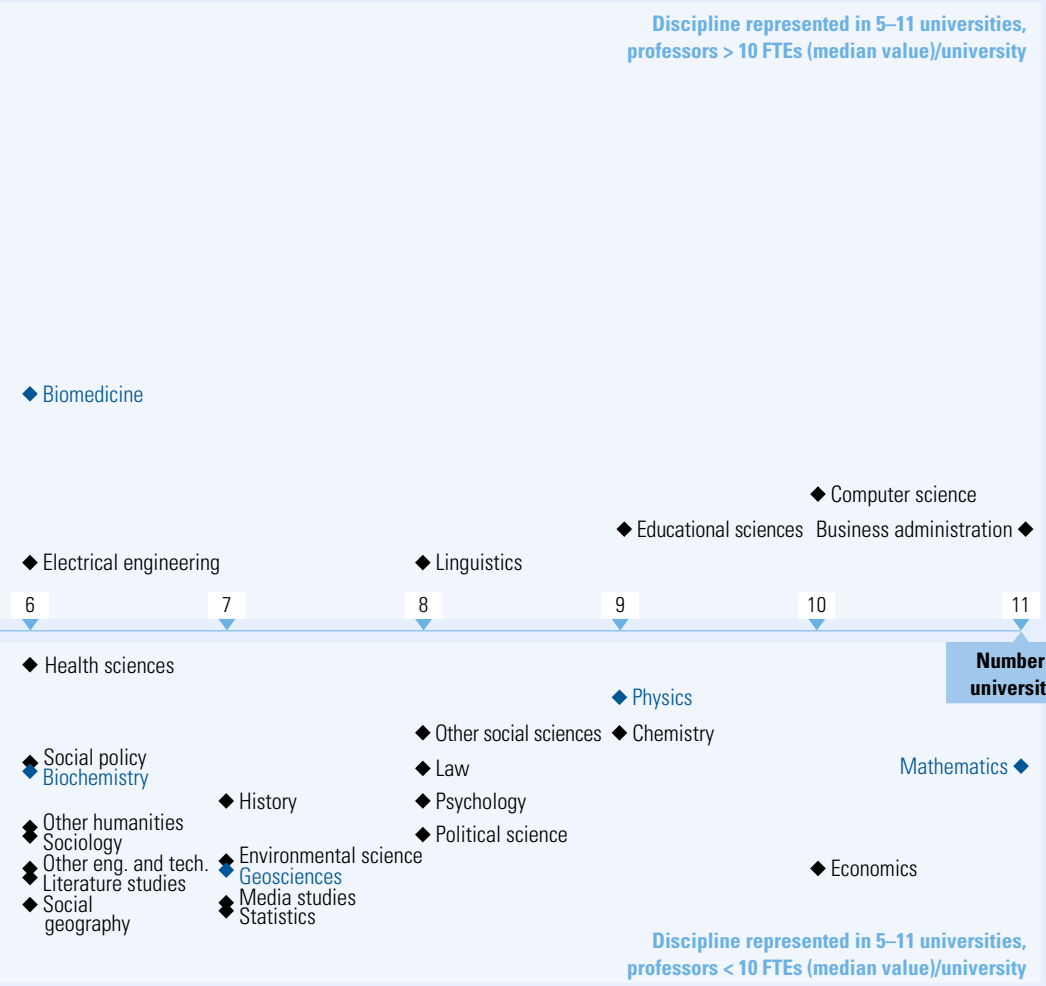
The number of universities and the median value of tier IV position full-time equivalents by discipline in 2012. The discipline's top 10 index in 2009–2012 is illustrated by colours (pink indicates clearly above world average and blue at the level of the world average in the discipline).



The disciplines are colour-coded according to the top 10 index in 2009–2012: ≥ 1.15; 1.14–0.95; ≤ 0.94. Black is also used to indicate disciplines for which the top 10 index cannot reliably be calculated due to the small publication count in the Web of Science database.

The disciplines of mathematics and statistics shown in the figure have been combined in the bibliometric analysis. The colour coding is applied to mathematics, as the publication volume for statistics is clearly smaller in the WoS database. In the bibliometric analysis, nanotechnology has been combined with materials engineering, nursing science with health sciences and economics with business administration.

[8] *Discipline unit refers to the representation of a discipline in a university and is not necessarily the same as a department or faculty.*



There are 297 "discipline units" in Finnish universities, when a unit is defined as a discipline in a university in accordance with the classification of disciplines. In this context, unit does not refer to a department or equivalent. To qualify as a discipline unit, the discipline must have at least one full-time equivalent in a tier IV position. There are a total of 54 disciplines and 14 universities. In 42 of the disciplines, the median value of tier IV position FTEs is less than 10. Some of the discipline names have been abbreviated in the figure to the first word in their name (for the official names, see Appendix 2).

Sources: University data collection by the Ministry of Education, Science and Culture 2013; Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

Almost all universities have a maximum of nine disciplines that have at least one-fifth of the FTEs of the professors of the discipline (tier IV) in Finland (Table 1). In the majority of universities, there are only a few disciplines in which the publication output is at least one-fifth of the publication output of the discipline in Finnish universities (Table 1 and Figure 12). The social sciences and humanities are inadequately represented in this data based on WoS publications.

TABLE 1

The number of disciplines in which the university accounted for at least 3% and at least 20% of the discipline's tier IV position full-time equivalents in 2012 and of the publications (fractionalised publication count according to WoS) in 2009–2012.

Universities	Tier IV position FTEs (total of 54 disciplines)		Fractionalised publication count (total of 30 disciplines)	
	Disciplines with minimum FTEs of		Disciplines with a minimum publication count of	
	3%	20%	3%	20%
AALTO	26	15	19	9
HANKEN	2	0	1	0
UH	35	27	29	19
UEF	32	9	27	3
JYU	23	6	22	2
ULA	6	1	0	0
LUT	7	3	10	1
OULU	35	8	29	1
ARTS	2	1	0	0
TUT	15	6	15	2
UTA	23	6	13	0
UTU	34	9	24	2
UVA	8	0	1	0
ÅAU	24	1	11	1

The total number of the discipline's FTEs for which the percentages have been calculated only includes those universities that have reported at least one FTE to the discipline. The classification of disciplines used includes 54 disciplines.

