PUBLICATIONS OF THE ACADEMY OF FINLAND 7/12

THE STATE OF SCIENTIFIC RESEARCH IN FINLAND 2012

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Edited by
Leena Treuthardt and Anu Nuutinen

ACADEMY OF FINLAND

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ISSN 0358-9153
ISBN 978-951-715-836-7 (print)
ISBN 978-951-715-837-4 (PDF)

Translated by David Kivinen
Page layout: DTPage Oy
Kopio Niini Oy, 2012

CONTENTS

DESCRIPTION

Publisher	Academy of Finland	Date 12 December 2012
Author(s)	Leena Treuthardt and Anu Nuutinen (eds)	
Name of publication	The State of Scientific Research in Finland 2012	
Abstract	The Academy of Finland has reviewed the state of scientific research in Finland at three-year intervals since 1997. The 2012 review explores the Finnish research system, different disciplines and the research thematically in the fields of the grand challenges. Part I of the report studies the changes in the operating environment and reviews the state and position of the Finnish research system in international comparison. The themes cover degree education and researcher training as a basis for research, the economic and human resources of research activities, and the output and impact of research. The selected reference countries are Austria, Denmark, Ireland, the Netherlands, Norway, Sweden and Switzerland. The higher education and research systems in these countries are roughly of the same size and sufficiently similar in terms of their operations to those in Finland. Part II includes discipline-specific analyses by the Academy of Finland's Research Councils of the development of the operating environment and the framework conditions for research. The Research Councils also identify the areas of strengths, weaknesses, opportunities and threats (SWOT) of research and make development proposals for the research fields within their remit. The Research Councils' reviews are based on the assessments of the state of different disciplines made by 42 discipline-specific task forces in autumn 2011.The task forces were attended by a total of 366 researchers. In recent years, several international actors have expressed their views of the role of research in solving the grand challenges facing society. As part of this work, the Academy's Board pinpointed six specific grand challenges in summer 2011: The Northern Climate and Environment; Sustainable Energy; Dialogue of Cultures, A Healthy Everyday for All; Knowledge and Know-how in the Media Society; and The Ageing Population and Individuals. Part III provides a thematic overview of the extent to which Academy-funded projects have dealt with themes associated with these grand challenges. Part III has been written by Professor Timo Aarrevaara and researchers Arto Aniluoto, Paula Ranne and Reetta Ruotsalainen from the Network for Higher Education and Innovation Research (HEINE) at the University of Helsinki. Part IV of the report includes the conclusions of the state of scientific research in Finland based on the reviews presented in Parts I–III. In addition, Part IV presents development proposals for further strengthening Finnish scientific research and the Finnish research system.	
Keywords	review, scientific research, discipline, operating environment, R&D, grand challenges	
Name and number of series	Publications of the Academy of Finland 7/12	
ISSN	0358-9153	
ISBN	Print 978-951-715-836-7	PDF 978-951-715-837-4
Number of pages	94	
Distributed by	Academy of Finland, POB 131, FI-00531 Helsinki, viestinta@aka.fi	
Published by	Academy of Finland	
Place and date of printing	Kopio Niini Oy, 2012	
Other information	www.aka.fi/publications www.aka.fi/tieteentila2012 > English	

FOREWORD

The Academy of Finland has reviewed the state of scientific research in the country once every three years since 1997. The present review aims to further improve the practical utility of the results for purposes of national science policy decision-making as well as for the development of universities, research institutes and the Academy itself. The review has been designed to reflect the specific needs of the Academy of Finland, the Ministry of Education and Culture and universities and research institutes in their respective development roles within the national research and innovation system.

The Steering Group for the 2012 review of the state of scientific research in Finland was chaired by the President of the Academy of Finland: Professor Markku Mattila from 12 April 2011 to 29 February 2012 and Professor Heikki Mannila from 1 March 2012. Chair of the Academy Board, Professor Arto Mustajoki served as Vice Chair of the Steering Group. The other Steering Group members were: Riitta Mustonen, Academy of Finland Vice President for Research; Professor Aila Lauha, Chair of the Research Council for Culture and Society; Professor Erkki Oja, Chair of the Research Council for Natural Sciences and Engineering; Professor Paavo Pelkonen, Chair of the Research Council for Biosciences and Environment; Professor Tuula Tamminen, Chair of the Research Council for Health; Director Leena Vestala (until 30 April 2011) and Counsellor of Education Erja Heikkinen (from 1 May 2011), Ministry of Education and Culture; Rector Lauri Lajunen, Universities Finland UNIFI; Director General Petteri Taalas, Finnish Meteorological Institute; and Director of Strategy Leena Treuthardt (responsible for the project), Academy of Finland. Secretary to the Steering Group was Assistant to the Management Heidi Varjus.

The members of the review secretariat were Senior Science Adviser Anu Nuutinen, Senior Science Counsel Jarmo Laine, Senior Science Adviser Annamaija Lehvo, Chief Adviser Ari Mikkelä (exchange of officials with Tekes), Science Adviser Janne Kurtakko, and university trainees Rita Koskinen, Aino Alatalo and Erkka Koski from the Management Support Unit; Senior Adviser Timo Kolu from the Biosciences and Environment Research Unit; Senior Science Adviser Hannele Kurki/Science Adviser Kaisa Vaahtera from the Culture and Society Research Unit; Science Adviser Samuli Hemming from the Natural Sciences and Engineering Research Unit; Information Specialist Maija Miettinen from the Communications Unit; and EU Affairs Manager Heikki Holopainen/Senior Science Adviser Eeva Ikonen from the International Relations Unit.

Also playing a major role in this review were the 366 researchers who contributed to the work of 42 discipline-specific task forces: this comprehensive and detailed examination of the state-of-the-art in Finnish scientific disciplines would not have been possible without their invaluable input.

The third chapter of this report is written by Professor Timo Aarrevaara and researchers Arto Aniluoto, Paula Ranne and Reetta Ruotsalainen from the University of Helsinki Network for Higher Education and Innovation Research (HEINE).

I should like to take this opportunity to thank all the contributors to this project for their tireless work. I hope that the review will support efforts to further strengthening and improving Finnish science and research.

The Steering Group has approved the review report at its meeting on 29 August 2012.

President *Heikki Mannila*

INTRODUCTION

The first chapter of this report describes the *changing operating environment of Finnish science and the state of the Finnish research system in an international context*. Researchers and research funding agencies are under ever mounting pressure to demonstrate their effectiveness and impact. Education and science policy objectives have been updated at both national and international level with a view to improving framework conditions for research and to enhancing the quality and impact of research. The pursuit of these objectives is contributing to shape the operating environment of research; examples are provided by the development of doctoral training programmes and the European Union's framework programmes for research. The operating environment of scientific research is also impacted by factors or phenomena that are not directly connected to the process of doing research; these include climate change, globalisation and healthcare. The first chapter examines national and international statistics as well as results from the VINDI project, a joint undertaking by Tekes, the Finnish Funding Agency for Technology and Innovation, the Academy of Finland, Statistics Finland and the Research and Innovation Council,[1] drawing on data about Bachelor's and Master's degrees and postgraduate training as a foundation for research, the economic and human resources of R&D as well as the performance and impact of research.

International comparisons are made in a group of eight countries: Austria, Denmark, Finland, Ireland, Netherlands, Norway, Sweden and Switzerland. The higher education and research systems in the reference countries are similar enough in both size and organisation to those in Finland for meaningful comparisons to be made.

International comparisons based on R&D statistics are not without problems. On the one hand, methods of compiling statistics are constantly changing, and on the other hand, many statistics are based on questionnaires that may yield inaccurate data. Nevertheless, despite its inaccuracies, the statistical material used in the State of Scientific Research in Finland 2012 review has been regarded as an indispensable aid. The main sources used are OECD and Eurostat statistics, which are compiled using carefully researched and established principles and followed by national statistical authorities.

In the second chapter of the report, *the Academy's four Research Councils offer their analyses of the development of the operating environment and framework conditions for research, describe the strengths, weaknesses, opportunities and threats (SWOT analysis) of research by discipline, and submit development proposals for their respective fields*. The reviews by the four Research Councils are based on assessments made by 366

[1] See Luoma Päivi, Raivio Tuomas, Tommila Paula, Lunabba Johan, Halme Kimmo, Viljamaa Kimmo and Lahtinen Henri 2011. Better results, more value: a framework for analysing the societal impact of research and innovation. Tekes Review 288/2011.

researchers in 42 discipline-specific task forces during autumn 2011 on the state-of-the-art in different disciplines.[2] The evaluation task forces produced an analysis of the strengths, weaknesses and short-term threats and opportunities in each discipline. The assessments of the fields of ecology and evolutionary biology, plant biology, chemistry and sport sciences are based on international discipline assessments published by the Academy of Finland in 2011–2012. The results for each discipline are published on the Academy's State of Scientific Research 2012 website (www.aka.fi/tieteentila2012 > English).

In recent years, many international stakeholders have offered their views on the role of scientific research in resolving the grand challenges facing humankind. As part of this broader movement, in summer 2011 the Board of the Academy of Finland identified six grand challenges facing humankind and society. These challenges – The Northern Climate and Environment, Sustainable Energy, Dialogue of Cultures, Knowledge and Know-how in the Media Society, A Healthy Everyday Life for All, and The Ageing Population and Individuals – will be a major focus of research policy over the next few years ahead. The third chapter of the report provides *an overview of the extent to which Academy-funded projects have addressed these grand challenge themes*.

Finally, the fourth chapter presents the *conclusions about the state of Finnish scientific research based on the analyses in the previous chapters and offers a number of development proposals aimed at strengthening Finnish science and the Finnish research system*.

[2] The discipline classification is primarily based on the 2010 national classification of scientific disciplines by Statistics Finland and the Ministry of Education and Culture.

1 THE FINNISH RESEARCH SYSTEM IN INTERNATIONAL COMPARISON

1.1 Finnish research in a changing operating environment

International trends in development

Science and science policy have seen many changes in recent years: the grand challenges faced by humankind are attracting increasing research focus, multidisciplinary and interdisciplinary collaboration has continued to gain in importance, the various forms of open science have achieved growing prominence, economic austerity has limited the availability of research funding in many countries, and new countries are emerging as significant forces in science. All these changes are reflected in the choices that are made in the area of science and research funding.

Climate change, other environmental and energy issues, health and wellbeing as well as cultural dialogue involve wide-ranging problems that can only be resolved through a joint and concerted effort. Innovative and groundbreaking science plays a pivotal role in addressing these issues. Science policy has also adopted a new way of ordering its priorities: the former focus on priority areas within individual disciplines is now complemented by an emphasis on content-driven objectives.

The setting of targets and objectives based on important broad research questions highlights the need for multidisciplinary and interdisciplinary research. Interdisciplinary collaboration, of course, is not in itself a novel approach. The erosion of boundaries between disciplines and novel research approaches require audacity and innovative spirit on the part of both researchers and research funding agencies.

In the past couple of years, the European Union has placed increasing emphasis on the need for openness in science. This quite broad requirement includes such things as free access to research data and publications and taking advantage of citizen science research. It is also believed that greater openness will contribute to accelerating the progress of science. Although these calls for openness are well justified, there are still many obstacles that derive from finances and attitudes. In Finland the issue has even received attention in the Government Programme, but inevitably it will take some time for a new way of thinking to take hold.

It is commonplace to regard the United States as the world's leading science nation, by a long shot. Indeed, it is and will continue to remain a significant force, but right now we are witnessing a rapid shift in power relations in the world of science. Forecasts are that by 2014, China will overtake the United States in the number of publications indexed in western databases. The global map of research is becoming multipolar. The European Union, the United States and the Nordic countries will remain important science partners for Finland in the future, but at the same time the role of China and other BRIC countries (Brazil, Russia and India) is set to grow. With the increasing opportunities for research collaboration, it will also be necessary to make more conscious choices about which countries are the best partners in each field of research.

The founding of the European Research Council (ERC) in 2007 marked a significant step in the European research environment. Both researchers and politicians have been impressed by the ERC's consistent and rigorous emphasis on quality in deciding where to allocate its funding. Already it is clear that the ERC will significantly improve the prospects of the European research succeeding in the global competition. At the same time, though, the ERC reflects a collision of mutually contradictory objectives. On the one hand, there is a need for research funding based on specific research themes, but on the other hand, there must also be scope for investigator-driven basic research that covers all the various disciplines, provided that it meets the high international quality standards. Research policy is largely about striking a balance between these two principles.

The removal of hindrances and obstacles to the development of the European Research Area (ERA) is also regarded as a necessary condition for European growth.

With the exception of some emerging economies, the economic situation is increasingly precarious throughout the world. In some eurocrisis countries such as Portugal and Spain, massive cuts to central government expenditure have also profoundly affected the availability of research funding. However, there are also countries that despite the economic austerity have been keen to continue to invest in science and research. One example is Sweden. In Finland, cutbacks in central government finances have also affected universities and research funding agencies.

Changes in the Finnish science system

In 2012, universities were the single largest recipient of central government R&D funding, accounting for 29% or 583.3 million euros of total spending.[3] Tekes received 28% (552.4 million euros), the Academy of Finland 16% (320.7 million euros) and government research institutes 15% (306.3 million euros). University hospitals received less than 2% (36 million euros) of central government R&D funding. The proportions going to universities and the Academy of Finland have increased by a few percentage points in the 2000s, while those going to Tekes, government research institutes and university hospitals have declined.[4]

In recent years, the single most significant change in the Finnish research system has been the university reform that took effect from the beginning of 2010. Formerly organised as accounting offices, universities were reconstituted as independent institutions under public law or the Foundations Act. This gave them greater autonomy. The bulk of university funding still comes from the state budget in the form of allocations through the Ministry of Education and Culture. Given their increased autonomy, universities are now in the position to pursue a more active

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3 The figures here are based on data compiled by Statistics Finland, e.g. through questionnaires to central government agencies, ministries and government research institutes. In addition to receiving public funding, universities finance their research activities from international sources, from business enterprises and other domestic funding sources.

4 Tilastokeskus 2012. Suomen virallinen tilasto: Tutkimus- ja kehittämisrahoitus valtion talousarviossa 2012 [verkkojulkaisu]. Tiede, teknologia ja tietoyhteiskunta 2012. Helsinki. Accessed from www.stat.fi/til/tkker/2012/tkker_2012_2012-02-24_tie_001_fi.html, August 2012. [In Finnish only]

recruitment policy, for instance. At the same time, university boards and rectors gained a stronger position. The university reform saw the number of universities in the country reduced as a result of the merger of the Helsinki University of Technology, the Helsinki School of Economics and the University of Industrial Art and Design Helsinki into Aalto University; the merger of the University of Kuopio and the University of Joensuu into the University of Eastern Finland; and the merger of the University of Turku and the Turku School of Economics into the new University of Turku.[5] Following the entry into force of the new University Act, and in some instances while the legislation was still being drafted, many universities restructured their organisation, which typically led to larger administrative units.

According to a report put out by the Ministry of Education and Culture on the impacts of the new University Act,[6] those impacts are mainly seen in universities' strategic governance and management. Steps have also been taken to strengthen universities' financial management and to improve stakeholder collaboration. It is still too early to make a final assessment of the impacts of the new University Act on the quality of research and education, but what can be said is that university units in Finland are still comparatively small if considered in view of the goals of internationally competitive research and high-level education. The reprofiling of universities and their new division of labour are still to take final shape.

The criteria for the allocation of budget funding to universities will be revised from the beginning of 2013 based on a new funding model. This new model will introduce a new set of funding criteria for the measurement of the quality and impact of research and education. International element will also figure more prominently among the funding criteria.[7] The new University Act and new funding model will also imply a restructuring of the governance relationship between the Ministry of Education and Culture and universities.

The Act on the Academy of Finland was revised at the same time as the University Act. Some of the most important revisions included changes in the composition of the Academy Board and changes in the status of Academy Professors and Academy Research Fellows, whose contract of employment is no longer with the Academy of Finland but with the organisation where they are doing their research. It seems that the conditions for doing science have not been affected by these changes, either for Academy Professors or for Academy Research Fellows.

The system for funding doctoral training has changed considerably. In the previous system, graduate schools were funded by the Ministry of Education and Culture based on evaluations and recommendations by the Academy of Finland. This top-down system has now been discarded and universities themselves have assumed increasing responsibility for the provision

5 Opetus- ja kulttuuriministeriö 2011. Korkeakoulut 2011 – yliopistot ja ammattikorkeakoulut. Opetus- ja kulttuuriministeriön julkaisuja 2011:10. [In Finnish only]

6 Opetus- ja kulttuuriministeriö 2012. Yliopistolakiuudistuksen vaikutusten arviointi. Opetus- ja kulttuuriministeriön julkaisuja 2012:21. [In Finnish only]

7 Opetus- ja kulttuuriministeriö 2011. Laadukas, kansainvälinen, profiloitunut ja vaikuttava yliopisto – ehdotus yliopistojen rahoitusmalliksi vuodesta 2013 alkaen. Opetus- ja kulttuuriministeriön työryhmämuistioita ja selvityksiä 2011:26. [In Finnish only]

of doctoral training. Indeed, most universities now have their own doctoral programmes that are intended to provide more rigorous and systematic postgraduate training. Created in the mid-1990s within a very short space of time, the graduate school system significantly improved the standard of postgraduate training in Finland. The system has now been upgraded, and the results will be seen in a few years' time.

From the beginning of 2009, the Academy of Finland and universities introduced the full cost model in all jointly funded projects. This had two immediate consequences: first, the amount of funding awarded to individual projects increased and second, the number of projects receiving funding decreased. The full cost model has met with much criticism in the research community. Some of its worst problems with its initial implementation have now been rectified, but continued monitoring is needed to see whether the system really benefits the advancement of Finnish science and research.

The most fundamental condition for high-level research is an up-to-date research infrastructure. Following a decision by the Ministry of Education and Culture, the administration of national research infrastructure policy was delegated to the Academy of Finland in 2011. The Academy proceeded to appoint a broad-based expert committee that was charged with updating the national roadmap for research infrastructures and coordinating national preparations for European research infrastructure work. Since 2012, funds have been allocated directly from the state budget for purposes of research infrastructure development.

The development of the Finnish science system is evaluated at regular intervals by international experts. An international evaluation of Tekes, the Finnish Funding Agency for Technology and Innovation, was published in June 2012, and an international evaluation of the Academy of Finland will be completed in 2013. The purpose is to provide a broad overview of how the Academy has performed its mission and how it needs to adjust and adapt to the changing operating environment.

Government research institutes have an important role to play in the Finnish research system. In addition to their official functions, research institutes engage in a diverse range of research activities. An expert group appointed by the Ministry of Education and Culture at the initiative of the Research and Innovation Council to address the need to overhaul the sectoral research system proposed in September 2012 that research resources should be pooled to support policy-making and to provide a sound research foundation on which to address the major challenges facing society. The group also recommended that steps be taken to promote the functional and structural integration of government research institutes and so to advance interdisciplinary and multidisciplinary research. In the group's view, universities and research institutes should be pooled to form clusters of research, innovation and higher education and major drivers of research that will support the development of society.

The Research and Innovation Council occupies a central role in national science and innovation policy-making. In recent years tensions between research and innovation policy have subsided. The critical importance of research to innovations is widely recognised, as is the fact that research of international standards and high-quality education and innovation are not rival or mutually exclusive to each other but on the contrary can significantly support each other. Strategic Centres of Science, Technology and Innovation are a comparatively new instrument designed to generate and strengthen internationally competitive science and technology clusters and centres of excellence. A key premise of Strategic Centres is that scientific research and innovation are recognised as mutually supportive national resources and as conditions for welfare and wellbeing. The Strategic Centre network will be evaluated by the end of 2012.

1.2 Extent and level of education

General education and Bachelor's and Master's degree programmes

High-quality general education and Bachelor's and Master's degree programmes have a significant role in maintaining and developing the nation's knowledge base and skills. They also lay the foundation for high-quality postgraduate training and for the progress of science. Finnish society cannot be based on the import of skills and competencies.

Student achievement in comprehensive school and the quality of comprehensive education are measured in international PISA surveys. Results from the 2003, 2006 and 2009 surveys indicate that Finnish schoolchildren aged 15 had by far the strongest reading, mathematics and science skills among all the eight countries included in this comparison (Austria, Denmark, Finland, Ireland, Netherlands, Norway, Sweden and Switzerland)[8] (Fig. 1). Finland's results for reading skills have declined somewhat during the 2000s. The proportion of weak readers has increased to some extent, while that of excellent readers has decreased. There has also been an increase in interschool variation in student achievement.[9] The same declining trend for reading skills is also seen in the Netherlands, Sweden, Ireland and Austria. The second and third strongest readers in the 2009 PISA survey were from the Netherlands and Norway. The top three performers in mathematics and science were Finland, Switzerland and the Netherlands.

In Finland, the number of university students has increased sharply in recent decades. Compared to just 20,000 in the early 1960s, the figure had climbed to around 160,000 by the early 2000s.[10] The numbers continued to rise until 2006, peaking at over 176,000, but since then they have been edging down.[11]

In 2000–2010, Finland had the largest proportion of tertiary educated people aged 25–64 (Fig. 2). In 2010, the figure for Finland was 38%, compared to 37% in Ireland and 37% in Norway. The two countries that have seen the sharpest rise in educational level are Ireland and Switzerland: from 2000 to 2010, the proportion of tertiary educated people rose

[8] The higher education and research systems in the reference countries are similar enough in both size and organisation to those in Finland for meaningful comparisons to be made.

[9] Sulkunen Sari ja Välijärvi Jouni (toim.) 2012. PISA09. Kestääkö osaamisen pohja? Opetus- ja kulttuuriministeriön julkaisuja 2012:12. [In Finnish only]

[10] Pekkala Sari, Intonen Nina ja Järviö Maija-Liisa 2005. Suomen koulutusmenojen kehitys 1900-luvulla ja tulevaisuudessa. VATT-keskustelualoitteita 365. [In Finnish only]

[11] KOTA database. Ministry of Education and Culture.

Figure 1. PISA success (mean score for each performance indicator) in reading, mathematics and science in 2003, 2006 and 2009

Source: OECD, for 2003 and 2006 PISA Country Profiles database, for 2009 PISA 2009 database.

NB: The countries are listed in the order of their 2009 ranking on each performance indicator.

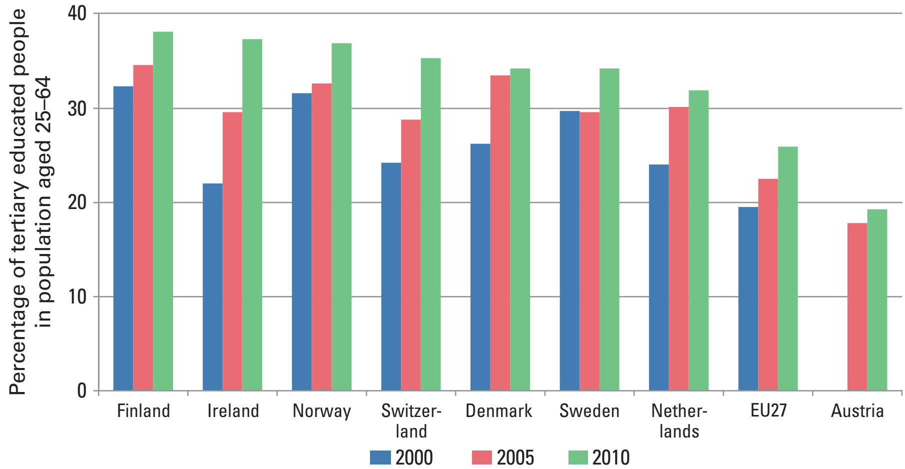

Figure 2. Percentage of tertiary educated people in population aged 25–64 in 2000, 2005 and 2010

Source: Eurostat Statistical database, Education, May 2012.

NB: The countries are listed in the order of the 2010 percentage of tertiary educated people. Data for Austria in 2000 not available.

by as much as 15 percentage points in Ireland and by 11 percentage points in Switzerland. These changes are so dramatic that they may well be explained by changes in statistical practices.

The EU target is that by 2020, at least 40% of the population aged 30–34 should have a tertiary education. The corresponding national target for Finland is 42%.[12] According to Eurostat figures, this target was in fact reached as early as 2003. In 2011, the figure recorded for the Finnish population aged 30–34 was 46%.[13]

In Finland the proportion of tertiary educated women in the population aged 25–64 was 44%, the highest figure for all the eight countries in this comparison in 2010 (Fig. 3). The corresponding proportion for men was 32%. The proportion of tertiary educated women was second highest in Norway and Ireland, 41% in both. The figures for men were higher than for women in three countries, viz. Switzerland (42%), the Netherlands (34%) and Austria (21%).

[12] European Commission 2011. Europe 2020 targets. http://ec.europa.eu/europe2020/pdf/targets_en.pdf.

[13] Eurostat Statistical database, Education, August 2012.

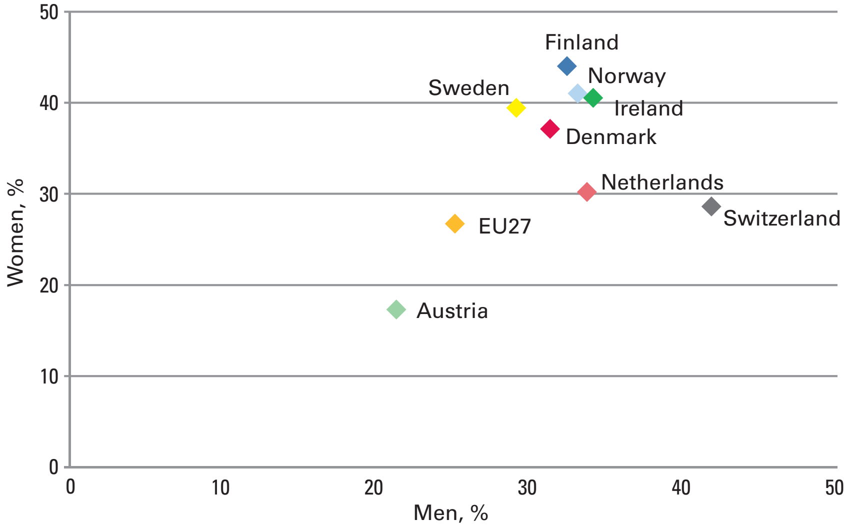

Figure 3. Percentage of tertiary educated women and men in population aged 25–64 in 2010

Source: Eurostat Statistical database, Education, May 2012.

Doctoral training

In 2009, the number of PhD degrees awarded in Finland per one million population was 308 (Table 1). In this comparison Finland ranked second after Switzerland; Sweden came third. The changes in the number of PhD degrees awarded have been greatest in Ireland (61%), Denmark (44%) and Norway (36%). Ireland has made increased funding available for postgraduate students in order to increase the number of PhDs in the country. In Denmark and Norway, the sharp relative increase in the number of PhD graduates is explained in part by the high wages paid to junior researchers, which has helped attract growing numbers of foreign postgraduate students into these countries. Norway, however, will struggle to retain this international researcher potential in the long term.[14]

In all the Nordic countries the median age of PhD graduates in 2000–2010 ranged between 33 and 36 years. In Denmark the average age at PhD graduation is slightly lower than in the other Nordic countries.[15]

In Finland, PhD graduates are more employable than people with a Master's degree, although the PhD unemployment rate has increased during the 2000s (Fig. 4). In 2009, 2.6% of the PhD workforce were unemployed. At the same time, the unemployment rate among Master's graduates was 4.7%. PhD graduates in the medical and health sciences fields are the most employable: the unemployment rate in this group was less than 1%.[16]

[14] Viljamaa Kimmo, Lehenkari Janne, Lemola Tarmo ja Tuominen Terhi 2010. Tutkimuspolitiikan välineet ja käytännöt – Viiden maan vertailu. Suomen Akatemian julkaisuja 2/10. [In Finnish only]

[15] NIFU (Nordic Institute for Studies in Innovation, Research and Education) R&D Statistics Bank / NORBAL, June 2012.

[16] Statistics Finland 2012. Official Statistics of Finland (OSF): Human resources of science and technology in 2010 [e-publication]. Science, technology and information society 2012. Helsinki. Accessed from www.stat.fi/til/tthv/2010/tthv_2010_2012-03-22_tie_001_en.html, June 2012.

Table 1. Number of PhD degrees awarded per one million population and percentage of degrees completed by women in 2004 and 2009

Countries	No. of PhD degrees per one million population	Percentage of PhD degrees awarded to women	No. of PhD degrees per one million population	Percentage of PhD degrees awarded to women	Change in no. of PhD degrees per one million population (%)
	2004	2004	2009	2009	2004–2009
Switzerland	375	38	442	42	18
Finland	**268**	**45**	**308**	**52**	**15**
Sweden	306	45	304	50	–1
Austria	299	40	273	43	–9
Ireland	169	46	272	46	61
Norway	165	40	224	46	36
Denmark	146	36	211	43	44
Netherlands	165	39	200	42	21

Source: Eurostat Statistical database, Science and technology, May 2012. Population data source OECD Statistical database, Country statistical profiles, June 2012.

NB: The countries are listed in the order of the 2009 number of PhD degrees per one million population. Data only available from 2004 onwards.

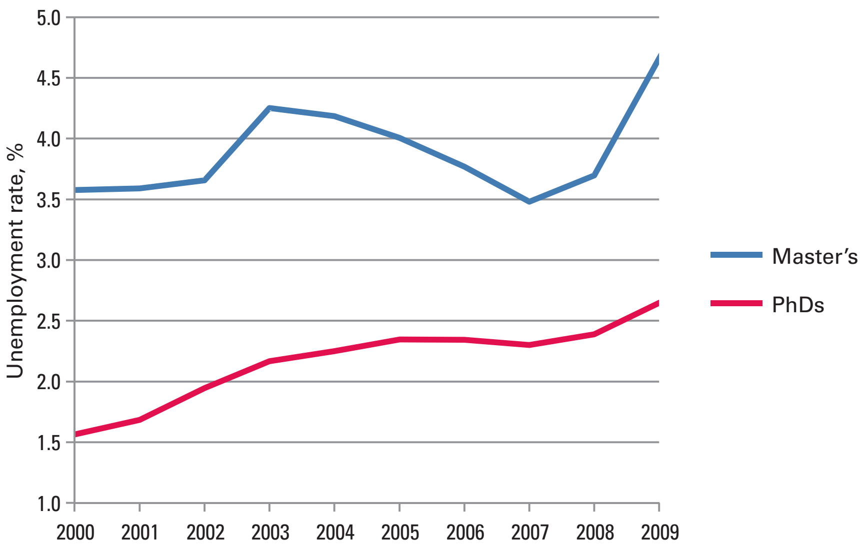

Figure 4. Unemployment rate among PhD and Master's graduates in Finland in 2000–2009

Source: Statistics Finland, Human resources of science and technology, database tables, June 2012.

NB: The PhD unemployment rate refers to the proportion of unemployed PhDs as a percentage of all PhDs in the labour force.

PhDs are primarily employed in universities (37% of all PhDs in 2009, Fig. 5). The second most important route of PhD employment is the health and social services sector (15%). The placement of recent PhD graduates differs only little from the placement of all PhDs in different sectors.

In Finland, non-native students accounted for 202 (13%) of all 1,518 PhD degrees awarded in 2010 (Table 2). In Denmark and

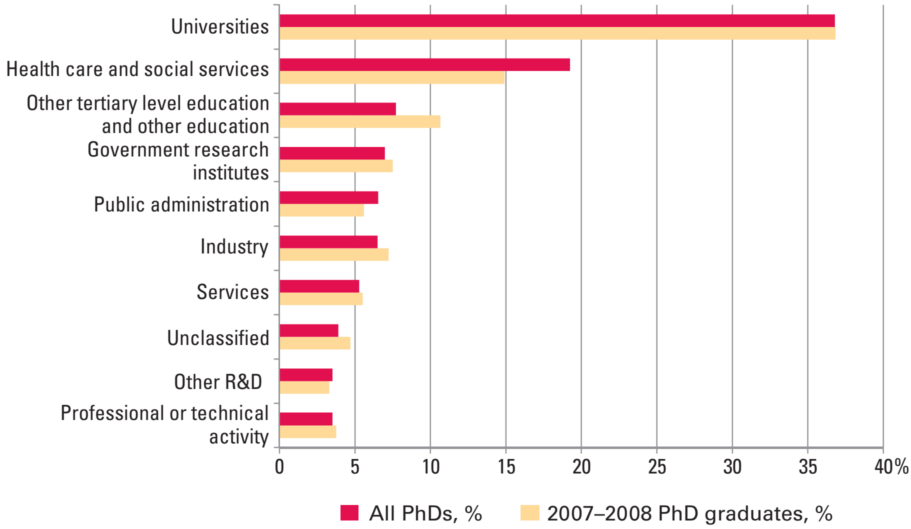

Figure 5. PhD placement in Finland by sector (proportion of all PhDs and proportion of PhDs who graduated in 2007–2008, as a percentage of employed PhDs) in 2009

Source: Statistics Finland 2011, separate dataset on PhD placement commissioned by the Academy of Finland.

NB: Standard Industrial Classification 2008. Unclassified refers to the proportion of PhDs for whom no placement data are available.

Table 2. Number of PhD degrees awarded to non-native students and percentage of all PhD degrees in four Nordic countries in 2008 and 2010

Countries	PhD degrees awarded to non-native students	Percentage of PhD degrees awarded to non-native students	PhD degrees awarded to non-native students	Percentage of PhD degrees awarded to non-native students
	2008	2008	2010	2010
Denmark	207	18	503	29
Norway	308	25	326	28
Sweden	481	17	461	18
Finland	**176**	**12**	**202**	**13**

Source: NIFU (Nordic Institute for Studies in Innovation, Research and Education) R&D Statistics Bank/ NORBAL, June 2012.

NB: It is possible that the data for Sweden and Denmark are underrepresentative because information on the nationalities of all PhD graduates is not available for either of these countries. If it is assumed that all the PhDs whose nationalities are unknown are non-native, then the 2010 figures for PhDs completed by non-native students in Denmark and Sweden would have been 36% and 22%, respectively. Figures are available from 2008 onwards. The source material does not cover Austria, Ireland, the Netherlands and Switzerland.

Norway, non-native students accounted for almost one-third of all PhD degrees completed. In Sweden, too, non-native students accounted for a larger proportion (18%) of all PhD degrees than in Finland.

In Finland, the largest category of non-native PhD graduates in 2000–2010 consisted of students who based on their nationality came from other European countries (Fig. 6). The proportion of Asian students has increased somewhat during the 2000s.

During the 2000s, the number of non-native employed PhDs has increased in relative terms more sharply than the number of Finnish employed PhDs (Fig. 7). In 2009, the number of non-native employed PhDs was 171% higher than in 2000, while the corresponding increase for

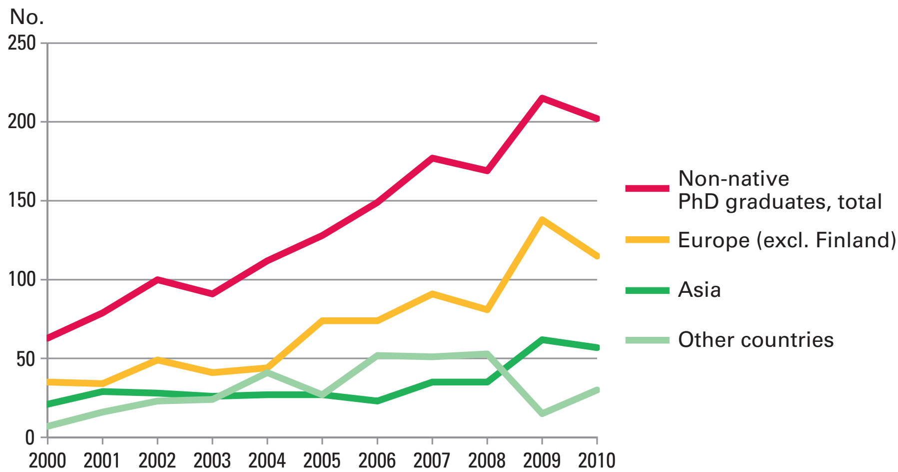

Figure 6. Number of PhD degrees awarded to non-native students at Finnish universities by continent of origin in 2000–2010

Source: Statistics Finland 2012, separate dataset commissioned by the Academy of Finland.

NB: The category 'other countries' also includes PhD degrees awarded to students whose nationality is unknown.

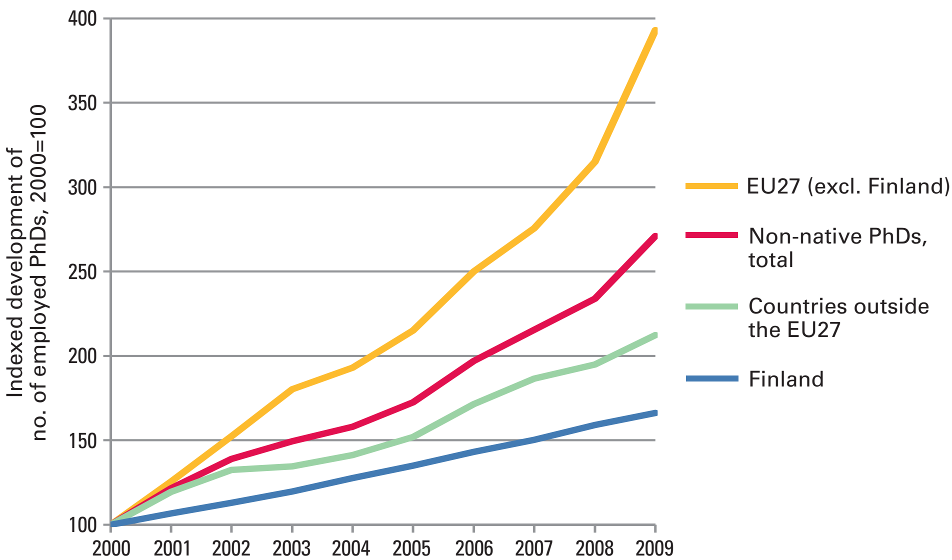

Figure 7. Indexed development (2000=100) of the number of employed PhDs in Finland by nationality in 2000–2009

Source: Statistics Finland, Human resources of science and technology, database tables, June 2012.

NB: The number of employed PhDs includes all employed people with a PhD degree, i.e. not only those in R&D positions.

Finnish PhDs was just 66%. In 2009, the number of non-native employed PhDs was 718, and the number of Finnish employed PhDs 19,321. In relative terms, the sharpest increase over the period under review has been recorded for the number of PhDs coming from EU27 countries.

1.3 Research funding

Overview of R&D expenditure

In 2010, Finland's R&D investment[17] totalled some 7 billion euros. One-quarter (26%) of this or 1.8 billion euros was covered from public funds. Domestic business corporations accounted for 4.6 billion euros, representing 66% of the total. Foreign sources accounted for 7% or 0.48 billion euros.