The data of the University of the Arts Helsinki combine the FTEs reported in 2012 by the Academy of Fine Arts, the Sibelius Academy and the Theatre Academy.

The Thomson Reuters Web of Science database covers only a part of the publications in the social sciences and humanities. Of these disciplines, only business studies and economics, and psychology are included in this analysis. The bibliometric discipline classification used includes 30 disciplines.

Sources: University data collection by the Ministry of Education, Science and Culture 2013; Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

FIGURE 12

The discipline's publication proportion by university in 2009–2012. The publication data are based on the fractionalised publication count according to WoS.

The colour of the square indicates the percentage of the university of the universities' fractionalised publication count in the discipline in the Web-of-Science-based data (the darker the colour, the higher the proportion). The figure shows the disciplines in which the universities' fractionalised publication count was greater than 100 in 2009–2012; hence, the following disciplines are missing: civil and construction engineering, medical engineering, sport sciences and veterinary medicine.

The disciplines are arranged in the figure so that the fields with a similar organisational breakdown are in close proximity. The universities are additionally arranged so as to group together universities with similar discipline profiles.

Source: Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014.

The heterogeneous field of research infrastructures

In most disciplines, research infrastructures have become an increasingly important precondition for high-quality research. Table 2 shows how the most important and strategically significant research infrastructures for research organisations are distributed in number by

TABLE 2

Research infrastructures by ESFRI discipline group, number of users and organisation.

ESFRI discipline groups	Number of users	AALTO	HANKEN	UH	UEF	JYU	ULA	LUT	OULU
Biological and medical sciences	Tens			42	16				9
	Hundreds	1		9		1			4
Energy	Tens	2		2				1	
	Hundreds								
E-science and mathematics	Tens			2					1
	Hundreds	1	1	1		1			
Natural sciences and technology	Tens	24		5				4	11
	Hundreds	1		2		1		1	
Material sciences and analytics	Tens	1		2	1			3	2
	Hundreds	2		3		1			1
Social sciences and humanities	Tens	1	3			9	6		2
	Hundreds		8	4		2		1	
Environmental sciences	Tens			10	2				4
	Hundreds			15		3		1	1
Total	**Tens**	**28**	**3**	**63**	**19**	**9**	**6**	**8**	**29**
	Hundreds	**5**	**9**	**34**		**9**		**3**	**6**

ESFRI stands for the European Strategy Forum on Research Infrastructures. Overlapping responses from different organisations have been removed from the table; these were mainly memberships in international research infrastructures or partnerships in ESFRI research infrastructures. The organisation is the host organisation reported first.

The scale of the number of users was assessed on the basis of how many users on average the research infrastructure has annually (in 2012). The data collection guidelines defined users as the total number of the organisation's internal users (excl. undergraduate students) and external users. If relevant, remote users were also taken into account in the assessment of scale.

Tens of users means that the survey respondents reported the number of users of the research infrastructure as no more than 100 users annually. Hundreds of users indicates a number of users

organisation and discipline group. Based on the Academy of Finland's research infrastructure survey, especially the biological and medical sciences as well as the natural sciences and technology have many research infrastructures with tens of users per year. Research infrastructures serving hundreds of users were reported particularly in the environmental sciences, biological and medical sciences, as well as the social sciences and humanities.

ARTS	TUT	UTA	UTU	UVA	ÅAU	Research institutes	Polytech-nics	National Archives Service of Finland	CSC	TOTAL
		15	7		3	27	4			**123**
		3	6		2	10	3		1	**40**
	1					1	2			**9**
							1			**1**
							1		1	**5**
		1							9	**14**
	2		6	1	1	11	14			**79**
	1		13			3				**22**
	1		11		1	3	1			**26**
	2		1							**10**
2			5		1	5	2			**36**
4		2	1			2	1	12	1	**38**
			2			26	2			**46**
			6			22				**48**
2	**4**	**15**	**31**	**1**	**6**	**73**	**26**		**1**	**324**
4	**3**	**6**	**27**		**2**	**37**	**5**	**12**	**11**	**173**

ranging from 101 to more than 1,000 users. For 17 per cent of the research infrastructures, the number of users was reported in terms of research groups rather than individuals. Missing from the table are the 22 research infrastructures described in the survey responses for which the number of users was not reported.

In the biological and medical sciences, the three Åbo Akademi University research infrastructures, with tens of users annually, are shared with the University of Turku.

Source: Academy of Finland research infrastructure survey 2013, list of research infrastructures described in the responses. Academy of Finland 2014 (available only in Finnish).

Universities have recruited a great many professors in recent years

In 2010–2013, a total of 1,219 professors were recruited by universities and government research institutes, of which 1,155 by universities and 64 by government research institutes. Fifty-three per cent of the positions were fixed-term. The proportion of non-Finnish academics recruited as professors was 14 per cent. The number of recruitments increased from 2010 to 2013.

RECRUITMENT OF PROFESSORS

Professors recruited in 2010–2013: 1,219 persons in total

- women 357, men 852 (gender reported for 1,209 recruitments)
- non-Finns 166 (nationality reported for 1,191 recruitments)
- annual recruitment
  - 2010: 210
  - 2011: 267
  - 2012: 350
  - 2013: 385
  - not known: 7

1,155 professors to universities

- women 339, men 807 (gender reported for 1,146 recruitments)
- non-Finns 160 (nationality reported for 1,127 recruitments)
- permanent 533, fixed-term 615, not known 7
- annual recruitment
  - 2010: 200
  - 2011: 252
  - 2012: 331
  - 2013: 366
  - not known: 6
- professors in total 2012: 2,603 full-time equivalents
  - women's FTEs 665, men's FTEs 1,938

64 professors to government research institutes

- women 18, men 45 (gender reported for 63 recruitments)
- non-Finns 6 (nationality reported for 64 recruitments)
- permanent 40, fixed-term 22, not known 2
- annual recruitment
  - 2010: 10
  - 2011: 15
  - 2012: 19
  - 2013: 19
  - not known: 1
- professors in total 2012: 244 persons
  - women 67, men 177

Sources: Academy of Finland survey of professors 2013; University data collection by the Ministry of Education, Science and Culture 2013.