Finland has one of the world's highest R&D-to-GDP ratios. R&D expenditure as a proportion of GDP provides one angle on the intensity of research activities in society and is the most traditional and widely used indicator of R&D activity. However, in many research-intensive countries, the bulk of R&D activities are concentrated in the business enterprise sector, and therefore the indicator provides a more accurate measure of product development rather than of basic research conducted at universities. The Finnish Government Programme (22 June 2011) has set a 4% of GDP target for research, development and innovation activities. The current Finnish figure of 3.73% (2011) is considerably higher than the average for OECD countries, although the figure has dropped back since 2010[18] and seems to be continuing on a downward track.

In 2010, the world's highest R&D-to-GDP ratios were recorded for Israel (4.40%), Finland (3.87%) and South Korea (3.74%).[19] Among the eight countries included in the current comparison, the sharpest increase is seen for Austria (Fig. 8). Sweden and the Netherlands are the only countries where R&D expenditure as a proportion of GDP was lower in 2010 than in the early 2000s.

In 2010, the ratio of Finnish public R&D-to-GDP was 0.99%. The corresponding ratio for Sweden was the same (data for 2009). The highest figure among the eight countries included in the comparison was recorded for Austria (1.07%). With the exception of Ireland, the figures for all countries in this comparison are higher than the 2009 averages for EU27 and OECD countries. All the countries included in the comparison except for the Netherlands invested more public funds in R&D as a proportion of GDP towards the end of the period under review (2009/2010) than in the early 2000s.

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17 "Research and development activity (R&D) is understood as systematic work undertaken to increase the stock of knowledge and use it to devise new applications. The defining criterion is that the purpose of the activity should be the presence of an appreciable element of novelty. Research and development activity includes basic research, applied research and experimental development." Source: Statistics Finland 2012. Official Statistics of Finland (OSF): Research and development [e-publication]. Helsinki. Accessed from www.stat.fi/til/tkke/kas_en.html, June 2012.

18 GDP 2011 is based on the Ministry of Finance's forecast. Source: Tilastokeskus 2011. Suomen virallinen tilasto: Tutkimus- ja kehittämistoiminta 2010 [verkkojulkaisu]. Tiede, teknologia ja tietoyhteiskunta 2011. Helsinki. Accessed from www.stat.fi/til/tkke/2010/tkke_2010_2011-10-27_tie_001_fi.html, June 2012. [In Finnish only]

19 OECD Main Science and Technology Indicators MSTI 2011/2 dataset.

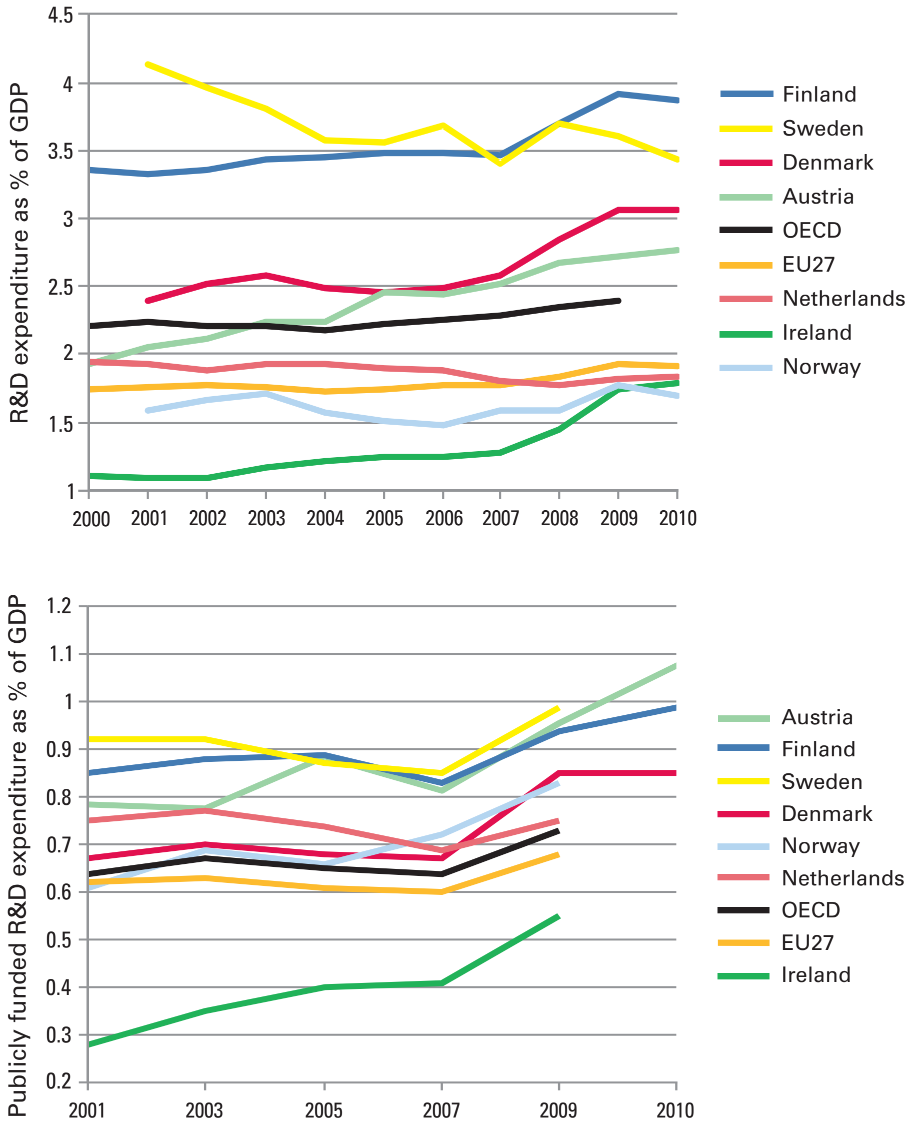

Figure 8. R&D expenditure as a percentage of GDP in 2000–2010 and publicly funded R&D expenditure as a percentage of GDP in 2001–2009/2010

Source: OECD Main Science and Technology Indicators MSTI 2011/2 dataset.

NB: The countries are listed in the order of their ranking in the latest dataset available. The most recent data available from 2009 or 2010. Swedish figures for the ratio of R&D expenditure to GDP are not available for 2002, and therefore the figure presented is the average of 2001 and 2003. Publicly funded R&D expenditure as a percentage of GDP is only given for 2001 onwards because data for 2000 are missing for many countries. Since there are only a few countries for which data are available for each year, the Figure is primarily based on data from every other year. Switzerland is excluded from the comparison because of the scarcity of available statistics. In 2008, Switzerland's R&D expenditure as a percentage of GDP was 2.99% and publicly funded R&D expenditure as a percentage of GDP was 0.68%.

In 2010, the two countries with the highest absolute R&D investment figures were the Netherlands (12.8 billion dollars[20]) and Sweden (12.5 billion dollars). Finland's R&D expenditure was 7.6 billion dollars (around 7.0 billion euros). Relative to population, Finland had the highest R&D expenditure per capita figure at around 1,400 dollars in 2010.[21]

Public organisations account for more than half of all R&D activities in only one of the countries in this comparison, i.e. the Netherlands (Fig. 9). In the Netherlands, the higher education sector accounted for 41% of total R&D expenditure and government-sector organisations for 12% in 2010. In Finland, the higher education sector's proportion at 20% (1.4 billion euros) was the smallest of all the countries included in the comparison. Government-sector research accounted for 10% (0.7 billion euros) in Finland. Norway had the

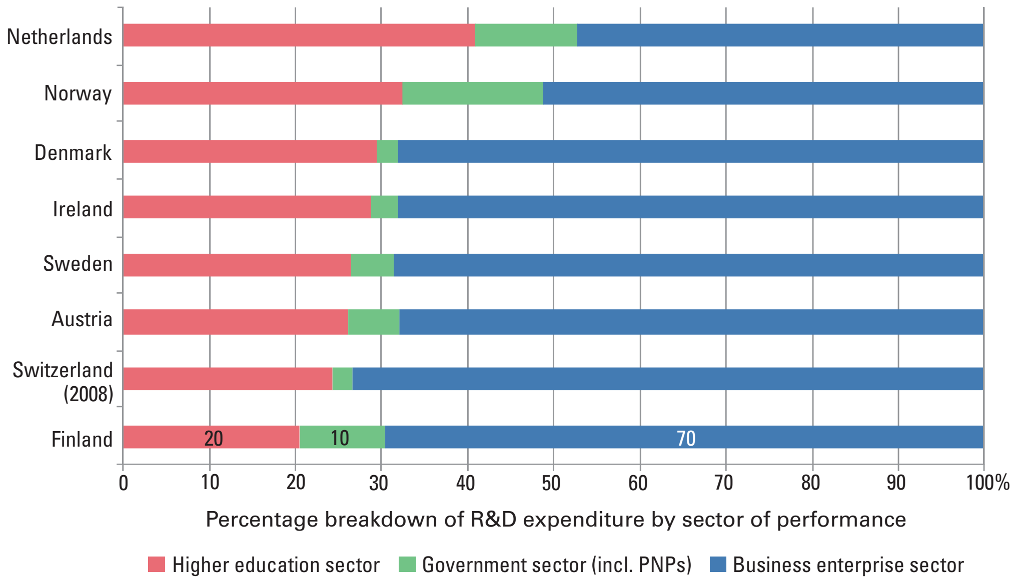

Figure 9. R&D activities by sector of performance (contribution of different sectors as a percentage of national R&D expenditure) in 2010

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: Data for Switzerland from 2008. The countries are listed in the order of the higher education sector's proportion of R&D activities. The higher education sector includes universities, polytechnics and (e.g. in Finnish statistics) university hospitals. The government sector comprises other public organisations that engage in R&D. In Finland, government research institutes account for the bulk of government-sector R&D. In this Figure, the government sector also includes private non-profit organisations (PNPs), which in Switzerland accounted for 1.6% of R&D expenditure and in other countries for 0–0.7%, the Finnish figure in 2010.

[20] OECD Research and Development Statistics (RDS), June 2012. R&D expenditure is expressed in PPP current dollars. Statistics Finland defines purchasing power parity (PPP) as follows: Purchasing power parity is an exchange rate by which the prices of commodity baskets in two countries are made equal in a common currency. Source: Statistics Finland, International price comparison, www.stat.fi/meta/til/kvhv_en.html, September 2012.

[21] OECD Main Science and Technology Indicators MSTI 2011/2 dataset. R&D expenditure is expressed in PPP current prices.

highest figure for government sector R&D activity at 16%. With respect to business enterprise sector R&D activity, the countries included in the comparison can be divided into two groups: in the Netherlands and Norway businesses account for around one-half of total R&D expenditure, in other countries for about 70% (in Finland 4.9 billion euros).

The focuses of R&D activity, and particularly the level of R&D activities in the business enterprise sector, are very much influenced by the national industry structure, historical and economic conditions as well as educational and policy priorities. Norway's industrial structure, for instance, rests heavily on oil, natural gas, fisheries and the forest industry. Industries based on the processing of raw materials and natural resources are not as research-intensive as medical and electronic industries, for example.[22] The Netherlands has a very large service sector, which goes some way towards explaining the lower than average level of business enterprise sector investment in R&D activities.[23]

Public and other sources of funding

The relative weight of public funding in R&D funding overall varies widely between the countries included in the comparison. In Norway, where the Research and Innovation Fund (est. 1999) has guaranteed stable and long-term access to public research funding,[24] almost half or 47% of R&D activities were funded from government sources in 2009 (Fig. 10). Switzerland (23% in 2008) and Finland (26%, 1.8 billion euros in 2010) recorded the lowest shares of public funding. Apart from state budget funding, other national sources accounted for 0.4–3% of R&D funding in the countries included in the comparison (in Finland 1% or 93 million euros in 2010).

During the 2000s, the relative increase in publicly funded R&D activities (R&D expenditure) has been particularly sharp (139%) in Ireland (Fig. 11). In Finland the trend has been rather more moderate: in 2010 public R&D expenditure was 38% higher than in 2001.

Public R&D funding can also be examined from the vantage point of its socio-economic objectives. This implies a shift in focus to state budget planning and to national surveys. It is particularly interesting to compare the development of funding earmarked for general advancement of knowledge,[25] i.e. primarily for scientific basic research. All funding from the Academy of Finland, for instance, comes under this heading. In 2011, the proportion of funding allocated to general advancement of knowledge ranged from 13% of public R&D funding in Austria and Norway to 31% in Ireland. Funding set aside for general advancement of knowledge has increased during the 2000s in all the countries included in the

[22] The Research Council of Norway 2011. Report on Science & Technology Indicators for Norway 2011. Oslo.

[23] Viljamaa Kimmo, Lehenkari Janne, Lemola Tarmo ja Tuominen Terhi 2010. Tutkimuspolitiikan välineet ja käytännöt – Viiden maan vertailu. Suomen Akatemian julkaisuja 2/10. [In Finnish only]

[24] Viljamaa Kimmo, Lehenkari Janne, Lemola Tarmo ja Tuominen Terhi 2010. Tutkimuspolitiikan välineet ja käytännöt – Viiden maan vertailu. Suomen Akatemian julkaisuja 2/10. [In Finnish only]

[25] In this analysis, general advancement of knowledge does not include research that is funded from universities' core budget resources.

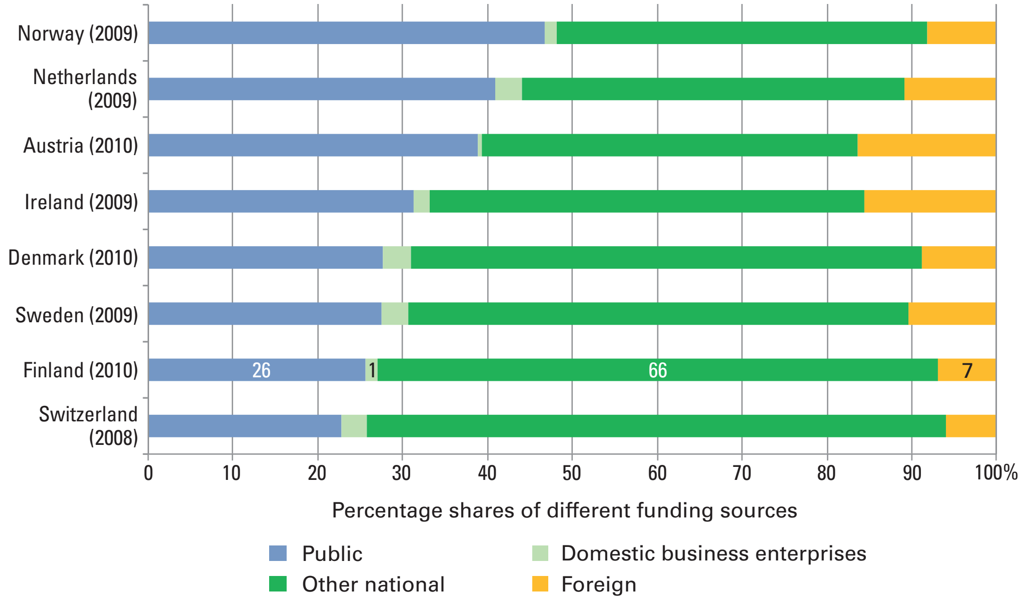

Figure 10. R&D funding structure (percentage shares of different funding sources) in 2009/2010

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: The countries are listed in the order of the percentage of public R&D funding. Data for Switzerland from 2008.

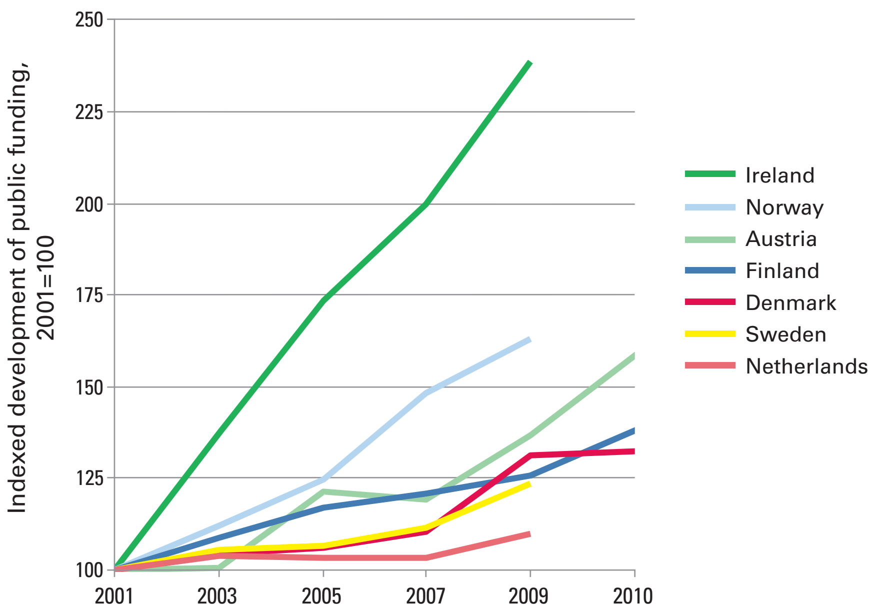

Figure 11. Indexed development (2001=100) of public R&D funding in 2001–2009/2010

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: Public R&D funding = publicly funded R&D expenditure in PPP 2005 dollars. Since there are only a few countries for which data are available for each year, the Figure is based on data for every other year. For Switzerland data are not available for the years in question. In Switzerland, publicly funded R&D expenditure increased by 36% from 2000 to 2008.

comparison.[26] In Finland the figure was 18% (366.6 million euros) in 2011.[27]

The proportion of domestic corporate funding was highest in Switzerland (68%) and Finland (66%, 4.6 billion euros). In Switzerland, R&D is funded most particularly by several business corporations in the pharmaceuticals, chemical and mechanical engineering industries.[28] In Finland, the bulk of corporate funding has come from Nokia, which in absolute terms had the eighth highest R&D investment in the whole world. In 2010, Nokia invested some 14% of its turnover in R&D, although this investment has now been falling and its ranking has dropped accordingly from its third place in 2009. On average, the top 20 R&D investors spent some 11% of their turnover on research and product development.[29]

The proportion of funding from foreign sources ranged from 6% to 16% in the countries included in this comparison. Austria and Ireland recorded the highest proportions of foreign funding at 16%. The figure for Finland was 7% (479 million euros). In Austria foreign funding comes primarily from foreign businesses.[30] Ireland, for its part, has been actively involved in EU framework programmes for research, and the country has a long tradition of collaboration with North American researchers.[31]

EU funding for R&D has been increased in all countries under examination during the 2000s (Fig. 12, data for the Netherlands and Switzerland not available). Sweden and Finland have had the most success in obtaining EU funding. In Sweden, R&D funding from EU sources totalled 164 million dollars, in Finland 133 million dollars in 2009. Sweden's EU funding increased by 98%, Finland's by 84% in 2001–2009. In current prices, EU funding for Finnish R&D was 141 million euros in 2009.

Even though EU funding for R&D in Finland has increased, Finnish research teams have had only average success with their applications under the European Union's Seventh Framework Programme for Research (FP7, 2007–2013): 23% of applications involving Finnish researchers were awarded funding. The average rate of success in all EU countries was 22%.[32] In the case of coordinated projects, the success rate has been slightly lower: Finland obtained funding for 17% of Finnish-coordinated project applications, compared to an average of 21% for all EU countries. The success rates vary between

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26 OECD Main Science and Technology Indicators MSTI 2011/2 dataset. The increase in funding allocated to general advancement of knowledge reflects nominal change since the amount of funding is expressed in the database in current prices.

27 Tilastokeskus 2012. Suomen virallinen tilasto: Tutkimus- ja kehittämisrahoitus valtion talousarviossa 2012 [verkkojulkaisu]. Tiede, teknologia ja tietoyhteiskunta 2012. Helsinki. Accessed from www.stat.fi/til/tkker/2012/tkker_2012_2012-02-24_tie_001_fi.html, August 2012. [In Finnish only]

28 Research in Switzerland: www.swissuniversity.ch/research-in-switzerland.htm, June 2012.

29 Booz&Company 2011: THE GLOBAL INNOVATION 1000. Why Culture Is Key. Strategy+business 65/2011.

30 Statistics Austria: www.statistik.at/web_en/statistics/research_and_development_r_d_innovation/index.html, June 2012.

31 Viljamaa Kimmo, Lehenkari Janne, Lemola Tarmo ja Tuominen Terhi 2010. Tutkimuspolitiikan välineet ja käytännöt – Viiden maan vertailu. Suomen Akatemian julkaisuja 2/10. [In Finnish only]

32 Based on projects under contract negotiations in October 2011.

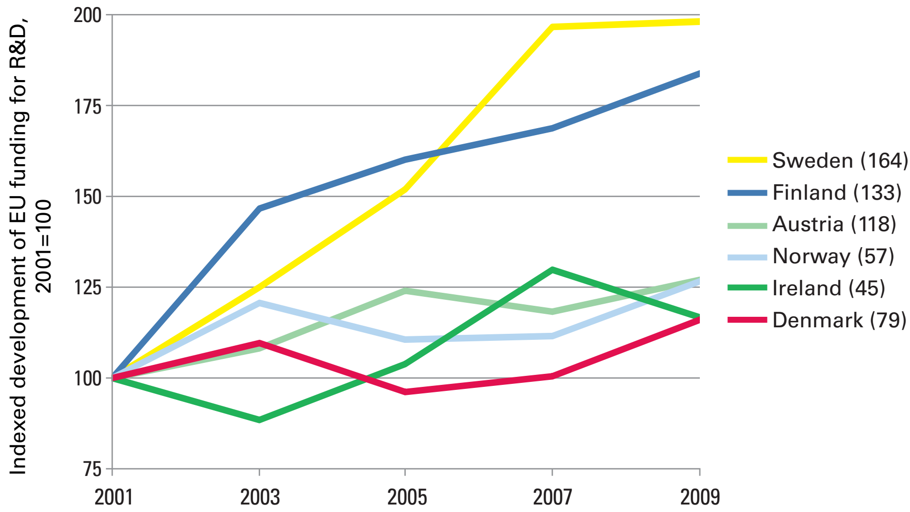

Figure 12. Indexed development (2001=100) of EU funding for R&D in 2001–2009. Volume of funding in PPP (million 2005 dollars) in 2009 is given in parentheses after the name of each country.

Source: OECD Research and Development Statistics (RDS), August 2012.

NB: EU funding refers to the amount of R&D expenditure (in PPP 2005 dollars) funded through EU framework programmes for research and through structural funds. Since there are only a few countries for which data are available for each year, the Figure is based on data for every other year. The most recent data available from 2009. Austria's data are for 2002, 2004, 2006, 2007 and 2009. Data for the Netherlands and Switzerland not available.

different specific programmes and themes. Universities received 40% and government research institutes 36% of the FP7 funding awarded to Finland; major corporations and SMEs received some 9% each. The combined share of other organisations was 6%.[33]

Launched under FP7, ERC funding allows research teams to undertake ambitious large-scale projects and to take bigger risks in research, which can lead to significant scientific breakthroughs. ERC funding decisions are based entirely on criteria of scientific quality. The most successful applicants among the countries in this comparison have been Switzerland (22%) and Austria and the Netherlands, which in 2007–2011 both recorded success rates of 14% (application countries are determined on the basis of the site of research rather than the researcher's nationality). Denmark (9%), Sweden (9%) and Norway (8%) have had roughly the same success rates. Finland and Ireland have obtained funding for 6% of their ERC applications, the lowest success rate among the eight countries compared. Having said that, success rates do vary to some extent from one call for applications to the next.[34]

Research in the higher education sector

The following section looks in some more detail at research activities in the higher education sector and explores the development of its funding for research.

[33] Tekes/EUTI 2012. Raportti Suomalaiset ja EU:n tutkimuksen seitsemäs puiteohjelma (2007–2013), 31.1.2012. [In Finnish only]

[34] ERC funding statistics.

Table 3. R&D volume per capita in the higher education sector (in PPP 2005 dollars) in 2010 and change in volume (%) in 2002–2010

Countries	Higher education sector R&D expenditure in PPP 2005 dollars per capita	Change, %
	2010	2002–2010
Sweden (2001, 2010)	305	28
Denmark	290	58
Netherlands	276	25
Switzerland (2002, 2008)	276	25
Norway	266	46
Austria	255	37
Finland	**251**	**37**
Ireland	185	110

Source: OECD Research and Development Statistics (RDS), June 2012. Population data source OECD Statistical database, Country statistical profiles, August 2012.

NB: The countries are listed in the order of 2010 R&D expenditure. Change is measured from R&D expenditure in PPP 2005 dollars. The Austrian higher education sector expanded in 2007 when the organisations responsible for teacher training (Pädagogische Akademien) were integrated as part of the higher education sector. In Norway data collection procedures for university hospitals changed in 2007, which affects the analysis of change in the higher education sector.

Measured in terms of per capita R&D expenditure, Sweden has the largest higher education sector among the eight countries here (Table 3). In Finland, per capita R&D expenditure in the higher education sector in 2010 was 266 euros.[35] In 2002–2010, per capita R&D expenditure increased by 37%. The sharpest increase in higher education sector R&D expenditure since the beginning of the 2000s has been recorded in Ireland (110%), although Ireland also had the lowest reference level. Denmark recorded the second largest increase: research in the higher education sector was up by 58%.

The disciplinary profiles of the higher education sectors in the eight countries included in this comparison, as determined on the basis of their research expenditure, differ from one another most particularly with respect to the shares of medical and health sciences and natural sciences (Fig. 13). The OECD category of natural sciences comprises both the exact natural sciences and biosciences. In Norway (36%), Sweden, the Netherlands and Denmark, around one-third of all higher education sector research was conducted in the medical and health sciences fields in 2009. The corresponding proportion in Ireland was considerably lower, and lowest among all the countries in this comparison at 18%. On the other hand, the proportion of natural sciences was highest in Ireland at 32%. In the Netherlands and the other Nordic countries except Finland, the natural sciences accounted for just under one-fifth of the higher education sector's research expenditure.

In Finland, the natural sciences, social sciences and medical and health sciences accounted for 22–25% and engineering and technology for 19% of total research

[35] 251 PPP 2005 dollars.

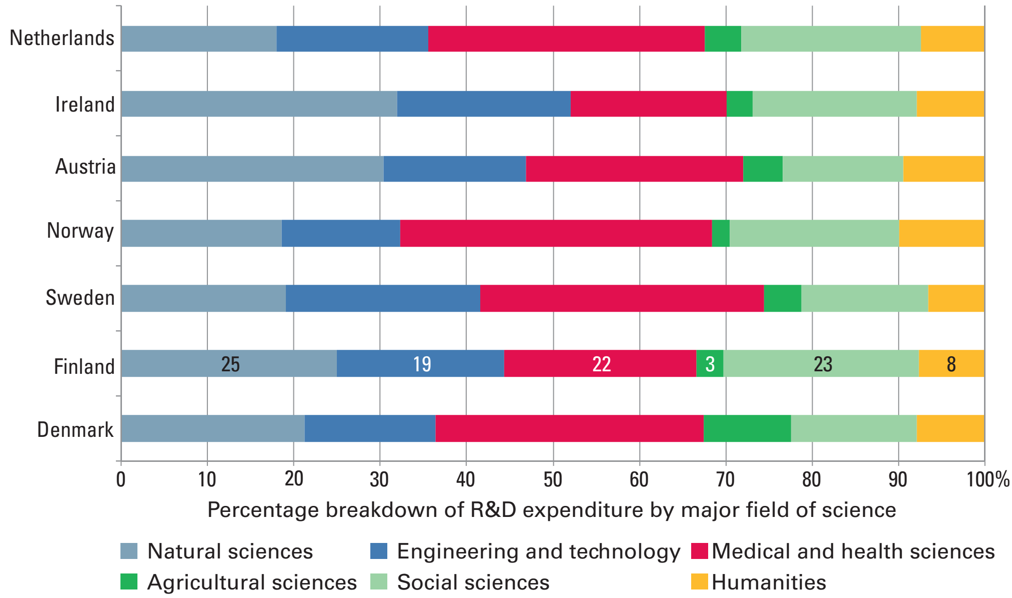

Figure 13. Breakdown of R&D expenditure in higher education sector by major field of science (percentage of total expenditure) in 2009

Source: Eurostat, Science, technology and innovation database, May 2012.

NB: The disciplines are listed in the order of the OECD's major fields of science. Most recent data available from 2009. Data for Switzerland not shown because of inadequate classification of disciplines. Less than 1% of all research in Sweden falls under the category of unclassified.

expenditure in the higher education sector in 2009. Humanities research accounted for 8% of total research expenditure and agricultural sciences for 3%. The corresponding proportions for these major fields of science in the other reference countries are roughly the same, although in Denmark the proportion of agricultural sciences (10%) is higher than in other countries. These figures for the overall volume of research are further increased by work undertaken at government research institutes, which is not included in the figures for the higher education sector.

Funding for research in the higher education sector

Core budget funding of Finnish institutions of higher education comes from the Ministry of Education and Culture. There is no specified figure for the proportion of this funding that should be earmarked for R&D purposes. R&D activities at higher education instutions are funded not only from core budget allocations but also from other sources, including public funding agencies such as the Academy of Finland and Tekes, the Finnish Funding Agency for Technology and Innovation, other national funding bodies, domestic business enterprises and foreign sources of funding. Statistics on R&D activities in the higher education are compiled from a variety of sources, and to some extent they are derived by computation. Each year, Statistics Finland conducts a separate survey among organisations in the higher education sector, and it also consults various administrative datasets. Statistics are compiled in line with OECD recommendations and EU regulations.[36]

In all the countries included in this comparison, research in the higher education sector is primarily funded from public sources (Fig. 14). However, the proportion of public funding, i.e. core budget funding allocated to research (institutional funding) and other public funding vary widely. In Austria, Norway and Switzerland, 66% of research carried out in the higher education sector was covered from core budget sources in 2009.

In Finland, the proportion of core budget funding was just 46% (594 million euros). The most important other sources of funding are public funding organisations, which accounted for 34% (439 million euros). The most significant sources of public funding are the Academy of Finland and Tekes. In Sweden, the proportion of funding from other than core budget sources was the same as in Finland.

Ireland had a much lower proportion of core budget funding (26%) than the other countries included in this comparison, but

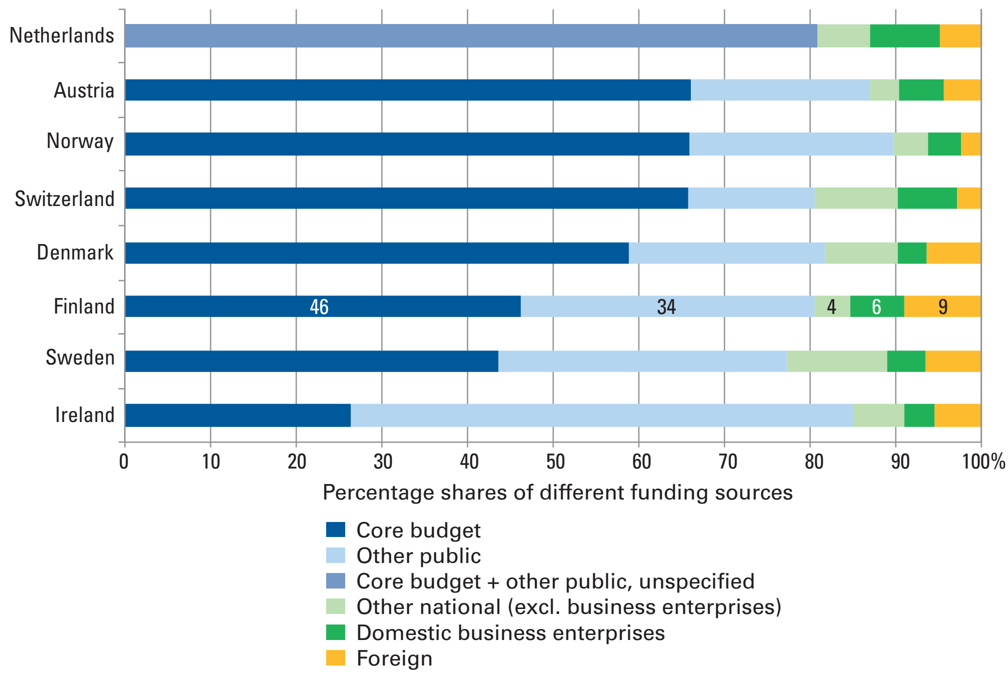

Figure 14. Higher education sector R&D funding structure (percentage shares of different funding sources) in 2009

Source: OECD Research and Development Statistics (RDS), May 2012.

NB: Data presented for 2009 because more recent figures are lacking for several countries. Funding data for the Dutch higher education sector do not distinguish between core budget funding (general university funds for research GUF) and other public funding. The countries are listed in the order of the proportion of core budget funding allocated for research purposes. In Finland, the statistics are compiled on the basis of survey data obtained from research organisations in the higher education sector and administrative datasets. Percentages for Finland add up to 99 because of rounding.

36 Tilastokeskus 2012. Suomen virallinen tilasto: Tutkimus- ja kehittämistoiminta [verkkojulkaisu]. Laatuseloste: Tutkimus- ja kehittämistoiminta 2010. Helsinki. Accessed from www.stat.fi/til/tkke/2010/tkke_2010_2011-10-27_laa_001_fi.html, September 2012. [In Finnish only]

accordingly the highest proportion of competitive funding (58%). Irish science policy has placed a premium on competitive funding. The main engine behind this development has been the Irish Science Foundation (SFI, est. 1998), which has funded research most particularly in the ICT and bio sectors. The mission set for the SFI was to provide enough funding to raise the standard of research in Ireland and to attract leading international researchers to work in Ireland. Another important priority for Ireland has been to ensure that research teams have sufficient critical mass and high enough quality standards to succeed in the competition for funding.[37]

1.4 Human resources in research

R&D personnel

Finland had the highest number of R&D personnel[38] as a proportion of the total employment. The same result was found in an examination of R&D personnel employed in the higher education sector and the government sector, for instance in government research institutes. In 2010, 23 persons per 1,000 employed persons worked in R&D position in Finland (Fig. 15). Seven of them worked in the higher education sector and three elsewhere in the government sector. The number of R&D

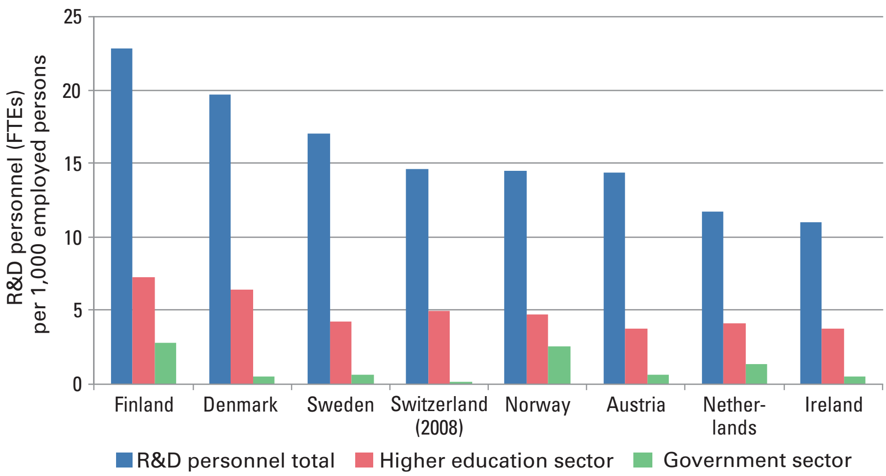

Figure 15. R&D personnel (FTEs) per 1,000 employed persons overall, in the higher education sector and in the government sector in 2010

Source: OECD Research and Development Statistics (RDS), June 2012, and for the employed population OECD Short-Term Labour Market Statistics, June 2012.

NB: Number of R&D personnel is measured in full-time equivalents (FTEs) in research. The number of employed persons is based on the employed population aged 15–74. In this Figure the government sector does not include private non-profit organisations (PNPs).

37 Viljamaa Kimmo, Lehenkari Janne, Lemola Tarmo ja Tuominen Terhi 2010. Tutkimuspolitiikan välineet ja käytännöt – Viiden maan vertailu. Suomen Akatemian julkaisuja 2/10. [In Finnish only]

38 Research and development personnel: "Research and development personnel are people who during the statistical year have spent at least 0.1 person-years (or 10% of their time) in an R&D unit doing administrative, office or other support work that is directly linked to R&D work or R&D projects. This category does not include people belonging to central departments who have done general administrative or office work serving the whole unit." Source: Statistics Finland 2012. Official Statistics of Finland (OSF): Research and development [e-publication]. Helsinki. Accessed from www.stat.fi/til/tkke/kas_en.html, June 2012

personnel as a proportion of the total employment varies widely between the countries in this comparison. In Ireland the number of R&D personnel is less than half the number in Finland. These differences are primarily due to differences in the number of R&D personnel working in the business enterprise sector, since the differences between R&D personnel numbers in the higher education sector and the government sector as a proportion of the total employment are only marginal.

In 2010, the business enterprise sectors in Sweden (71%) and Austria (68 %) had the highest proportions of R&D personnel among the countries included in this comparison (Fig. 16). In Norway the business enterprise sector was the smallest R&D employer, accounting for no more than 50%. In relative terms the biggest higher education sectors were those in the Netherlands, Ireland and Switzerland, where more than one-third of R&D personnel worked at higher education institutions. The proportion of R&D personnel working in the government sector was highest in Norway at 17%.

In Finland, R&D positions in the business enterprise sector accounted for the majority (55%, 30,559 FTEs) of total R&D personnel (55,897 FTEs) in 2010. The higher education sector accounted for 32% (17,924 FTEs) and the government sector (primarily government research institutes) for 13% (6,836 FTEs). In Finland, total R&D personnel numbers have increased only slightly in the 2000s: in 2010 the number of R&D personnel was 5% higher than in 2001 (Fig. 17). In relative terms, the sharpest increase has been recorded for R&D personnel in Ireland and Austria (around 50%).

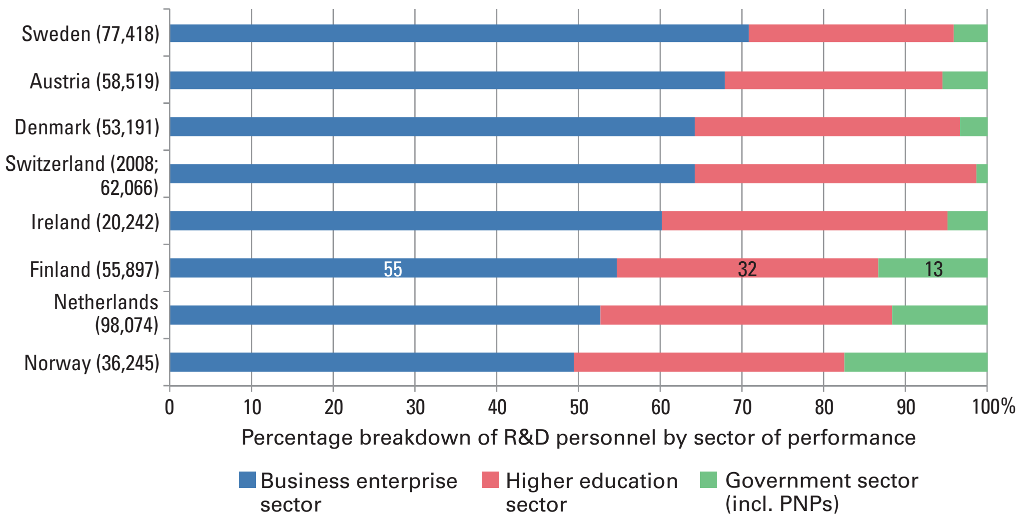

Figure 16. Breakdown of R&D personnel by sector in 2010. Total R&D personnel number in FTEs given in parentheses after the name of each country.