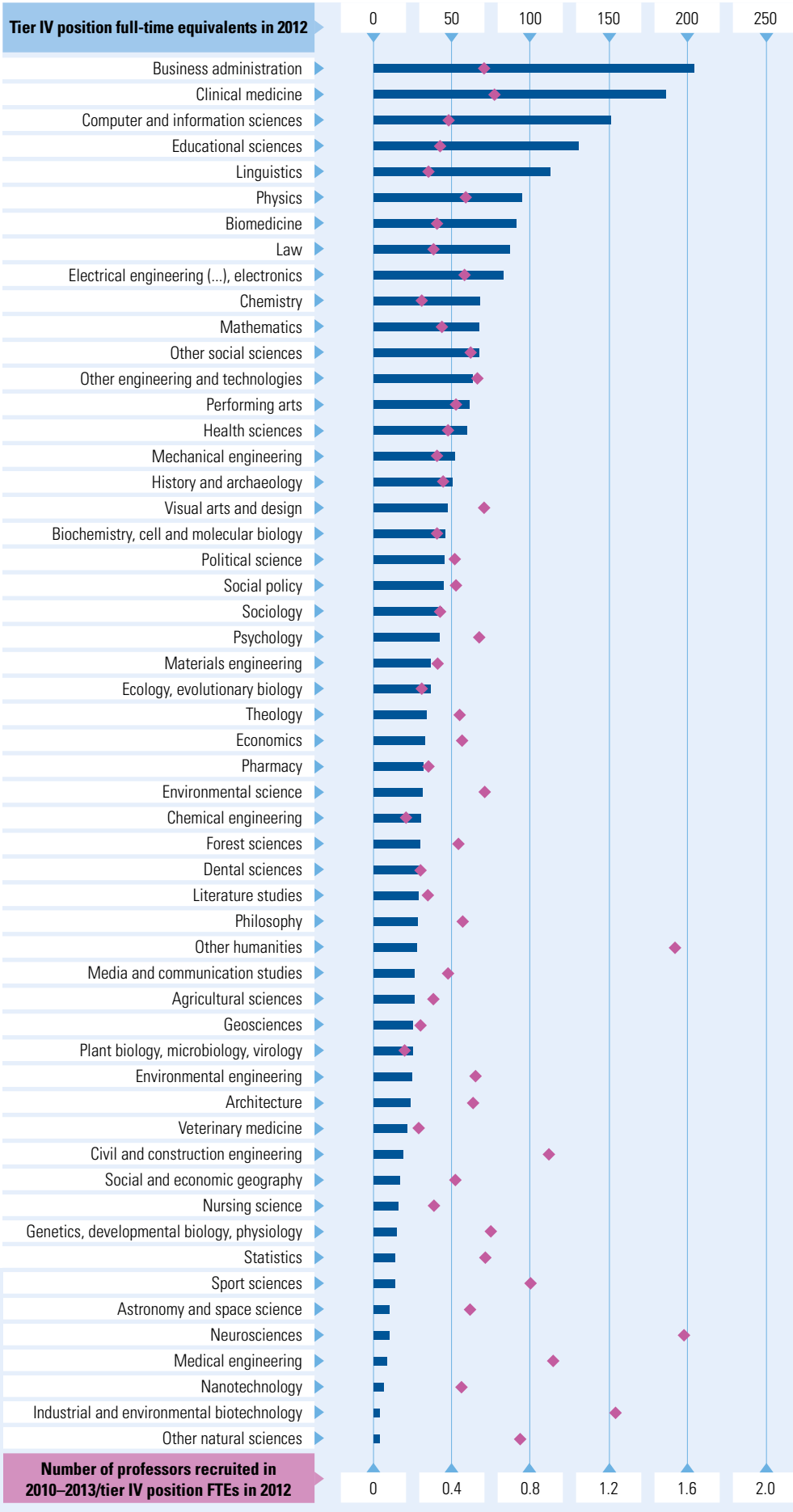
The breakdown of the 1,155 recruitments of professors by universities by discipline is shown in Figure 13. The proportion of the recruitments to the total number of professors in the discipline varies a good deal between disciplines.

FIGURE 13 (OPPOSITE PAGE)

By discipline, the number of professors recruited by universities in 2010–2013 in proportion to tier IV position full-time equivalents in 2012, and total tier IV position full-time equivalents in 2012.

The number of professors recruited in 2010–2013/tier IV position FTEs in 2012 is 0.44 for all disciplines. In disciplines in which the number of tier IV FTEs is small, the ratio is more arbitrary.

In eleven cases, no discipline was defined for the professors recruited; these have been omitted from the figure. Tier IV positions in the university research career model include those of professor, Academy Professor, research professor and research director.



Sources: Academy of Finland survey of professors 2013; University data collection by the Ministry of Education, Science and Culture 2013.

On the basis of the data, 45 per cent of professors recruited by universities had earned their doctoral degree in the same university to which they were recruited (Table 3).

The proportion of non-Finns of the university professors was small by international standards: just 7 per cent in 2012. Of the professors recruited, 14 per cent (160 persons) were non-Finns, indicating that their proportion of professors is growing.

TABLE 3

The number of professors recruited by universities in 2010–2013, place of taking doctoral degree, number of non-Finns by organisation and tier IV position full-time equivalents.

	AALTO	HANKEN	UH	UEF	JYU	ULA	LUT	OULU
Professors recruited in total	225	11	290	109	115	12	47	74
Of these, the number who took their doctoral degree at the same university	78	1	140	47	53	5	32	37
The proportion (%) who took their doctoral degree at the same university	35	9	48	43	46	42	68	50
Place of taking doctoral degree not reported	77	0	67	5	1	2	4	1
Total recruited non-Finns	54	4	39	9	18	1	1	12
Non-Finns who took their doctoral degree at the same university	5	1	3	1	0	0	0	1
Tier IV position FTEs	340	27	574	257	222	46	81	220

TABLE 4

Number of applicants per recruitment by university in 2010–2013.