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: Number of R&D personnel indicated in FTEs in research. Government sector includes private non-profit organisations, which in Finland accounted for around 1% of R&D personnel, and in Austria, Denmark and Sweden for less than 1% in 2010. For other countries no data are available on R&D personnel in the private non-profit sector. Swiss data for 2000 and 2008, Austrian data for 2002 and 2010.

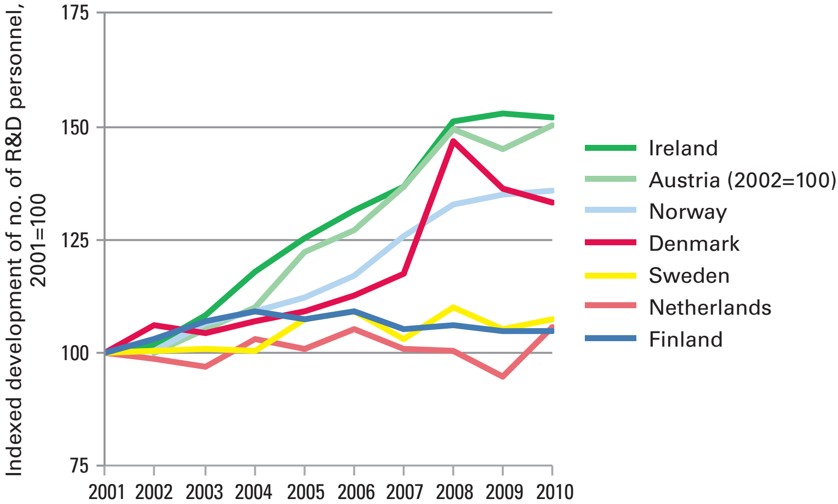

Figure 17. Indexed development (2001=100) of number of R&D personnel (FTEs) in 2001–2010

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: Number of R&D personnel based on FTEs in research. Some data are incomplete, comparative data for Switzerland not available. Change percentage for Austria calculated from 2002 because data for 2001 are not available. Austrian data for 2003 and Swedish data for 2002 are computed as means for the previous and following years. Some of the data for Sweden are underrepresentative.

Most R&D personnel do not have postgraduate training. In 2009, the proportion of personnel with postgraduate training (PhD and licentiate) in Finland was 18%, less than in Ireland, Sweden and Norway (Fig. 18). In Austria the proportion was roughly the same as in Finland. The percentage has slightly increased since 2003. The level of qualifications has risen significantly in Ireland, where the proportion of R&D personnel with postgraduate training was 21% in 2003 and 31% in 2009.

The level of qualifications of Finnish R&D personnel varies across different sectors (Fig. 19). In the higher education sector, 31% of R&D personnel (at universities 34%) had doctorate-level training in 2010. In the government sector (including private non-profit organisations), the corresponding proportion was 22%. In the business enterprise sector, only 4% of R&D personnel had a PhD, which significantly affects the result that the percentage of PhDs in Finland's total R&D personnel is only half (15%) the corresponding percentage for the higher education sector. In the government sector, the proportion of R&D personnel with other university qualifications than a doctorate is somewhat higher than in other sectors. A polytechnic degree (31%), then, is far more common among R&D personnel in the business enterprise sector than in other sectors.

During the 2000s, the number of R&D personnel with a doctorate (as calculated from person-years in research) has increased significantly and at almost the same rate in all sectors in Finland (Fig. 20). In 2010, the number of R&D personnel with a doctorate was 56% higher than in 2000. In the business enterprise sector, the corresponding increase was even faster at 60%, although the absolute number of PhDs among R&D personnel is slightly lower in the business enterprise sector than in other sectors.

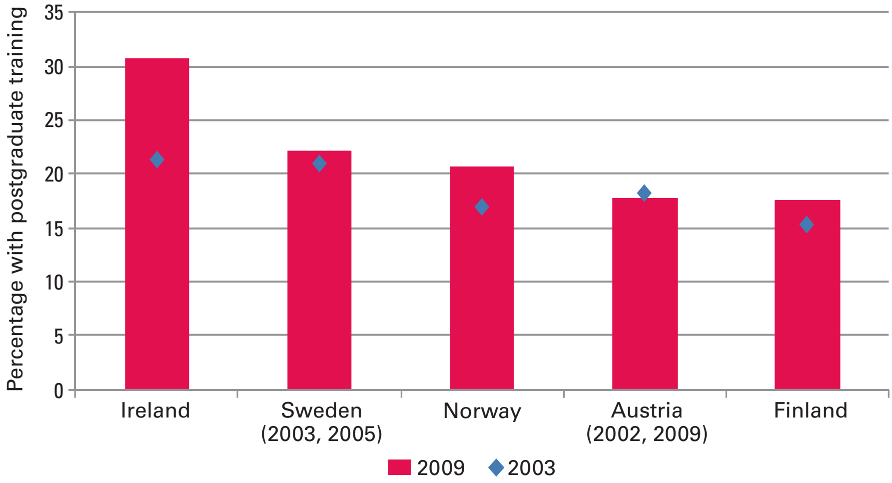

Figure 18. Percentage of R&D personnel with postgraduate training (calculated from personnel numbers) in 2003 and 2009

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: Postgraduate training refers to a second stage of tertiary education (ISCED level 6) leading to an advanced research qualification. Finnish figures include persons with a PhD and licentiate's degree. Limited data available for pre-2003 years. Data for Denmark, the Netherlands and Switzerland not available.

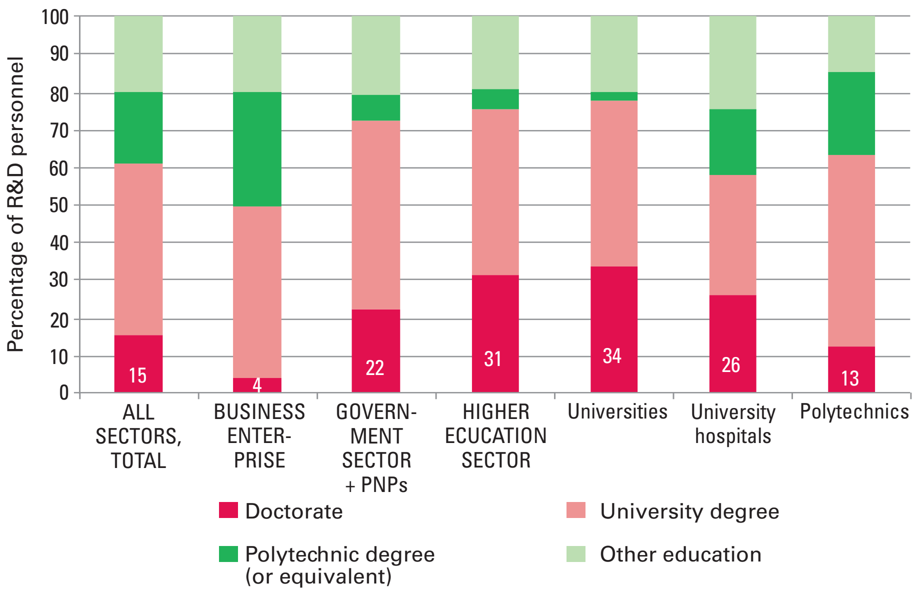

Figure 19. R&D personnel in Finland (FTEs) by education and sector and in the higher education sector by type of organisation in 2010

Source: Statistics Finland, Research and Development, database tables, June 2012.

NB: Number of R&D personnel based on FTEs in research. University degree comprises all other university degrees except doctorates. PNPs = Private non-profit organisations.

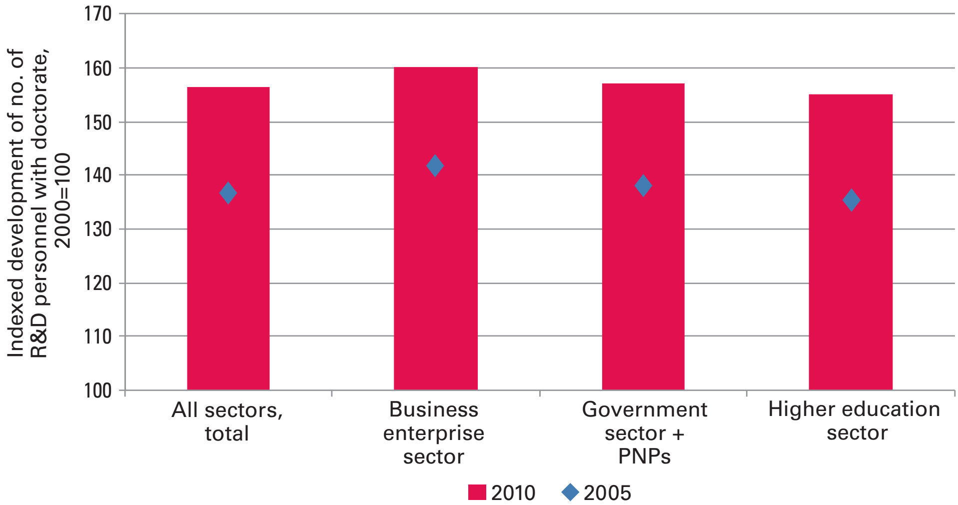

Figure 20. Indexed development (2000=100) of R&D personnel with a doctorate (FTEs) by sector in Finland in 2005 and 2010

Source: Statistics Finland, Research and Development, database tables, June 2012.

NB: Number of R&D personnel based on FTEs in research. PNPs = Private non-profit organisations.

Research personnel in the higher education sector

The number of research personnel in the higher education sector has increased most sharply in Ireland, where the number of FTEs in research in 2010 was 122% higher than in 2002 (Fig. 21). In the Finnish higher education sector, the number of FTEs in research has increased only marginally: in 2010 the figure was just 6% higher than in 2002.

By major field of science, the higher education sectors in the eight countries included in this comparison differ most significantly in terms of the relative proportions of research personnel in the natural sciences and in medical and health sciences (Fig. 22). Research personnel numbers in the natural sciences are highest in Austria, Ireland and Finland; and in the medical and health sciences in Norway, the Netherlands and Denmark. In Finland natural sciences accounted for 27% of total FTEs in research in the higher education sector in 2010. The proportions for engineering and technology, medical and health sciences, and social sciences were around one-fifth each. Of research personnel, 7% worked in the humanities and 3% in agricultural sciences.

Internationalisation of research staff at Finnish universities

Non-native nationalities accounted for 13% of research staff at Finnish universities (total 2,308 FTEs). The proportion of non-native researchers was highest at the earlier stages of the research career (doctoral students 17% and postdoctoral researchers 18%). In 2011, the proportion of non-native lecturers and other researchers on the third tier of the research career was 10%, among professors and equivalent 6%.[39]

[39] Ministry of Education and Culture reporting portal (Vipunen), May 2012. Systematic data collection on the nationality of research personnel at Finnish universities only started in 2010, and therefore no time series are available.

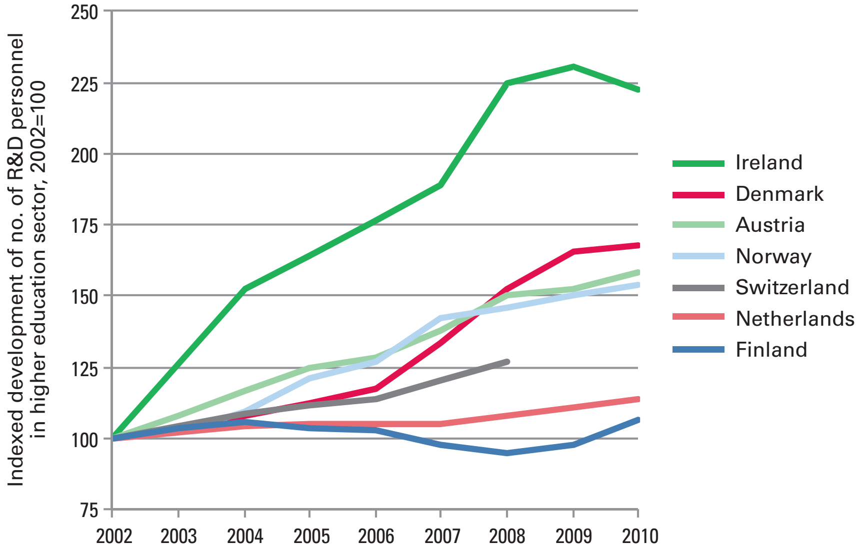

Figure 21. Indexed development (2002=100) of R&D personnel in higher education sector (FTEs) in 2002–2010

Source : OECD Research and Development Statistics (RDS), June 2012

NB: Number of R&D personnel in the higher education sector based on FTEs in research. Some data are incomplete. Austrian data for 2003 and Swiss data for 2003, 2005 and 2007 are computed as means for the previous and following years. Data for Sweden are not available because data collection procedures for the Swedish higher education sector changed in 2005, which impacts the analysis of the development of FTEs in research in the higher education sector. The Austrian higher education sector expanded in 2007 when the organisations responsible for teacher training (Pädagogische Akademien) were integrated as part of the higher education sector. In Norway data collection procedures for university hospitals changed in 2007, which affects the analysis of change in the higher education sector.

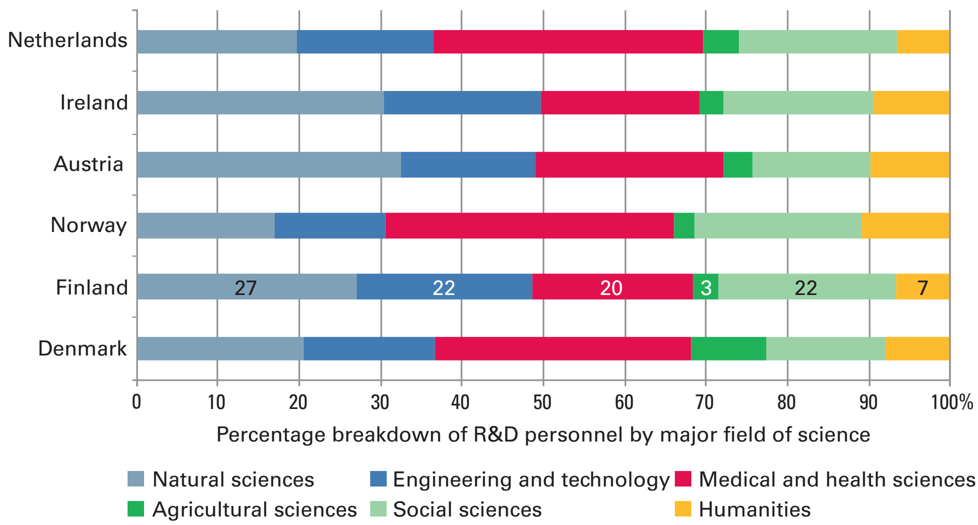

Figure 22. R&D personnel in the higher education sector (FTEs) by major field of science in 2009

Source: OECD Research and Development Statistics (RDS), June 2012.

NB: The disciplines are listed in the order of the OECD classification of major fields of science. Most recent data available from 2009. Percentages for Finland add up to 101 because of rounding. Data for Sweden and Switzerland are not available because of an incomplete disciplinary classification.

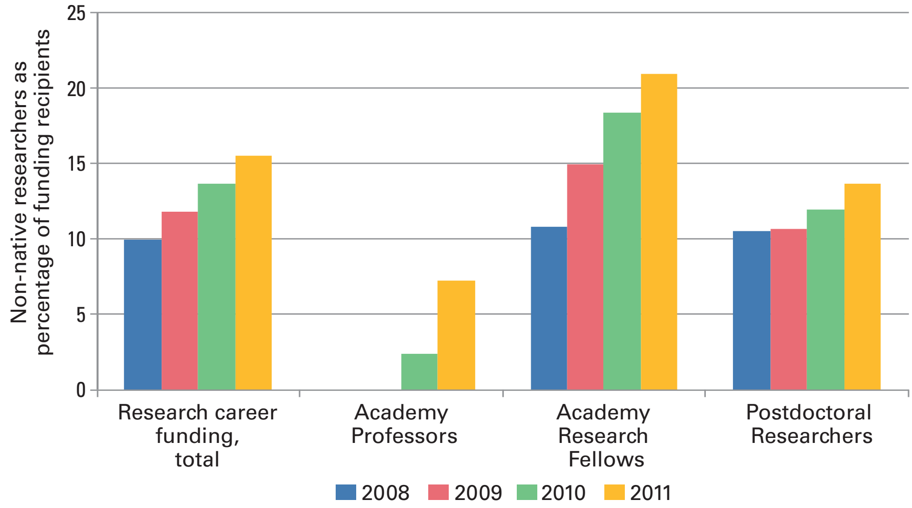

Figure 23. Non-native researchers as a percentage of researchers receiving Academy research career funding, total and by funding instrument in 2008–2011

Source : Academy of Finland funding statistics 2012.

NB: Research career funding covers the personal wages of the principal investigator as well as funding for immediate research costs for a fixed term. In Finland the Academy is also financing non-native researchers working at Centres of Excellence in Research and in research projects. In 2008 and 2009, the Academy of Finland did not provide funding for a single non-native Academy Professor.

There is an increasing number of non-native researchers at Finnish universities whose work is funded by the Academy of Finland. The proportion of non-native researchers who have received research career funding has increased from 10% in 2008 to 15% in 2011 (Fig. 23). Growth has been fastest among researchers who have been awarded an Academy Research Fellowship, for which competition is fierce: in 2008 10% of researchers who were awarded funding for an Academy Research Fellowship were from outside Finland. In just four years, the proportion had risen to over 20% in 2011.

Jointly administered by the Academy of Finland and Tekes, the Finland Distinguished Professor Programme (FiDiPro) allows Finnish universities and research institutes to hire leading foreign researchers for a fixed term in Finland; Finnish researchers who have worked extended periods abroad are also eligible to apply. Since 2006, the Academy of Finland has provided funding for 47 FiDiPro Professors. Tekes, for its part, has provided funding for 47 FiDiPro Professors. In 2009, Tekes launched a FiDiPro Fellow Programme, which is designed to attract promising research talents in the early stages of their career into Finnish research teams. To date, 13 researchers have benefited from the programme.[40]

[40] Academy of Finland and Tekes funding statistics. Researchers funded in 2006–2012 (June).

1.5 Performance and impact of research

Bibliometrics as a measure of impact

Bibliometric indicators have been used for several years as an ancillary evaluation tool[41] at the research system level and as a measure of the impact of research in various indicator reports[42]. Publishing practices vary in different disciplines, and therefore international publication databases are not equally well suited to analysing publishing in these different cases. The Thomson Reuters Web of Science databases aim to cover the most important scientific journals in each discipline. Medical and natural science publications have the most representative coverage in the databases, whereas mathematics and engineering and technology are slightly less well covered. Overall, however, these databases still provide the best coverage of scientific journals published in the English language. In the social sciences and humanities, large numbers of monographs and articles are published in national or other than English-language scientific journals that are not included in Web of Science databases.[43] Countries also differ in their disciplinary profiles, which further complicates international comparisons. The interpretation of bibliometric results must always take account of the limitations associated with international databases and bibliometric methods of analysis.

The bibliometric dataset used for the 2012 review on the state of scientific research in Finland consists of publications included in the Thomson Reuters Web of Science databases.[44,45,46] The analysis covers four types of publication, i.e. articles, review articles, letters and proceedings papers. All publications in which at least one author has a Finnish address are classified as Finnish publications. Publication numbers are fractionalised between the countries of the contributing authors.

Numbers of citations are also fractionalised between the countries contributing to the publication. Self-citations have been removed. The number of citations received has been computed for the year of

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41 See e.g. Löppönen Paavo, Lehvo Annamaija, Vaahtera Kaisa and Nuutinen Anu (eds.) 2009. The State and Quality of Scientific Research in Finland 2009. Publications of the Academy of Finland 10/09. Elsevier 2011. International Comparative Performance of the UK Research Base – 2011. A report prepared for the Department for Business, Innovation and Skills.

42 See e.g. National Science Board 2012. Science and Engineering Indicators 2012. Arlington VA: National Science Foundation (NSB 12–01).
NordForsk 2011. Comparing Research at Nordic Universities using Bibliometric Indicators. A publication from the NORIA-net 'Bibliometric Indicators for the Nordic Universities'. NordForsk Policy Briefs 4–2011.

43 Ministry of Education and Culture 2011. Report from the Finnish Citation Index Working Group II. Finnish research organizations' publications and citations in the Web of Science, 1990-2009. Reports of the Ministry of Education and Culture, Finland 2012:18.

44 Certain data included herein are derived from the Science Citation Index Expanded, Social Science Citation Index, Arts & Humanities Citation Index, and Conference Proceedings Citation Index – Science and Conference Proceedings Citation Index – Social Science & Humanities, all prepared by Thomson Reuters®, Philadelphia, Pennsylvania, USA, © Copyright Thomson Reuters ®, 2012.

45 For further information on the Thomson Reuters Web of Science databases, see: thomsonreuters.com/content/science/pdf/Web_of_Science_factsheet.pdf, August 2012.

46 The bibliometric analyses were conducted by Postdoctoral Researcher Raj Kumar Pan and Associate Professor Santo Fortunato from Aalto Univerity.

publication and the following two years. Citation numbers for 2009 and 2010 are not complete because limited data availability means that only citations received by the end of 2010 are included in the figures for these years. All results are presented in three-year intervals. The same methodological choices apply to all citation indicators. The methods are described in more detail in Appendix 1.

Thomson Reuters Web of Science databases define the discipline of a publication based on the journal in which it appears. Each journal, in turn, can be ascribed to no more than six different disciplines.[47] Each publication is field-normalised for the calculation of citation indicators, whereby the number of citations received is compared to the world average for the disciplines to which the scientific journal and thereby the publication is classified.

Development of publication numbers

In 2008–2010, a total of 15,674[48] scientific publications were published in Finland. Relative to population, Finland had the third highest number of publications in the countries included in this comparison (Fig. 24), following Switzerland and Sweden. The order of the top four publishing countries has remained unchanged from 2003–2005 to 2008–2010.

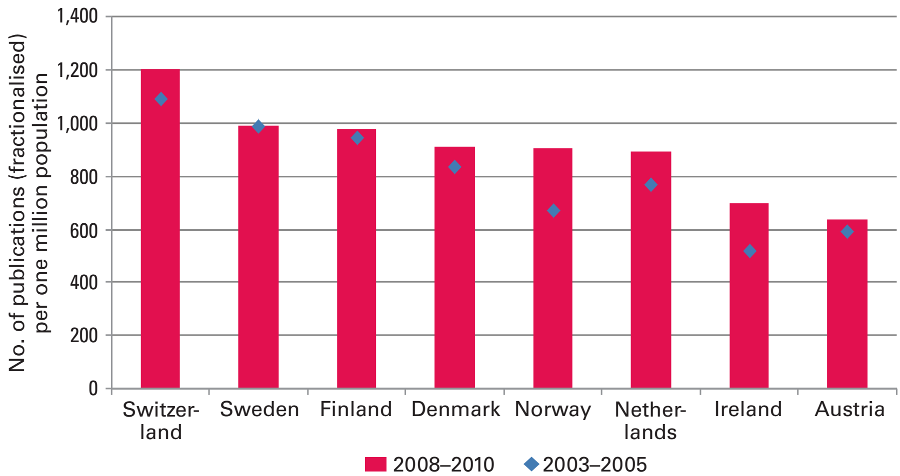

Figure 24. Number of publications per one million population per year on average in 2003–2005 and 2008–2010

Data source: Thomson Reuters 2012. Bibliometric analyses by Raj Kumar Pan and Santo Fortunato, Aalto University 2012. Population data source OECD Statistical database, Country statistical profiles, August 2012.

NB: Publication numbers are fractionalised between the countries contributing to each publication. The countries are listed in the order of publication numbers relative to population for the most recent period.

[47] Ministry of Education and Culture 2011. Report from the Finnish Citation Index Working Group II. Finnish research organizations' publications and citations in the Web of Science, 1990-2009. Reports of the Ministry of Education and Culture, Finland 2012:18.

[48] This is the fractionalised number of publications in the types of publication included in the analysis. Since the dataset does not include monographs nor all of the scientific journals in which Finnish researchers publish, the absolute number of Finnish scientific publications is higher than that indicated.

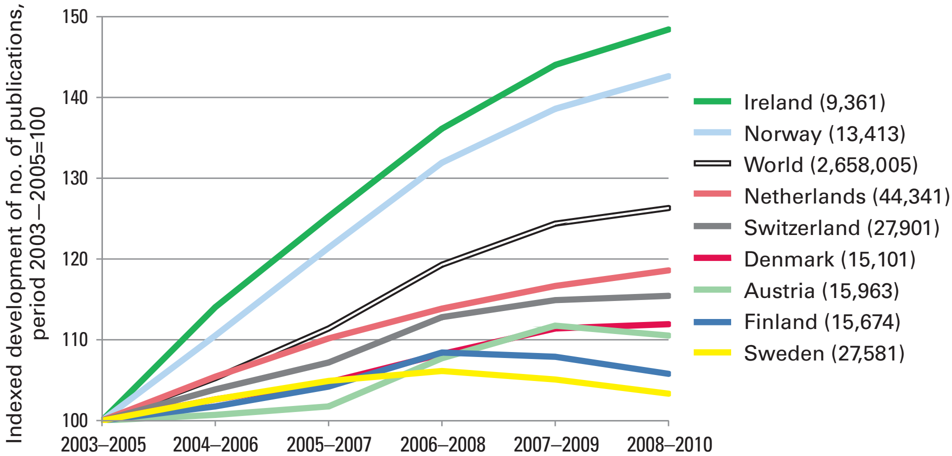

Figure 25. Indexed development (2003–2005=100) of publication numbers in 2003–2010. Fractionalised publication number for 2008–2010 shown in parentheses after the name of each country.

Data source: Thomson Reuters 2012. Bibliometric analyses by Raj Kumar Pan and Santo Fortunato, Aalto University 2012.

NB: Publication numbers fractionalised between the countries contributing to each publication.

Publication numbers have increased most sharply in Ireland (48%) and Norway (43%), well above the world average of 26%[49] in 2003–2010 (Fig. 25). In other countries included in the comparison, growth rates have been more moderate. Finnish publication numbers in 2008–2010 were 6% higher than in 2003–2005. However, it is noteworthy that publication numbers in Finland and Sweden have been declining after 2006–2008. In Austria, too, the number of publications in the period under review was down from the previous period for the first time ever.

Citation indicators

Swiss, Dutch and Danish publications received more citations than world publications on average throughout the 2003–2010 period (Fig. 26). The difference to the other countries included in the comparison is clear. All eight countries have been above the world average since 2005–2007. Finnish publications received 6% more citations (relative citation impact 1.06) than world publications on average in 2008–2010. This is slightly more than in the early part of the period under review, when Finland's relative citation impact (1.01) was around the world average.

Top 10% publications refer to publications that rank among the 10%[50] of the most cited publications in the world. The Top 10 index is constructed by comparing each country's most cited publications as a proportion of the country's total publication number to the world's most cited publications as a proportion of total

[49] The world number of publications means the total number of publications in the Web of Science databases. During the 2000s, publishing has increased particularly sharply in China and South Korea (National Science Board 2012). In addition to the growth of publishing, the number of publications in the databases has increased with the increasing number of journals included in the databases. Source: National Science Board 2012. Science and Engineering Indicators 2012. Arlington VA: National Science Foundation (NSB 12-01).

[50] Top publications can also be defined as the top 1% or top 5% of most cited publications in the world.

world publications, whereby the world average is one. The strongest countries in this analysis were Switzerland, the Netherlands and Denmark (Fig. 27), while Finland ranked last. In 2008–2010, 13% of Swiss publications ranked among the most cited world publications; this is 52 % more than in the world on average (top 10 index 1.52). During the same period, 9% of Finnish publications ranked among the world's top publications. This is roughly the same figure as in the world on average.

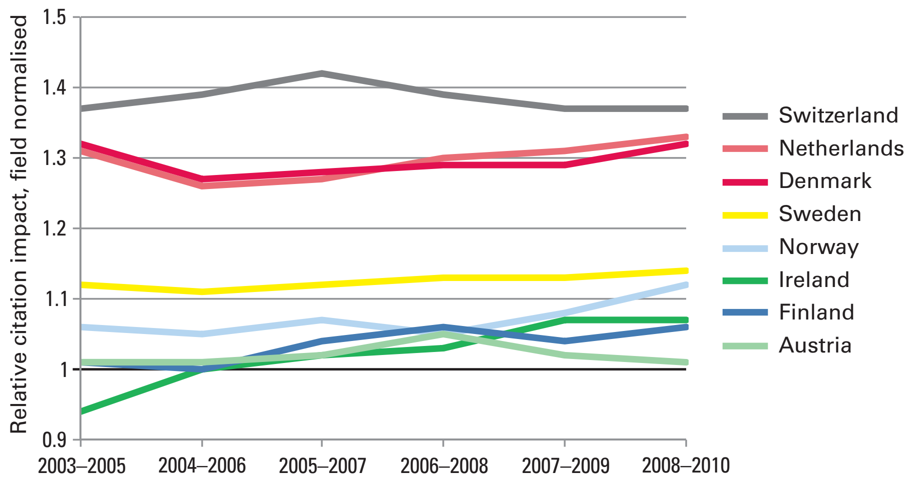

Figure 26. Development of relative citation impact in 2003–2010. World average level is 1.

Data source: Thomson Reuters 2012. Bibliometric analyses by Raj Kumar Pan and Santo Fortunato, Aalto University 2012

NB: A country's relative citation impact measures how many citations more or less publications from that country have received in comparison with the world average over a certain period of time.

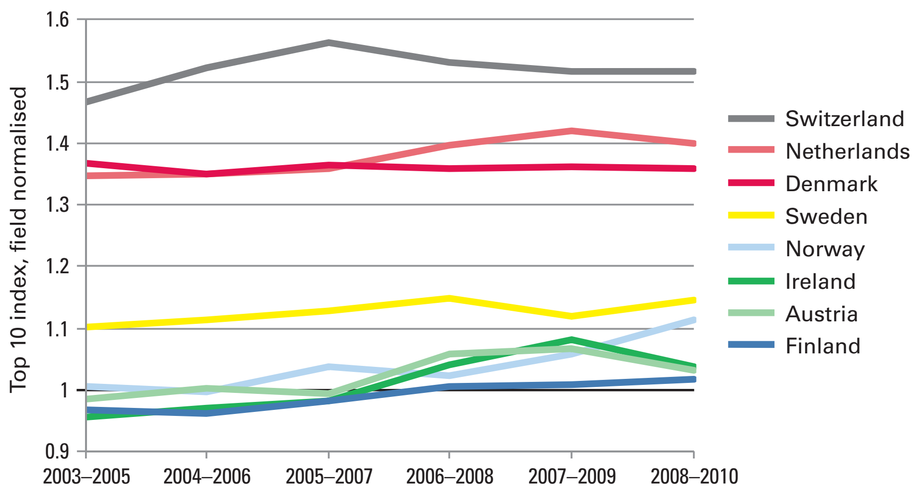

Figure 27. Development of Top 10 index in 2003–2010. World average level is 1.

Data source: Thomson Reuters 2012. Bibliometric analyses by Raj Kumar Pan and Santo Fortunato, Aalto University 2012.

NB: A country's top 10 index measures how many publications more or less than the world average rank among the top 10% of the most cited publications in the world.

International co-publishing

International co-publishing has increased significantly in Finland over the past 20 years. In the early 1990s, only one in four Finnish publications[51] involved researchers from other countries. By the turn of the millennium, the proportion had risen to 40% and in 2006–2009 almost one-half (49%) of Finnish publications were the result of international collaboration. [52]

In a Nordic comparison,[53] 29% of Finnish publications (fractionalised number of publications) were produced in international collaboration in 2005–2008. The corresponding proportion for Denmark was 33% and for Norway and Sweden 32%. International co-publications receive significantly more citations than national publications. Finland's international co-publications received 23% more citations than the world average in 2005–2008. Accordingly, the relative citation impact of national publications was 3% below the world average. Among the four Nordic countries included in the comparison, Denmark's international co-publications received the largest number of citations in relative terms, 43% more than the world average in 2005–2008.

Patents

Bibliometric indicators describe the internal impact of science, whereas patents[54] can provide useful insight into the possible economic impact of R&D. Patent indicators also have their own limitations that must be taken into account in interpreting the results. There are various reasons why not all inventions are patented, and patenting practices differ between different branches. The processing of patent applications is a time-consuming process, and therefore patent statistics can lag up to several years behind advances in actual R&D. Since patent statistics do not distinguish between different types of patents but only give total numbers, the evidence they provide of economic impact is indicative only.[55] Nonetheless, they do provide an additional and broader perspective on the impact of research, and the analyses of patent statistics below take account of the restrictions just mentioned.

Switzerland has by far the highest number of EPO patents among the countries concerned, i.e. 304 per one million population in 2009–2011 (Fig. 28). Finland ranks third in this comparison with 120 EPO patents per one million population.

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51 The number of publications for Finland is non-fractionalised: international co-publications in Finland are defined as comprising all publications in the category of publications included in the analysis that have at least one Finnish author and one from some other country.

52 Muhonen Reetta, Leino Yrjö and Puuska Hanna-Mari 2012. International co-publishing in Finland. Reports of the Ministry of Education and Culture, Finland 2012:19.

53 NordForsk 2011. Comparing Research at Nordic Universities using Bibliometric Indicators. A publication from the NORIA-net 'Bibliometric Indicators for the Nordic Universities'. NordForsk Policy Briefs 4–2011.

54 Statistics Finland defines a patent as follows: "A patent is an exclusive right granted by the relevant authority for a given period of time (usually 20 years) to the inventor or holder of rights to the invention. A patent will only be granted on condition that the invention is new, innovative (i.e. based on non-evident knowledge) and applicable to industrial use." Source: Statistics Finland 2012. Official Statistics of Finland (OSF): Patenting [e-publication]. Helsinki. Accessed from www.stat.fi/til/pat/2010/pat_2010_2011-11-03_laa_001_fi.html, August 2012.

55 Alanen Aku 2005. Patenteilla mitaten olemme huipulla. Tilastokeskuksen Tietoaika-lehti. Online article, www.stat.fi/tup/tietoaika/ta_04_05_patentit.html, August 2012. [In Finnish only]

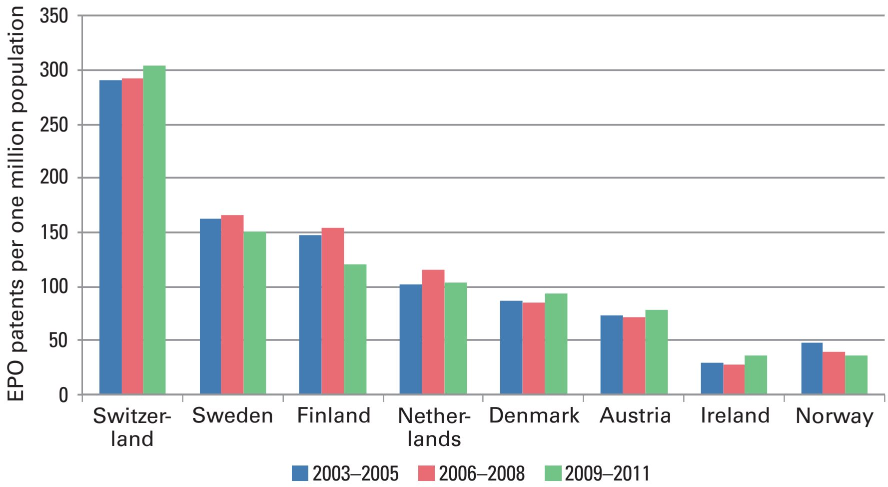

Figure 28. EPO patents per one million population in 2003–2011

Source: European Patent Office, Statistics, August 2012. Population data source OECD Statistical database, Country statistical profiles, August 2012.

NB: Patent statistics describe the number of patents granted. The countries are listed in the order of the number of EPO patents relative to population in 2009–2011.

However, Finland's number of EPO patents has declined in 2009–2011 from earlier periods. Norway and Sweden have seen similar trends.

Switzerland also has the largest number of patents granted in the United States (222 USPTO patents per one million population in 2009–2011, Fig. 29). Finland had more

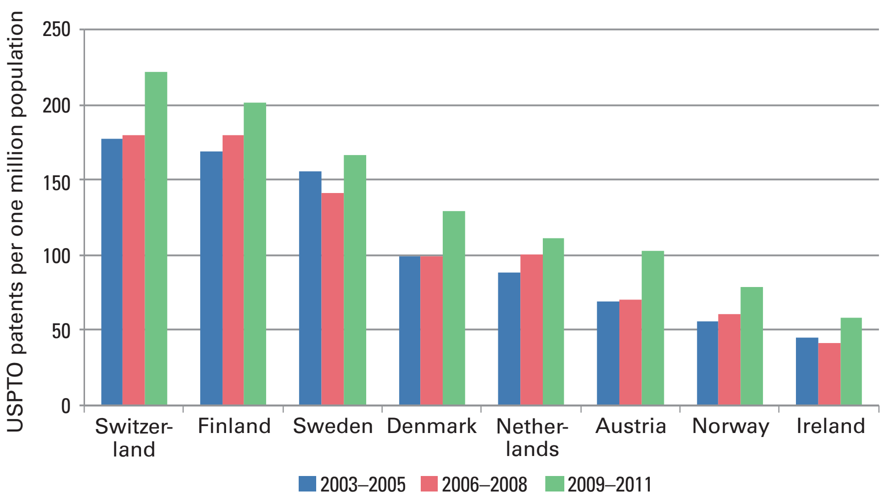

Figure 29. USPTO patents per one million population in 2003–2011

Source: U.S. Patent and Trademark Office, TAF database, August 2012. Population data source OECD Statistical database, Country statistical profiles, August 2012.

NB: Patent statistics describe the number of patents granted. The countries are listed in the order of the number of USPTO patents relative to population in 2009–2011.

USPTO patents than EPO patents, i.e. 202 per one million population in 2009–2011. This was the second highest figure among the countries included in the comparison. Finland's number of USPTO patents has increased in 2003–2011. All other countries in this comparison have also seen an increase in their USPTO patents during the period under review.