	AALTO	HANKEN	UH	UEF	JYU	ULA	LUT	OULU
Number of recruitments in 2010–2013	225	11	290	109	115	12	47	74
Number of applicants in recruitment reported	130	2	134	42	38	8	5	52
Finnish applicants on average	12	8.5	6.5	4.2	8	2.6	2.4	3.8
Non-Finnish applicants on average	38.9	10.5	1.7	0.4	5.6	0.4	0.8	0.8
Finns, median value	9	8.5	5	3.5	6	2	2	3.5
Non-Finns, median value	21	10.5	0	0	1	0	1	0
Average number of applicants in total	50.9	19	8.2	4.5	13.5	3	3.2	4.5
Median value	30	19	6	3.5	7.5	3	4	3.5

In the recruitment of professors, universities most often used an open application process or an invitation procedure. There was an average of eleven applicants per each university application process (Table 4). The number of applicants was only reported for approximately half of the cases. As the universities' recruitment procedures differ in a variety of ways, the numbers of applicants are not directly comparable.

ARTS	TUT	UTA	UTU	UVA	ÅAU	TOTAL
31	43	68	95	19	16	**1,155**
7	27	27	45	6	9	**514**
23	63	40	47	46	56	**45**
14	0	3	12	6	0	**192**
4	5	2	3	3	5	**160**
0	3	0	1	1	0	**16**
41	147	208	276	49	116	**2,603**

The 225 professors recruited by Aalto University include 54 assistant professors. Other universities did not report assistant professors.

Sources: Academy of Finland survey of professors 2013; University data collection by the Ministry of Education, Science and Culture 2013.

ARTS	TUT	UTA	UTU	UVA	ÅAU	TOTAL
31	43	68	95	19	16	**1,155**
13	27	44	63	10	15	**583**
6.3	4.4	6.1	7.2	4.2	3.1	
11.4	1.3	0.1	0.9	0.7	1.9	
5	4	5	6	5	2	
1	1	0	0	0	1	
17.7	5.7	6.2	8.1	4.9	5.1	
8	5	5	6	5	4	

The application process at Aalto University is somewhat different from that of other universities. The 225 professors recruited by Aalto University include 54 assistant professors. Other universities did not report the application processes that were targeted at applicants at the assistant professor level. Moreover, some of the Aalto University recruitments involved the appointment of several professors in the same process. The numbers of applicants at different universities are, therefore, not comparable.

Source: Academy of Finland survey of professors 2013.

A total of 64 professors were recruited by government research institutes in 2010–2013 (Table 5), which amounted to 5.5 per cent of all professors recruited. The number of professors in government research institutes in 2012 was 244.

TABLE 5

The number of professors recruited by government research institutes in 2010–2013 and the number of professors in 2012 by organisation.

	Professors in 2012	Professors recruited in 2010–2013
Finnish Food Safety Authority Evira	10	2
Finnish Geodetic Institute	9	4
Geological Survey of Finland	5	2
Finnish Meteorological Institute	20	5
National Consumer Research Centre	3	1
Agrifood Research Finland	26	10
Finnish Forest Research Institute	19	6
Centre for Metrology and Accreditation	1	0
National Research Institute of Legal Policy	3	1
Finnish Game and Fisheries Research Institute	5	2
Finnish Environment Institute (SYKE)	21	15
Radiation and Nuclear Safety Authority	7	4
Technical Research Centre of Finland VTT	39	2
National Institute for Health and Welfare	53	3
Finnish Institute of Occupational Health	22	6
Government Institute for Economic Research	1	1
Government research institutes in total	**244**	**64**

Source: Academy of Finland survey of professors 2013.

Discussion: Science and research are changing – can Finland keep up?

Digitalisation, the considerable investments of emerging countries in science and the development of the global scientific community are all changing the way science is done and are intensifying competition.

Finland's success is built on expertise based on science, research and research-based higher education. Other countries are also pursuing success based on expertise. If our scientific community cannot renew itself and keep up with the other reference countries, this may result in intellectual and economic stagnation.

A great deal has happened in the Finnish research system in recent years. After the completion of the State of Scientific Research in Finland report for 2012, universities have developed their own strategic choices and recruited a considerable number of new professors. The Academy of Finland, Tekes, the activities of the Strategic Centres for Science, Technology and Innovation and the Research and Innovation Council have been evaluated. As a consequence of the resolution on Government research funding and the overall reform of government research institutes, government research institutes are being combined into increasingly larger entities, and a new Strategic Research Council has been set up at the Academy of Finland. In addition, the funding system for researcher training has been reformed, public data resources have been made accessible, open science and research practices have been promoted, and a national research infrastructure strategy and updated roadmap have been created. In order to support the research profiling of universities, part of their funding is being transferred to and will be allocated on a competitive basis via the Academy of Finland. Polytechnics have stepped up their research, development and innovation activities, and these RDI activities are taken into account in their new funding model. At the same time, public RDI funding is declining in real terms.

These reforms are aimed at creating more attractive research clusters, increasing collaboration and supporting strategic choices. The goal is higher quality and a greater impact in research. In an international comparison of the state of scientific research, however, it may be questioned whether the reforms are sufficient and whether they are being implemented quickly enough.

Science policy and strategic choices require the support of discipline- and organisation-specific knowledge. The State of Scientific Research in Finland 2014 report brings together a wider range of key statistics on the state of Finnish research in a summary and on the

Academy of Finland website than ever before. The results do not provide a comprehensive picture of the state of scientific research, but they do point to issues that should be given particular attention. The data compiled are intended to provide support for decision-making for the improvement of the preconditions for research. The characteristics of the indicators and the results of the analyses have been discussed above. This section presents some reflections based on these findings.

The level of scientific research in Finland is falling behind that of the other observed countries

The focus of the State of Scientific Research in Finland 2014 report is on the scientific impact of research, but only from the narrow perspective offered by citation indicators. The impact of research as a whole is a very complex phenomenon, and a comprehensive review requires other, complementary perspectives. There are many uncertainties involved in citation indicators. The findings of the citation indicators can be considered comparable when reviewed by country, however, and they provide a reasonably accurate picture of the level of scientific research in different countries.

Based on citation indicators, the level of scientific research in Finland is stable and above the world average, but in this millennium, we have clearly fallen behind many other OECD countries. The countries that were ahead of Finland in the early 2000s have maintained or increased their lead. In addition, compared to the situation in the early 2000s, Belgium, Australia, Germany, Ireland, Austria and Norway have overtaken Finland.