Institutions of higher education and research institutes as business partners

The impact of research undertaken by institutions of higher education and research institutes can also be assessed by comparing innovative companies in different countries based on whether they have collaborated in their innovation with research organisations. Finland ranks highest among the countries in this comparison (data for Denmark not available) both when examining major corporations and SMEs (Fig. 30). Over two-thirds or 68% of Finland's innovative major companies and 26% of innovative SMEs had collaborated with organisations in the higher education sector or research institutes in 2006–2008.

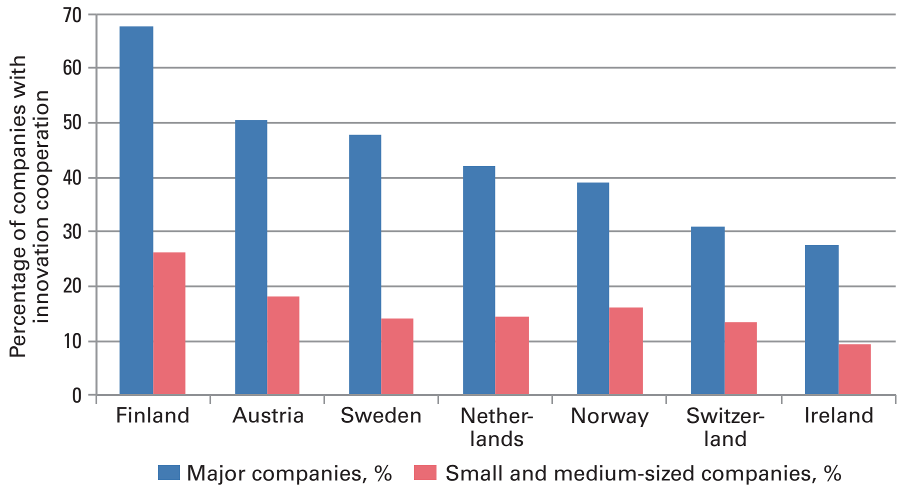

Figure 30. Percentage of innovative companies engaging in innovation cooperation with organisations in the higher education sector or research institutes by size of company in 2006–2008

Source: OECD 2011. OECD Science, Technology and Industry Scoreboard 2011.

NB: OECD data based on Eurostat-coordinated Community Innovation Survey (CIS 2008) and in part on national data sources. Data for Denmark not available.

2 FINNISH SCIENCE AND RESEARCH: A REVIEW BY THE ACADEMY'S RESEARCH COUNCILS

2.1 Biosciences and environmental research

Many of the grand challenges facing humankind today have to do with the relationships between humans and nature. Following international bodies such as the United Nations and the European Union, the Academy of Finland too has identified challenges that science and research can help to resolve by building up a relevant knowledge base. Some of the global problems that are affecting societies around the world include the excessive use of natural resources, climate change from fossil fuels combustion, the sixth wave of anthropogenic extinction and the continuing loss of biodiversity. Likewise, the shortage of clean water, population growth, the scarcity of land for food production, and the development of antibiotic-resistant bacterial strains due to the overuse of antibiotics are far-reaching threats that affect most people in the world. These problems have been brought about by human activity, and they can be resolved by human activity.

Biosciences and environmental research have a crucial role to play in addressing these grand challenges faced by humankind. Research and new knowledge provide the basis for informed policy decisions that lead towards an environmentally, culturally and economically more sustainable future. Finnish biosciences and environmental research is world class and in some areas at the very cutting edge of international science. Researchers in these key areas of strength are well placed to find sustainable solutions to the problems mentioned above, but this requires constant investment in the development of Finnish research and the national research system.

Research environment, funding and infrastructures

High-quality research requires the proper allocation of research resources. The full cost model that has been adopted in the Finnish research system in line with the recommendation by the European Union has attracted much justified criticism. At universities it is said to have created even more bureaucracy and unnecessary regulation. As for research funding, it has actually reduced the amount of funds allocated directly to research funding available and driven up the overheads funded by the Academy, which has been seen as particularly problematic by researchers in the fields of biosciences and environmental research that depend heavily on laboratory and field studies. The full cost model, as it stands today, is ineffective both at the system level and in project funding, and it provides no incentives for universities and government research institutes to improve their efficiency. Under the EU's forthcoming Framework Programme for Research and Innovation (Horizon 2020), the percentage of overheads will be limited to 20%. This would be a suitable benchmark for research funding in Finland, too, and clearly improve the efficiency and impact of the Academy of Finland, for instance. The success rate for applications submitted to the Academy currently stands at no more than around 17%, down by almost one-half since 2008. As a result, a significant proportion of even the most highly rated projects remain without funding.

One of the problems in many fields of biosciences and environmental research is the lack of audacious risk-taking. The Academy's premier tool for supporting new innovation and risk-taking has been its funding for Centres of Excellence in research. Indeed, both the Academy and other funding agencies should increase the availability of high-risk funding for younger scientists and researchers in particular. Higher risk-taking also paves the way to true new innovations and to surprising new discoveries. Major challenges often require new approaches and interdisciplinary cooperation – but these often involve significant risks of failure as well.

Finnish scientists and researchers have received an increased proportion of the funding awarded through EU financing instruments, but their involvement in framework programmes has been on the decline. The preparation of funding applications and the associated reporting duties are clearly considered a burden that takes away from the time that can be dedicated to research. Universities and research institutes should set strategic goals for the acquisition and application of EU funding, and introduce new support services to help accomplish these goals. Centralised support services can help to minimise the amount of time that researchers need to spend on application formalities and improve the prospects of their applications being successful.

Finnish research excellence in the biosciences and environment field can help overcome the grand challenges facing humankind. For instance, EU/ERC projects ongoing at the Finnish Centre of Excellence in Metapopulation Research at the University of Helsinki are working to develop methods, analyses and software tools for the ecologically sustainable allocation of nature conservation resources. The solutions proposed take balanced account of natural heritage, costs, forms of land use, and alternative measures of nature conservation. 'Zonation' and other Finnish-developed software packages are already in use in several countries.

The 2009 report on the state and quality of scientific research in Finland[1] drew attention to the rapid ageing of equipment and hardware in biosciences and environmental research and to the scarcity of funding available for upgrading this equipment. Infrastructure funding remains a current problem despite the new appropriations included in the state budget. The proposed annual sum of 4 million euros for research infrastructure is clearly not enough to cover the needs of all fields of research. This is a serious problem for the fields of biosciences and environmental research that depend heavily on infrastructure. Infrastructure use is currently fragmented and to some extent inefficient. A broader assessment of common needs and the development of joint national strategies for infrastructure acquisition and use would facilitate optimised infrastructure use, the hiring of permanent staff and the taking of a longer-term view on the replacement and

1 Löppönen Paavo, Lehvo Annamaija, Vaahtera Kaisa and Nuutinen Anu (eds.) 2009. The State and Quality of Scientific Research in Finland 2009. Publications of the Academy of Finland 10/09.

development of infrastructure. In these areas, the Academy of Finland has an important coordinating role to play based on the targets specified.

The planning of infrastructure use calls for closer national and international collaboration. Biocenter Finland and CSC – IT Centre for Science are good examples of this type of broadly-based infrastructure cooperation. Biocenter Finland is committed to promoting bioscience and biomedicine development in Finland by coordinating the development of emerging technologies. The Biocenter has won broad acclaim for its work, and it is considered important that it can continue this work and that it can be further improved. CSC, then, provides IT support and resources to universities, research institutes and private businesses: modelling, computing and information services.

Finland is involved in many international collaborations such as EMBL, EMBO, European infrastructure projects (e.g. LTER and LTSER) and the CSC supercomputing infrastructure. All these collaborations facilitate shared infrastructure use beyond the national level. Scientists working in different fields also make use of specific international infrastructures within their respective fields, such as protein crystallography and marine research vessels. On the other hand, there is a widespread perceived need for the introduction of new methods aimed at closer collaboration with major European centres (e.g. nanoimaging at the European XFEL Centre).

Forest sciences, agricultural sciences as well as ecology and environmental sciences all depend on field studies that make use of Finland's extensive network of research stations and laboratory facilities as well as marine research and water research infrastructures. Network cooperation that has developed favourably in recent years should be further promoted.

Key national infrastructures in Finland include SMEAR (Station for Measuring Forest Ecosystem-Atmosphere Relations) and FinLTSER (Finnish Long-Term Socio-Ecological Research Network), which are crucial to ensuring the framework conditions for Finnish research excellence. The time series collected at the Hyytiälä SMEAR II station using diverse methods of measurement shed important light on atmospheric and boreal ecosystems as well as on the interactions between climate change and the biosphere. This information will help scientists better understand natural feedback mechanisms in the atmosphere and explore possible ways of combating climate change.

FinLTSER accumulates long-term time series for research and monitoring purposes in currently nine areas in Finland, including land ecosystems, fresh and brackish water ecosystems, and agricultural and urban environments. Smart systems have been developed among others for monitoring and studying the Baltic Sea, providing real-time information on the state of the marine environment for purposes of modelling development and predicting future changes.

Researcher training

The Finnish graduate school system has been up and running for almost 20 years now. The previous report on the state and quality of scientific research in 2009 described the Finnish system of PhD training as diverse, broad-ranging and systematic. The graduate school system has contributed to strengthening PhD training in this field, to increasing productivity and to improving cooperation between universities and research institutes. At the same time, it has helped create good interaction between new scientists entering the field and those who on completion of their doctoral studies move over to work in business and administration. One of the main concerns raised in the biosciences and environmental research workshops organised for the current, 2012 review of the state and quality of scientific research in Finland was that the failure of universities to work together closely enough in researcher training might result in the loss of advantages of the nationally integrated system. Smaller fields in particular have serious concerns about how their researcher training will be organised in the future.

> Food safety and healthy eating are paramount to a healthy everyday life. Securing food safety and exploring the associations between nutrition and health depend on high-quality research in this field. For instance, much of the research conducted at the Finnish Centre of Excellence in Microbiological Food Safety Research is concerned with human intestinal microbes, food-borne diseases, bacterial properties and microbe-host interactions. The significance of food and its various ingredients to a healthy everyday life has also been addressed in a number of the doctoral theses of the Finnish Graduate School on Applied Bioscience: Bioengineering, Food and Nutrition, Environment (ABS).

In recent years, major advances have been made in developing the Finnish research career system. University tenure track systems help strengthen the commitment of talented young people to a career in science and research. As yet there are not enough tenure track vacancies at universities, and overall the system needs to be further strengthened. This will at once provide a more solid base for recruiting new professors in place of those who will be retiring over the next few years. The FiDiPro system (Finland Distinguished Professor Programme) should be assessed for its efficiency and at the same time new strategies developed for the recruitment of talented young researchers who are on the earlier, third level of their research careers. This will also facilitate targeted recruitments in areas where there is a competence deficit in Finland.

Research cooperation and mobility

Several international evaluations of biosciences and environmental research in Finland have drawn attention to the problem of inadequate national and international mobility and cooperation. The Finnish research system is quite small when compared to the major science nations, and international mobility is therefore paramount to reaching the forefront of science and to pushing its boundaries. International engagement is also an important asset for anyone seeking employment in other sectors of society or in business. In this globalising world, experts in every area need to have skills of international cooperation, regardless of what type of job they are doing. International experience is particularly invaluable for job prospects with an international organisation such as the EU, OECD, UN, World Bank, FAO, UNEP, UNDP, IUCN, WMO or HELCOM. The development of the European Research Area calls for increased cooperation with other European countries.

The Research Council for Biosciences and Environment has on earlier occasions, too, drawn attention to the inadequate support available for researchers with families and to the problems they face on returning home from abroad. Researchers are less willing to move abroad because they are concerned not only about their family, but also about their own employment prospects when they get back. To reduce these obstacles, framework conditions for international mobility should be further improved with a view to making mobility more attractive and rewarding. National cooperation and mobility should also be promoted. Cooperation through doctoral programmes has contributed to promote the integration of the Finnish research system.

Business cooperation

A current problem in many fields of biosciences and environmental research is the lack of commercial innovation capability in the business enterprise sector. A stronger capacity for innovation would allow for closer business cooperation and help translate the results of basic research into practical products and services. In the food and pharmaceuticals industries, for instance, there are only very few major companies that have the resources to invest in R&D and to hire PhDs with specialised training. Corporations such as Valio, Kemira, Raisio, Neste and major forest industry companies have sufficient economic potential to make significant R&D investment. Growth companies, by contrast, are often smaller players with limited opportunities to hire specialised experts. The Academy and Tekes, the Finnish Funding Agency for Technology and Innovation need to work more closely in areas where basic research can link up with an applied business interface. Businesses often tend to view basic research projects as too risky for their investment. However, these projects also have the potential to deliver significant benefits. The development of Strategic Centres for Science, Technology and Innovation to ensure that they make better use of basic research will also facilitate closer industry-academia cooperation. Cooperation with foreign businesses should also be encouraged, especially in areas of application where there are no domestic operators.

In the global economy, Finland has profiled itself as a prominent investor in, and developer of, knowledge-intensive production. Not only products but also knowledge-intensive services and the export of expertise constitute a significant portion of the Finnish economy and export opportunities. Traditional exports of expertise need to be backed up by scientific excellence and target-oriented planning, part of which is the assessment of scientists' and researchers' international experience. In the forestry sector, for instance, expert tasks include the development of forest inventories, good administrative practices and ecological studies with Brazil, China and India for monitoring, reporting and verification purposes in line with the REDD+ framework.

> The development of antibiotic-resistant bacteria has emerged as a major threat to the health of both humans and animals. Microbes play a significant role in the early stages of the food chain, and any disruption to the function of microbes can have far-reaching consequences. Microbiological research in Finland is of a very high standard, but the field is rather fragmented and there is not strong enough industry cooperation. Industry-research cooperation in particular needs to be supported through an umbrella organisation.

Improving knowledge and awareness about biosciences and environmental research

General awareness about biosciences and environmental research has shown some improvement. For instance, the public health and economic implications of cerebral diseases and disorders has brought increased exposure in society to neurosciences and paved the way to their recognition as an independent discipline. However, there are many fields where more active information is needed to highlight its scientific and social impact. The Crafoord Prize awarded to Professor Ilkka Hanski has received surprisingly little attention in Finland, given that it is often described as the equivalent of a Nobel Prize for biosciences.

A shortage of bioinformaticians impedes the development of various fields of biosciences and environmental research. For instance, in order to achieve potential breakthroughs in molecular biology and genomics, a change through bioinformatics is needed in the way these disciplines work and in their methodological foundation.

The development of genetic sequencing technologies has brought a phenomenal increase in the amount of data that need processing, but it is just not possible to analyse them all. There is a shortage of both competent people and to some extent of computing capacity. For this reason, many datasets remain underutilised or completely unused. A cohesive development strategy is needed for the bioinformatics field, and substantial investment is needed so that bioinformatics research units and teams can hire the experts they need. So great is the demand for both Finnish and foreign experts that even the strongest Finnish teams are having difficulty recruiting high-calibre experts. Bioinformatics is a discipline where the basic skills acquired can also be applied to such areas as the development of communication technologies. It is felt that funding for basic research is hard to come by, which is hampering progress and development in the field. Bioinformatics has wide-ranging application in such areas as ageing research and healthcare and welfare studies, both of which are directly relevant to the Academy's strategy and the grand challenges it has defined.

Biosciences and environmental research: strengths, weaknesses, opportunities and threats

Strengths

- Basic research is of a high international standard, in some areas it is cutting-edge.
- Most research is characterised by high levels of international engagement.
- Existing skills and knowledge are strong enough to meet global environmental challenges.
- Projects are multidisciplinary and interdisciplinary by nature.
- There are close links between science and practical applications.
- Both the biosciences and environmental research have a strong national and well-networked graduate school system and several high-quality doctoral programmes.
- Funding is readily available for mobility and internationalisation.
- Tenure track systems have been launched at some universities.
- Finnish PhDs and postdoctoral researchers have demonstrably high levels of competence.
- PhD placement rates are high in most fields.
- Biocenter Finland and other shared national infrastructures.
- Long time series, databanks and information resources collected by research institutes and research stations.

Weaknesses

- There is a shortage of bioinformaticians.
- The full cost model has adversely affected success rates for Academy funding, creating inefficiencies and undermining motivation.
- There is a scarcity of high-risk funding.
- Disciplines are increasingly fragmented; in some fields there is a lack of critical mass and national cooperation.
- Some fields suffer from a shortage of students and researchers with necessary maths, physics and chemistry skills.
- There is no strategy in place for the recruitment of foreign students.
- Tenure track system is lacking at most universities.
- There is not enough national and international mobility.
- High age at PhD graduation.
- Lack of organised infrastructure use and funding mechanisms in some fields.
- Shortage of staff specialising in infrastructure use.

Opportunities

- Bioinformatics skills and competencies are improving.
- High standards of skills and knowledge in bioeconomy solutions.
- Increasing cooperation between natural sciences and social sciences.
- Consortium funding is on the increase.
- Regeneration and revitalisation through generation changes.
- FiDiPro funding for younger but established research career stages (stages 3–4 of research career ladder).
- Increased cooperation with EU countries, Nordic countries and BRIC countries (Brazil, Russia, India, China) and development of systematic international cooperation.
- Early internationalisation, family subsidies, support for repatriation.
- Work underway to develop mechanisms for international student and teacher exchange.
- Increased funding opportunities for high-risk projects.
- Increasing cooperation between academia and industry in research and PhD training.
- Businesses showing growing interest in the practical application of research results.

Threats

- Constrained access to funding for basic research (e.g. continuation of full cost model).
- Failure to achieve greater scientific impact.
- Fixed-term contracts are at odds with sustainable research careers.
- Finland does not appeal to top foreign researchers and PhD students.
- Recruitment difficulties and shortage of motivated PhD students.
- Motivation of researchers on the decline.
- The decommissioning of networked national doctoral programmes adversely affects competition and collaboration between graduate schools.
- The mobility of Finnish researchers and PhD students is constantly decreasing.
- Funding available for Biocenter Finland is on the decline.
- Ageing of hardware.
- Funding for information assets and time series is drying up.

Development proposals

Steps are needed to bridge the competence deficit in bioinformatics. Finland needs a strategic plan of action for the next few years ahead in order to bridge the bioinformatics competence deficit in the biosciences. This plan must take long-term account of the qualification requirements in the biosector, opportunities for interdisciplinary cooperation, continuing education needs in bioinformatics and the international recruitment of bioinformaticians. Adequate resources must be made available to bridge the competence deficit.

Optimum infrastructure use requires closer strategy-based national and international cooperation. The recommendations laid down in the national infrastructure roadmap for biosciences and environmental research continue to remain relevant. Finland must aim to achieve an internationally leading position in areas of existing strong competencies, infrastructures and information assets. The Finnish LTSER and its collaboration with international LTSER networks further the production of environmental knowledge, the open dissemination of that knowledge and its application in different ecosystems. The future of Biocenter Finland must be secured, and the centre must make the best possible use of its position and coordinating role to develop national infrastructures. The state-owned CSC – Finnish IT Centre for Science can provide broad support for biosciences and environmental research in the areas of IT solutions, software development and computing capacity. Stronger strategic cooperation is needed in several fields to ensure that infrastructures are up-to-date, to optimise infrastructure use and to avoid overlap in investment.

Steps are needed to improve the effectiveness of Academy of Finland funding. Funding approval rates must be significantly increased in order to minimise the unnecessary burden on clients, i.e. researchers and research teams. Allocations for overheads as a percentage of total funding must be reduced; the current percentage of close to 100% is too high. The applications approval rate can be increased by setting a maximum value for overheads in line with the EU's forthcoming Horizon 2020 Framework Programme, where overheads will be capped at 20%. Academy of Finland FiDiPro funding opportunities should be targeted at younger scientists and researchers than is currently the case. One important target group consists of researchers who have recently completed their Academy Research Fellow term and who have gained their qualifications abroad. Funding for high-risk ventures must be increased. Research projects must also get more of their funding from EU sources.