Another clear result of the bibliometric analyses is that publications created in international cooperation have a greater scientific impact than those written in Finland alone. This applies to all disciplines for which the top 10 index measuring scientific impact could be calculated. In many disciplines, the difference is considerable between publications written in Finland alone or in international collaboration. Internationalisation clearly pays off. However, internationalisation for its own sake is not enough; the right research partners must be found and enticed into collaboration. The leading figures in Finnish research have a highly international approach in their work and publication activities. As a whole, however, international collaboration could be enhanced.

The results of the bibliometric citation analyses for universities and government research institutes do not differ systematically from one another: there are disciplines in both organisational groups at a level clearly either above or below the international average. The results within one discipline are generally similar both in the university sector and in government research institutes.

Expertise and knowhow are among the key assets of a nation. It is a matter of concern that Finland is falling behind important reference countries. High-quality research has significant intrinsic value. In addition, research promotes employment, innovation and growth, all of which contribute to wellbeing. The result of the bibliometric reviews naturally raises the question of what should be done differently in Finland.

The science, innovation and education system is an integrated whole. The size and structure of the system varies a great deal between countries, as do its focus areas, career systems, funding opportunities, degree of internationalisation and historical factors. The effects of changes in the funding of the system or in other activities appear slowly. The university

reform carried out in early 2010, for instance, gave universities a more autonomous status and increased their operational freedom in many ways. The impact of this major reform can hardly be visible in the bibliometric results yet, as the most recent data are from 2012.

Cause-effect relationships are difficult to identify in analyses of science policy. Some features of the Finnish research system already recognised do emerge from the material in this report: its fragmentation and, in particular, the small unit size; somewhat inward-looking recruitment policies; and a low level of internationalisation. These three factors are strongly interlinked. Large, high-quality units are able to attract high-quality researchers and students. Successful recruitment, in turn, improves the quality of research and enables new initiatives.

Active recruitment of professors

Finnish universities have recruited a great many professors between 2010 and 2013. In a twenty-year time span, these decisions translate into choices worth 5–9 billion euros, at a conservative estimate, in the use of funding and the direction of research. Turnover has been high as the baby-boom generation has started to retire. The impact of these recruitments on the level of scientific research in Finland will not, however, be seen for another few years.

Recruitment practices vary greatly between universities. Tenure-track systems would seem to offer great potential for reaching a wider and more international group of applicants than with the more traditional career systems, where the number of applicants for professorships is rather small, at least in some fields. The deployment of recruitments to posts in different disciplines in universities has been driven by the immediate needs arising from retirements on the one hand, and the strategic choices made by universities on the other. There has been a turnover among the professors in government research institutes in 2010–2013 as well. The recruitment rate of professors by government research institutes is clearly lower than in universities, however.

National and international mobility remains limited. Approximately 45 per cent of the professors recruited have taken their doctoral degree at the university to which they were recruited. The number of non-Finnish professors is growing, but slowly.

The proportion of competitive funding varies across disciplines

The amount of competitive funding within a discipline can be regarded as a fairly accurate indicator of the quality of the research, even as a kind of performance indicator. The amount of funding from the European Research Council (ERC), for example, is generally regarded as a quality indicator. On the other hand, competitive funding, like all other funding, is also a measure of input.

The comparison of disciplines clearly shows that the amount of competitive funding in the field depends in a complex way on the quality of research, national policies and the traditions of funding. If the proportion of a specific discipline of Finnish competitive funding is clearly higher than its proportion of university core funding, the question arises whether this is due to the excellence of the discipline, the reluctance of universities to finance research in the discipline through core funding, the decisions by which the discipline has been exceptionally generously endowed with competitive funding, or perhaps something else.

Many small disciplines in many different universities

Compared to leading international universities, all of the discipline units in Finnish universities are small and unable to cover even all major research areas. The current size of disciplines in different universities is the result of implicit or explicit choices.

Reviewed by discipline (54 disciplines), the Finnish university institution is still rather fragmented. Twenty-seven of the disciplines are represented in six or more universities; in 21 of these, the median value of the professorial full-time equivalents was less than 10 in 2012. Measured with bibliometric methods, not one of these 27 disciplines was clearly above the world average in the period 2009–2012 (with a top 10 index value of at least 1.15).

The university disciplines having the greatest scientific impact are represented in no more than five universities. Eight disciplines had a top 10 index clearly above the world average in 2009–2012. Of these, agricultural sciences and veterinary medicine are represented in just one university, construction engineering in three, pharmacy and dental sciences in four, and clinical medicine, ecology, evolutionary biology, and materials engineering in five universities. The median value of the professorial full-time equivalents in ecology, evolutionary biology, materials engineering and construction engineering is small.

When reviewing the size of disciplines in different universities, it can be seen that very few bold choices have been made regarding focus. While many Finnish universities produce publications in several disciplines, they are major players on a national level in only a few of them. A similar result is also obtained on the basis of professorial full-time equivalents. This is a clear indication that choices between disciplines have seldom been made in the development of universities. When such a number of disciplines is hosted, none of them receive a great deal of resources.

Unit size is also of relevance to research infrastructures. The Academy of Finland research infrastructure survey of 2013 and Finland's Strategy and Roadmap for Research Infrastructures 2014–2020 reveal the large number of infrastructures and the investments required for their maintenance. The collaborative use of research infrastructures enables higher-quality work, and with the increase of remote access options, users may, in some cases, be far apart just as well as in the same location.

Recruitment and critical mass

Ultimately, the quality of scientific research is guaranteed by the researchers: even the best of conditions do not suffice alone. The appeal of research units is crucial to the recruitment of professors and students. From the perspective of a potential employee or student, it is important to know what kinds of research partners are working in the unit and what kind of research and teaching environment it has to offer. High-quality research, good partners, competent students and sound research infrastructures will attract new high-calibre researchers, who, in turn, will further improve the quality and impact of the unit.

The relationship between unit size and quality or appeal is in no way predetermined. The results of the citation analyses and success in obtaining competitive funding vary greatly across disciplines and organisations. The citation indicator values cannot reliably be calculated for discipline units with a small publication volume. Even a small unit can produce high-quality research with an impact: an individual researcher can produce high-quality

research alone and collaborate successfully with researchers working elsewhere. Small units are vulnerable, however. If a key person retires or changes jobs, this may significantly weaken the unit's expertise in research as well as in teaching.

Similarly, a large number of professors and other staff does not necessarily indicate the actual existence of a critical mass. For example, if a major university discipline employs ten professors with widely diverging research interests, their actual opportunities for collaboration may be limited. In such a case, the seemingly large size of the unit does not provide any particular advantage.

From the perspective of high-calibre research and top-quality teaching, however, it does help to have competent colleagues and potential research partners in the offices next door. A research partner does not necessarily have to be from the same discipline; phenomenon-based and multidisciplinary research may flourish best in an environment where researchers from different fields work side by side. If the research interests of ten professors in a major discipline even partly overlap, they can benefit greatly from each other.

In terms of education needs, this would probably mean that postgraduate training is not provided in all areas of the discipline. Master's-level education can be provided even if not all areas are represented among the employees of the department. In professional subjects, it is naturally important that training covers the entire scope of the subject. An attractive working and learning environment enables high-quality teaching, diverse research collaboration and successful recruitment of researchers and students. For a researcher, the size of the university is probably of less importance than the opportunities for collaboration offered by the researcher's immediate environment; this often strongly correlates with the size of the unit.

Recommendations

RECOMMENDATIONS

Key recommendation: towards higher-quality research through choices, exclusions and collaboration

- Universities should quickly develop their research profiles so as to focus on their key strengths and the new initiatives emerging from these.
- Division of work and collaboration is required, along with exclusions and long-term investment in the areas of strategic value to the respective organisation.
- Opportunities for collaboration between universities and government research institutes should be leveraged better.

Specific recommendations

- Choices are put into practice in recruitment: active and open recruitment is essential.
- Systematic and long-term international collaboration is needed.
- Strategic choices and collaboration must be increased in the construction and use of research infrastructures.
- The research funding system must strongly encourage making choices.
- Evidence-based planning and decision-making must be raised to a new level in science policy.

Key recommendation: towards higher-quality research through choices, exclusions and collaboration

Based on our review of the state of scientific research and its development in Finland, there has clearly been a need for the reforms initiated in recent years. Unfortunately, the state of research still appears fragmented, and we are falling further behind our reference countries. We cannot afford this.

Choices must be made. Significant reforms in the division of work and collaboration are required, along with exclusions and long-term investment in the areas of strategic value to the respective organisation. Bold choices must be made in the entire research system to support strengths and new initiatives.

Not everything can or should be done, but what we choose to do must be done well. The university reform gave universities the opportunity to formulate their own strategies and make their own choices, and they must now use this opportunity. Universities should quickly develop their research profiles so as to focus on their key strengths and the new initiatives emerging from these. The needs of education should be provided for by making use of opportunities for collaboration. The division of work and collaboration between universities and government research institutes should be further enhanced in order to raise the level of scientific research.

Specific recommendations

Choices are put into practice in recruitment: active and open recruitment is essential

Choices are implemented through recruitment. Although thematic choices and research profiling are important, excessively narrow definitions of teaching and research areas should be avoided in the recruitment of professors. A professor's career can span decades, and quality and the ability for renewal are of greater value than a perfect fit with the current teaching and research needs. It is crucial that the researchers recruited are capable of developing their research and teaching throughout their career in collaboration with the local, national and international research communities.

Recruitment processes need to be enhanced. New career systems, still partly under development, will allow for more flexible recruitment practices, and tenure-track career paths are internationally more attractive than the old system. The new opportunities should be actively exploited. As a rule, all professorships should be open to international application.

Systematic and long-term international collaboration is needed

The international co-publications of researchers working in Finland have a clearly greater scientific impact than publications written in Finland alone.

The time span in the development of science is long. Therefore, research organisations and researchers must emphasise systematic, long-term, strategic and high-quality international collaboration. Research organisations must update and implement their internationalisation plans so that the actions genuinely improve the quality of research. Research funders should actively support international research collaboration.

Strategic choices and collaboration must be increased in the construction and use of research infrastructures

Research infrastructures are an important element in modern research. There are a great many infrastructures, with growing funding needs in the future. The efficient and extensive use of infrastructures in research, teaching, service tasks and business activities produces the best return on the investments made in them.

A systematic approach to and cooperation in the acquisition and use of research infrastructures should be significantly increased. Research profiling choices should also provide clear guidance for the development of research infrastructures: before making a commitment to a specific research infrastructure or its upgrade, there must be a clear picture of the other decisions regarding funding, staff, university profiling and cooperation that have an impact on the utilisation of the infrastructure. In its funding decisions, the Academy of Finland should particularly support the funding of infrastructures that are built and used in a collaborative way.

The research funding system must strongly encourage making choices

Universities should quickly draw up plans to profile themselves around their strategically selected research strengths. In disciplines that provide researcher training, the research must be on a good international level and, in some areas, approach the highest international standards. Every university must have several research areas in which the research produced is at an internationally high level.

Funding solutions should provide support for boosting research excellence. The choices made by universities will have a direct impact on the funding to support the profiling of universities, to be launched in 2015. Choices that are aimed at improving quality should also have a significant impact on the distribution of the strategy funding in the university framework budget.

Evidence-based planning and decision-making must be raised to a new level in science policy

The assessments made by universities and government research institutes of their own research, the data collection of the Ministry of Education, Science and Culture, Statistics Finland data, bibliometric analyses, the State of Scientific Research in Finland report and international comparisons now provide a wealth of material for the decision-making of research organisations. More effective use should be made of the systematically collected and often publicly available data repositories in the development of science policy and research organisations. By combining the data, a multifaceted picture can be obtained of the current situation and, to some extent, of future trends.

Research organisations, research funding organisations and science policy decision-makers should employ a much wider knowledge base in order to critically review their own activities and develop their structures and operating methods. In addition, they must make strategic choices and exclusions to support areas of strength and new initiatives.

Material and methods

The data on funding are based on the data collection by Statistics Finland on research expenditure by funding source. In this summary, competitive funding is defined as research expenditure funded by the Academy of Finland, Tekes and the EU Framework Programme for Research and Innovation in 2012. The figures illustrate the use of funding in the year in question, not, for example, funding awarded by the Academy for a multi-year funding period. EU funding from the EU Framework Programme for Research and Innovation does not include funding granted by structural funds, for example.

Due to the changes in the data collection on competitive funding, the discipline-specific statistics can currently only be reviewed as a cross-section (year 2012). In the future, it will be possible to review time series as well.

The material describing teaching and research staff is based on the university data collection carried out by the Ministry of Education, Science and Culture, in which universities report their teaching and research staff as full-time equivalents by discipline and by research career tier.[9] For this summary, the FTEs of tier IV positions have been used. Tier IV positions in the university research career model include those of professor, Academy Professor, research professor and research director. This approach was chosen on the assumption that the tier IV position staff of a discipline are an indication of the scientific establishment of the discipline in the organisation.

Due to the changes in the data collection on teaching and research staff, the discipline-specific statistics on the organisations can currently only be reviewed as a cross-section (year 2012). In the future, it will be possible to review time series as well.

The material on the recruitment of professors is based on the data collected by the Academy of Finland from universities and government research institutes through surveys in 2013–2014. The data describe the recruitment of professors in 2010–2013 and the Finnish professoriate in universities and government research institutes. Professors were defined to be persons working in tier IV positions in universities and as research professors and research directors in government research institutes. The data were collected by discipline and by organisation.

The data on research infrastructures are based on the Research infrastructure survey carried out jointly by the Finnish Research Infrastructure Committee and the Academy of Finland's State of Scientific Research in Finland 2014 project in the autumn of 2013. The survey respondents included universities, government research institutes, polytechnics, the National Archives Service of Finland and CSC — IT Center for Science Ltd. Based on the results, the objective was to gain an overall picture of the research organisations' most important and strategically most significant research infrastructures to complement Finland's Strategy and Roadmap for Research Infrastructures 2014–2020[10]. The report on the research infrastructure survey responses and a list of the research infrastructures described in them were published in March 2014.[11]

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[9] *The material is available via the Vipunen statistical portal of the Ministry of Education, Science and Culture, and the National Board of Education in Finland (vipunen.csc.fi) (currently only in Finnish).*

[10] *Finland's Strategy and Roadmap for Research Infrastructures 2014–2020. Helsinki 2014.*

[11] *Research infrastructure survey 2013: Summary of survey responses. Academy of Finland. Helsinki 2014. (Available only in Finnish.)*

DATA SOURCES

Funding	Statistics Finland 2013.
Teaching and research staff	University data collection by the Ministry of Education, Science and Culture 2013. The data reported by the universities are available via the Vipunen statistical portal of the Ministry of Education, Science and Culture, and the National Board of Education in Finland (vipunen.csc.fi, in Finnish).
Recruitment of professors	Academy of Finland survey of professors 2013.
Research infrastructures	Academy of Finland research infrastructure survey 2013.
WoS publications and top 10 index	Thomson Reuters, Web-of-Science-based data (WoS), Bibliometric computing CSC, 2014. Certain data included herein are derived from the Science Citation Index Expanded, Social Science Citation Index and Arts & Humanities Citation Index, prepared by Thomson Reuters®, Philadelphia, Pennsylvania, USA, © Copyright Thomson Reuters ®, 2014. Results prepared for the Academy of Finland by CSC – IT Center for Science, Ltd (Yrjö Leino). © Copyright CSC – IT Center for Science, Ltd, 2014.
Publications reported by universities	Publication data collection by the Ministry of Education, Science and Culture in 2013 and 2014. Statistics compiled of the data reported by the universities are available in the Vipunen statistical portal of the Ministry of Education, Science and Culture, and the National Board of Education in Finland http://vipunen.csc.fi (in Finnish). Publication data can also be browsed in the JUULI publication data portal at www.juuli.fi > English.

Bibliometric analyses

The bibliometric citation analyses are based on scientific journal publications indexed in the Thomson Reuters Web of Science database and on the number of citations they have gained. The material used covers publications in the period 2000–2012; citations have been calculated on the basis of an open citation window. The analysis includes the publication types article, letter and review. The material in the citation database is not as appropriate for a detailed examination of publication activities in the social sciences or the humanities as in many other disciplines. Bibliometric computing was carried out by CSC. The addresses of Finnish research organisation publications have been checked.

This summary examines scientific impact as measured by bibliometric methods. The percentage of research with the greatest scientific impact can be analysed by examining the publications ranked in the top 10 per cent of the discipline in terms of the number of citations worldwide. The **top 10 index** selected as the citation indicator reflects how many more or fewer of the publications within the country or discipline are included in the 10 per cent of the most cited publications in the discipline in comparison with the international average.

Citation practices vary by discipline both in terms of how many earlier publications are generally cited, and how soon and for how long the publications are cited. As the material in the citation database is updated, the citation indicator values may change accordingly. The type of publication may also affect the citation accumulation. For these reasons, the number of citations gained by a publication is normalised in the calculation of bibliometric citation indicators by discipline (Thomson Reuters subject category), publication type (e.g. journal article and review article) and publication year. For example, publications produced in Finland are compared to the international level within the same discipline, the same publication type and the same publication year. Publications are fractionalised among countries, Finnish organisations and disciplines. The citation indicator is scaled so that the world average in each discipline is always one. One publication occurs in the calculation only once, and the co-publications of several organisations are not included in the calculation as multiple items.

Fractionalisation among countries means that a Finnish-Swedish publication, for instance, results in 0.5 publication points for both countries. If researchers from three Finnish universities have contributed to this publication, each organisation gains 1/3 x 0.5 publication points. Fractionalisation is also made among disciplines. One publication may be assigned 1–6 disciplines (subject categories) in accordance with the disciplines to which Thomson Reuters has classified the publication channel (scientific journal).[12]

The top 10 index is only shown when the fractionalised publication count of the discipline in the four-year period is at least 50. Despite this threshold, the top 10 index values of disciplines with small publication counts may vary a great deal between review periods. This does not, however, mean that the level of research in the discipline changes considerably over a few years.

In addition, the summary analyses the peer-reviewed scientific publications reported by the universities. Publication data by discipline are based on the annual university data collection by the Ministry of Education, Science and Culture. The publication count has not been fractionalised, so it differs from the publication count of the Web-of-Science-based data. In addition, the WoS does not cover all peer-reviewed publications.

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[12] *See also www.aka.fi/tieteentila > in English > Methods and classifications*

Appendices

Appendix 1. Key figures

Universities

Teaching and research staff

- In tier I–IV positions in 2012 in total: 16,763 FTEs
  - Proportion of non-Finns among staff in tier I–IV positions: 17% (2,798 FTEs)
- In tier IV positions in 2012: 2,603 FTEs
  - Proportion of non-Finns in tier IV positions: 7% (174 FTEs)
- Number of professors recruited in 2010–2013: 1,155 persons
  - Proportion of non-Finns of professors recruited: 14%

Doctoral degrees

- Doctoral degrees in 2012: 1,655 degrees
  - Proportion of doctoral degrees completed by non-Finns: 16% (270 degrees)

Funding

- Research expenditure in total: EUR 1.2 billion
  - Academy of Finland funding: EUR 251.3 million (Research expenditure funded by Academy of Finland in 2012)
  - Tekes funding: EUR 133.7 million
  - Funding from EU Framework Programme for Research and Innovation: EUR 46.7 million
  - EU funding in total: EUR 69.9 million

Government research institutes

Research staff

- Research staff in 2012 in total: 5,611 FTEs
- Number of professors in 2012: 244
  - Proportion of non-Finns among professors: 6%
- Number of professors recruited in 2010–2013: 64 persons
  - Proportion of non-Finns among professors recruited: 9%

Funding

- Research expenditure in total: EUR 536.9 million
  - Proportion of total funding: 54%
  - Academy of Finland funding: EUR 26.1 million (research expenditure funded by Academy of Finland in 2012)
  - Tekes funding: EUR 67.1 million
  - EU funding in total: EUR 46.0 million (Statistics on funding from the EU Framework Programme is not available in the same way as from universities.)

Sources: University data collection by the Ministry of Education, Science and Culture 2013; Statistics Finland 2013; Statistics Finland separate data on doctoral degrees 2014; Academy of Finland survey of professors 2013; Government research institutes' financial statements for 2012.

Appendix 2. University teaching and research staff by discipline

Discipline	Tier I–IV positions in total	Tier IV positions	Recruitment of professors in 2010–2013	Universities in which the discipline is represented (at least 1 FTE in tier IV positions)
	FTE	FTE	Persons	Number
NATURAL SCIENCES				
Mathematics	451	68	24	11
Statistics	72	14	8	7
Computer and information sciences	1,303	153	59	10
Physics	936	95	45	9
Astronomy and space science	72	10	5	3
Chemistry	597	68	17	9
BIOSCIENCES AND ENVIRONMENTAL SCIENCES				
Geosciences	127	25	6	7
Environmental science	228	32	18	7
Ecology, evolutionary biology	324	36	9	5
Biochemistry, cell and molecular biology	558	46	15	6
Plant biology, microbiology, virology	207	25	4	3
Genetics, developmental biology, physiology	139	15	9	4
Other natural sciences	39	4	3	2
ENGINEERING AND TECHNOLOGY				
Architecture	86	23	12	3
Civil and construction engineering	135	19	17	3
Electrical, automation and communications engineering, electronics (abbreviated as Electrical engineering (...), electronics)	748	83	39	6
Mechanical engineering	397	52	17	5
Chemical engineering	298	30	5	5
Materials engineering	333	36	12	5
Medical engineering	64	9	8	3
Environmental engineering	210	25	13	5
Industrial and environmental biotechnology	41	4	5	2
Nanotechnology	73	7	3	2
Other engineering and technologies	361	64	34	6

The national classification of disciplines includes the category "other disciplines" under all main fields of science. In the State of Scientific Research in Finland 2014 report, other medical sciences are combined with clinical medicine and other agricultural and forest sciences with agricultural sciences. Moreover, the applied discipline classification includes the category other natural sciences, other engineering and technologies, other social sciences and other humanities. Other engineering and technologies includes the food and beverage industries, while other social sciences includes multidisciplinary social sciences. However, it is possible that universities have made different interpretations of what part of full-time equivalents and research funding is recorded in the category "other disciplines". In the discipline of philosophy, full-time equivalents have been reported more than is actually the case.

MEDICAL AND HEALTH SCIENCES				
Biomedicine	691	92	30	6
Neurosciences	141	10	16	2
Clinical medicine	615	188	117	5
Dental sciences	113	30	7	4
Health sciences	283	60	23	6
Sport sciences	74	14	11	1
Nursing science	66	16	5	5
Pharmacy	272	32	9	4
AGRICULTURAL AND FOREST SCIENCES				
Agricultural sciences	151	26	8	1
Forest sciences	170	30	13	2
Veterinary medicine	154	22	5	1
SOCIAL SCIENCES				
Economics	130	33	15	10
Business administration	989	206	117	11
Law	315	88	27	8
Sociology	221	44	15	6
Social policy	196	45	19	6
Psychology	252	42	23	8
Educational sciences	985	132	45	9
Political science	219	46	19	8
Media and communication studies	137	26	10	7
Social and economic geography	78	17	7	6
Other social sciences	443	68	34	8
HUMANITIES				
Philosophy	139	28	13	5
Linguistics	849	114	32	8
Literature studies	147	29	8	6
Theatre, dance, music, other performing arts (abbreviated as Performing arts)	316	61	26	5
Visual arts and design	237	47	27	4
Theology	130	34	15	4
History and archaeology	252	51	18	7
Other humanities	155	28	43	6
Unspecified discipline (Only in staff statistics)	*44*	*1*	*11*	*1*
TOTAL	**16,763**	**2,603**	**1,155**	**297**

Examples of typical positions at different stages of research careers in universities:
Tier I: doctoral student, early-career researcher
Tier II: postdoctoral researcher
Tier III: university lecturer, Academy Research Fellow
Tier IV: professor, Academy Professor, research professor, research director

Sources: University data collection by the Ministry of Education, Science and Culture 2013; Academy of Finland survey of professors 2013.

Appendix 3. Abbreviations of the names of universities

Universities

AALTO	Aalto University
HANKEN	Hanken School of Economics
UH	University of Helsinki
UEF	University of Eastern Finland
JYU	University of Jyväskylä
ULA	University of Lapland
LUT	Lappeenranta University of Technology
OULU	University of Oulu
ARTS	University of the Arts Helsinki
TUT	Tampere University of Technology
UTA	University of Tampere
UTU	University of Turku
UVA	University of Vaasa
ÅAU	Åbo Akademi University

Hakaniemenranta 6 • PO Box 131, FI-00531 Helsinki
Tel. +358 295 335 000 • Fax +358 295 335 299

www.aka.fi/eng