International mobility must be encouraged and promoted at all stages of the research career. Support must be increased for researchers with families and equal opportunities provided for mobility. Mechanisms must remain in place to ensure that it possible and indeed an attractive option for researchers to return to Finland after spending periods abroad.

2.2 Cultural and social research

Distinctive characteristics of cultural and social research

The area of research covered by the Research Council for Culture and Society is characterised by its diversity. Interdisciplinary and multidisciplinary cooperation has continued to increase, which has opened up new research approaches and perspectives. Natural science methods, for instance, have gained increasingly prominence among the tools and datasets used in the fields of research under the Research Council. The concepts and views produced by humanities and social science research will have increasing impact throughout scientific research in general.

The fields of cultural and social research are characterised by the interweaving and interaction of distinctive national features and international engagement. National research is not and has never been a purely national exercise; doing science is inherently a dynamic process of international interaction. Another distinctive feature of the humanities and social sciences is that they are contextual, tied to a certain time and place. The national endeavour for disciplines interested in culture and society is to understand the nationally specific in what is a changing world. Finnish researchers, therefore, have a specific responsibility to explore Finnish culture and society, and to some extent, Nordic culture and society. In this process, the aim is both to strengthen the Finnish contribution to the international scientific debate, and at the same time to maintain the high international standard of research. Even though the focus is on national issues, it is important to have a close knowledge of the latest theoretical and methodological advances in the international scientific community.

Universities and research environments have seen a wave of changes in recent years. The constant process of restructuring has its flip side as well: in some areas, the lack of coordination has brought a growing workload for professors in particular, leaving them with less time for research. Furthermore, the scarcity of core funding in many areas of cultural and social research has necessitated external funding to support basic operations. The Academy of Finland continues to remain the most important source of external funding in these fields, although funding from the EU has gained increasing importance especially in the social sciences.

Researcher training in the fields of cultural and social research has undergone significant professionalisation. National graduate schools have performed excellently, providing high-class training. Publication practices continue to remain in flux, and the numbers of both international and co-authored publications have increased, even though monographs and edited volumes continue to have a strong position in the humanities.

One important future opportunity for cultural and social research is to set up new, creative forms of flexible cooperation with other disciplines. Social and scientific upheavals are often crucial turning points that can pave the way to new lines of scientific inquiry. The need for research evidence from the humanities and social sciences is pronounced at these key turning points in social development, in the wake of increasing globalisation, inequality and complexity. Many of the themes related to the specific grand challenges identified by the Academy of Finland call for cultural and social research.

The current climate of austerity in central government finances, coupled with escalating competition for research funding, presents a severe threat to all fields of cultural and social research because of the continued scarcity of alternative funding channels. A loss of autonomy in science and self-direction in research would seriously undermine the identity of research fields and compromise the framework conditions for doing research.

Cultural and social research: strengths, weaknesses, opportunities and threats

Strengths

- Research and researcher training in the fields under the auspices of the Research Council for Culture and Society are of very high standards.
- Cultural and social research is a diverse and wide-ranging field of study where different lines of inquiry work closely and effectively together.
- Many fields have well-established research traditions, a sound, theoretical foundation and a prominent international position.
- Even smaller fields of research are internationally well networked.
- Many fields are characterised by a strong multi-method approach, creating extensive and close links with other disciplines. Researchers in these fields are very much in demand as partners for multidisciplinary projects.
- Researcher training is of a high standard and PhD placement rates are very high, not just in universities but also in other sectors of society (e.g. arts research, theology, economics, education, social sciences, law).
- Disciplines under the auspices of the Research Council for Culture and Society are characterised by:
  - Interaction and exchange between the national and international
  - High levels of expertise in cultural identities and dialogue
  - High societal impact of research.
- The sector provides training for multiskilled and multitalented experts and puts them at the service of society.

Weaknesses

- Core funding for universities is inadequate, academic support services of research are limited and the ratio of teaching staff to students is low.
- Professors and other staff on permanent contracts have limited opportunities for research spells.
- Research funding is project-oriented, which detracts from diversity. In some fields, funding pressures push researchers towards applied research.
- There is still not enough international research funding, and there is substantial need for academic support services for research, including staff that can assist with application processes.
- Infrastructures are fragmented, and high costs limit access to analysis-ready datasets and registers.
- Most research activity is conducted through projects, which does not support the long-term development of research environments.
- National mobility is limited despite structural reforms.
- The number of international publications is still low, although this varies widely across different fields.
- The management and administration of research teams is not always professional.

Opportunities

- The funding of universities is shifting to put greater emphasis on quality.
- Larger university units enable new forms of cooperation.
- Advances in science are paving the way for new innovative, transdisciplinary lines of inquiry and to new research designs, such as experimental interventions.
- There is a growing demand for research in society in response to the challenges of globalisation and increasing multiculturalism, for instance.
- Interdisciplinary dialogue has increased, new research interfaces have been identified, a new kind of applied cooperation has strengthened (e.g. through the application of natural science and engineering methods).

- Many of the research themes related to the grand challenges facing society make up part of the core competence of researchers in the humanities and social sciences.
- International cooperation has assumed many new forms, and Finnish researchers have a growing role in international networks and research teams.
- The number of international publications from Finnish researchers has increased, and there are more Finnish experts on the editorial boards of international journals.
- National infrastructures (libraries, museums, archives, datasets, registers) must be developed (digitalisation, systematisation of datasets, dataset accumulation, development of joint data storage facilities).
- Steps are needed to develop tenure track and research leave systems.
- The development of PhD training can also contribute to improving postgraduate education.
- There is a demand in different sectors of society for PhD graduates in the fields of cultural and social research.

Threats

- The general appreciation of education in society may be eroded, universities and research organisations are at risk of being overcome by bureaucracy.
- Escalating competition may dilute the identity of humanities and social science research.
- Rapid, simultaneous and unpredictable changes occurring in the operating environment and short-sighted science policy.
- Inter-unit competition and lack of coordination in how units profile themselves may undermine research cooperation.
- Universities are threatened by a scarcity of resources.
- Funding allocated to basic research and relevant funding sources are decreasing.
- The full cost model for external funds of universities means that fewer researchers are hired in increasingly expensive projects, and consequently, that the overall number of projects funded is continuing to fall.
- Pressures of internationalisation are contributing to increasing detachment between research and public debate in Finland.
- Some lines of cultural and social research are at risk of being relegated into auxiliary disciplines and/or practices of technical expertise.
- Publishing practices may sit uncomfortably with the needs of research in the humanities and social sciences (output indicators that favour natural sciences).
- The costs of obtaining research datasets are rising, complicating access and creating inequalities between researchers.
- A career in research holds little attraction, there are difficulties with recruitment, and short-term employment is increasing.
- National cooperation in PhD training will be compromised if the funding allocated to researcher training is reduced and if the new structures create unhealthy competition.
- The future of networked doctoral programmes is uncertain.

Summary

Universities occupy a pivotal role in the Finnish research system, and any changes in their role therefore have significant repercussions. The joint institutions created in the humanities and social sciences in connection with the reform of university legislation have opened up new research opportunities and paved the way for interdisciplinary cooperation. However, the mere fact that two units are placed under the same administration does not necessarily generate cooperation.

In some areas of cultural and social research, an overzealous targeting of funding has meant that research themes are chosen on the basis of other than genuine research interests, for instance on their media appeal. Other, often smaller disciplines with well established research traditions are in turn at risk of decline as their existing professor retires. Human resources planning at universities should be geared towards supporting the development of smaller disciplines.

The workshops organised in connection with the 2012 review of cultural and social research in Finland highlighted a fundamental paradox: the fragmentation of this field of research is indicative not only of its ability to reinvent itself, but also points at the need to strengthen a common national research strategy. Steps are needed to further strengthen the strategic partnership of the Academy of Finland and universities.

Development proposals

The development proposals submitted by the Research Council for Culture and Society are addressed to the Government, the Ministry of Education and Culture, universities, the Academy of Finland and other research funding agencies.

Global challenges, national research system, Academy of Finland funding

- Public research funding must be strengthened.
- Steps are needed to ensure a sufficient amount of competitive research funding.
- National science policy must reflect global perspectives and the ethical dimensions of research.
- Adequate support must be provided to shore up national disciplines.
- The partnership between the Academy of Finland and universities must be reinforced.
- National strategic planning must be increased in the humanities and social sciences.
  - E.g. the Research Council should organise a seminar or workshop focusing on the future of different fields and their current themes of specific interest.
- A larger proportion of Academy funding must be allocated to established, leading-edge research teams and researchers, without neglecting new emerging fields of research.
- The Academy of Finland should encourage researchers to take on sufficiently ambitious projects, to follow new innovative lines of research, and to engage in interdisciplinary cooperation.
- Skills and competencies in the fields of cultural and social research should be marketed to Strategic Centres for Science, Technology and Innovation, and researchers for their part should make more effective use of Strategic Centre cooperation.

Research career and doctoral training

- National collaboration must be stepped up by facilitating cooperation among universities and by clarifying the structures and processes of doctoral programmes.
- Steps are needed to broaden the appeal of a career in research:
  - Academy project funding should better reflect the need for auxiliary support services in research, such as the need for assisting research personnel.
- Tenure track and research leave systems must be firmly established.
  - It is necessary to consider reinstating a funding mechanism comparable to

the Academy's former Senior Scientist funding.
- The networked national graduate school system must be retained in PhD training.
- The level and spread of national PhD training programmes must be adjusted based on education needs assessments.
  – PhD placement rates in different sectors of society vary across different fields of research.
- It is necessary to ensure that doctoral studies in the fields of cultural and social research can even in the future be carried out without having full-time graduate school funding.

International engagement, mobility and networks

- The recruitment of top international researchers as well as high-quality international cooperation must be stepped up.
- Mobility and networking must be increased.
  – E.g. research spells abroad must be long enough.
  – Early-stage researchers in particular should be encouraged to greater mobility; postgraduate studies, for instance, should include a research spell abroad.
- Success rates on international funding applications need to be increased, for instance by sharing good practices.
- International publishing must be facilitated.
- Nordic cooperation and networking must be strengthened.

Research infrastructures

- Research infrastructures in the fields of cultural and social research must be strengthened and related skills and competencies developed.
- The availability of library materials and services must be improved.
- Researchers must be encouraged to set up new national infrastructure projects.
  – E.g. the Finnish Social Science Data Archive at the University of Tampere and other similar archive facilities must be strengthened.
- Statistics Finland data must be made more readily accessible.
  – Negotiations should be conducted between Statistics Finland, Universities Finland UNIFI, the Ministry of Education and Culture and the Academy of Finland with a view to providing more diverse and reasonably-priced access to Statistics Finland data.
- Data and materials collected with public funds must be made available to scientists and researchers free of charge.
- Research funding must take into account the costs of market-oriented materials, licences and library databases.

The Research Council for Culture and Society considers it paramount that research in the fields it represents continues to make headway and to have a visible role in society. The Research Council's key objectives are to promote and strengthen the Humboldtian-model university, the autonomy of science and researcher-driven basic research.

2.3 Natural sciences and engineering research

The changing operating environment

For the disciplines that come under the Research Council for Natural Sciences and Engineering, the most significant changes in the research, development and innovation (RDI) environment in recent years have been the introduction of a new University Act and the university reform, the establishment of Strategic Centres for

Science, Technology and Innovation, the restructuring of sectoral research and the challenges arising from globalisation and mounting international competition.

It is still too early to offer a full assessment of the university reform and its impact. Universities have gained greater financial room to manoeuvre, and their funding has become more sustainable. Government now requires that universities profile themselves more clearly and invest in structural development. External evaluations conducted of disciplines and universities provide important points for purposes of profiling. Excessive self-profiling may also be counterproductive, complicating the growth of new emerging fields as well as mobility in Finland.

Strategic Centres for Science, Technology and Innovation are by now well-established in Finland. However, the experiences so far are rather contradictory. In practice, basic research has remained in a marginal position in the Strategic Centre framework, despite the willingness to support research excellence.

The role and functions of government research institutes remained a matter of ongoing debate. It is important that research institutes function properly and that they have good collaboration with universities. The creation of a joint forum for research institutes and universities would facilitate collaboration with the commercial and public sectors.

Major international research infrastructures are taking on a more prominent role in many fields. The Finnish presence in these infrastructures is not strong enough. Research conducted within these infrastructures produces world-class publications and increases the international visibility of Finnish research. In general, international engagement is becoming more and more important.

Globalisation calls for an international division of labour. Projects are on an increasingly large scale, and contributing partners must be large as well. Research teams in Finland should focus on being the best in selected key areas. Global business companies have been making some moves to acquire Finnish-based units. This trend should be supported in order to create and strengthen high-technology clusters.

International engagement

International mobility from the natural sciences and engineering fields in Finland is still not high enough. Incentives to spend periods abroad must be developed. Even shorter spells abroad can be beneficial and are often a more appealing idea for researchers with families. It is also worthwhile to support Nordic cooperation because it brings added value and helps to push things forward. In engineering fields in particular, the mobility of senior scientists is often complicated by their involvement in short-term applied projects and their close dependence on domestic networks.

At universities, new career systems and above all postdoctoral positions and professorships under the tenure track system have boosted international recruitment. The aim is to hire a larger proportion of international staff at all levels and to ensure that Finnish research personnel have enough international experience as a result of spending postdoctoral periods abroad, for instance. Direct collaboration among scientists and researchers is often more fruitful than funding agency cooperation, where the need to strike compromises easily leads to the best possible projects or the Finnish research strategy being sidelined.

International Master's programmes and the increasing recruitment of foreign postdoctoral researchers in Finland is a welcome trend in development. One reason why this is so important is that young people in Finland no longer show quite the same interest in natural sciences and engineering as they used to. EU doctoral programmes such as Erasmus Mundus and Marie Curie are considered to be quite good, but Finnish participation in these programmes is not strong enough. It is also important to provide support for universities to hire foreign personnel.

International funding, and EU funding in particular, tends to encourage the formation of larger consortia, which is not necessarily ideal from an efficiency point of view. Furthermore, the application process is notoriously bureaucratic. Support from universities is needed here. Many universities have now signed agreements of cooperation both in research and for the provision of degree programme tuition. Under these agreements, the expertise of these networks of cooperation can also be placed at the disposal of interested industry partners.

It is a welcome trend that under the new EU Horizon 2020 Framework Programme, an increased proportion of funding will be allocated to basic research. Furthermore, the European Research Council (ERC) will gain a more prominent role.

Strategic Centres and business cooperation

Strategic Centres for Science, Technology and Innovation are by now well established. However, the experiences so far are rather contradictory. In practice, basic research remains in a rather marginal position in Strategic Centres, despite the willingness to support cutting-edge research. Opportunities for long-term researcher-driven projects are quite limited in the Strategic Centre framework. Strategic Centres do not produce world-class research results that contribute substantially to the national economy, and several top research teams are completely excluded from Strategic Centre funding. This situation might change with the launch of the Academy's Strategic Centre projects. On the other hand, the Strategic Centre concept has given businesses increased opportunities to engage in long-term RDI and generally increased industry-academia cooperation.

External funding for research at universities and government research institutes is at a comparatively high level in Finland. However, this funding is often quite fragmented and short-term, which detracts from research teams' risk-taking capacity. Businesses in particular are unable or reluctant to invest in high-risk research projects whose outcomes are uncertain or a long way off in the future. Funding is very tight under existing mechanisms, and it is often impossible for researchers to find the resources they need to turn their development efforts and findings into an academic report or thesis. There is also a need to invest in training and education so that inventions and innovations coming out of research can be put to practical use through existing or new spin-off companies. The number of new spin-off companies founded is not high enough considering the current level of investment. Industry needs competent PhDs with diverse backgrounds so as to keep production and product development in Finland and to reduce the threat of companies moving out to other countries. Training and education should focus on teaching the tools of learning; jobs, technologies and industries are changing and developing at breakneck pace, and existing knowledge is becoming outdated and inadequate at an ever accelerating rate.

It is also difficult for public funding agencies to identify high-risk/high-gain projects. In the current environment of intense competition for research funding, public funding agencies are inclined to turn to the safest choices: only the most established teams can secure the funding they need. This obviously curtails the chances of significant new breakthroughs. Dependence on external funding has the effect of pushing research in a more multidisciplinary and applied direction, which of course has its positive effects, but in the natural sciences in particular it is possible that core basic research may suffer as a result.

Size of research teams

The optimum size of research teams and consortia can vary widely in different fields. International funding and an overly top-down approach encourage the formation of large consortia, which are not necessarily the ideal solution from an efficiency point of view. In input/output terms, communities built around personal contacts and a clear focus certainly have the upper hand.

However, new transdisciplinary fields do require larger research teams and set-ups. The current system where professors are nominated to individual disciplines serves to perpetuate the existing fragmentation and effectively hampers the development of multidisciplinary clusters. Approaches that cut across the boundaries of units, faculties and departments are needed to support the development of multidisciplinary environments.

National forums

For transdisciplinary fields such as energy engineering, geosciences or materials science and engineering, it is especially important to create national forums that monitor the development of the fields themselves and consider what response is needed to the changes in the country's industrial structure over, say, the next 5–10 years.

As national graduate schools are being phased out and taken over by university doctoral programmes, it is important to have broad dialogue about the content and volume of doctoral training programmes. Several universities have launched their own tenure track programmes. National discussion forums addressing the future of tenure track systems, especially in multidisciplinary fields, need to be established to support unit and faculty decision-making.

Education

One of the concerns for natural sciences and engineering fields is that as age groups continue to get smaller, so the number of upper secondary students choosing to take extended maths and natural sciences will continue to fall. At the moment, the number of students taking these subjects in the matriculation examination (in 2011, the number of students who took extended maths was around 10,000) is clearly lower than the number of available places at universities and polytechnics (some 15,000). Natural sciences and engineering fields are not getting enough high-achieving students. It is clear from the small proportion of women among students that there is untapped potential. The proportion of women declines steadily with career advancement, and there has been no improvement in this regard over the past ten years.

National graduate schools have played a key role in creating new areas of national strength (e.g. computational science). In smaller disciplines, graduate schools have made it possible to provide internationally competitive and broad enough study programmes. In addition, graduate schools have significantly furthered national networking and cooperation between universities and research institutes. It is important that these advantages are retained as the funding mechanisms for doctoral training are upgraded.

Research infrastructures

Natural sciences and engineering research often depend on expensive and large infrastructures, and with this in mind, a roadmap for national-level research infrastructures has been created to ensure appropriate prioritisation. In the future, it is important that strategic planning also comprises those (often international) infrastructures that are administered via independent organisations and that therefore are not included in the current roadmap. Lack of sufficient infrastructure investment has meant that the Finnish contribution to international research infrastructures and projects is smaller in relative terms than in other Nordic and smaller European countries, which in turn is reflected in a lower level of research impact in international comparisons of citation indices, for instance.

University research infrastructures are rapidly ageing, and the current level of university investment is not sufficient to replace the outdated equipment at a fast enough pace. At least so far, the introduction of the full cost model has not brought sufficient improvement to this.

Natural sciences and engineering research: strengths, weaknesses, opportunities and threats

Strengths

- Finland has several world-class research teams.
- National and international contacts are strong.
- Research has a strong industry background and well-developed links with business.
- Research in natural sciences and engineering has significant societal impact.
- There are strong national graduate schools in the natural sciences and engineering fields, with high job placement rates.

Weaknesses

- Finland has lacked both a clear research infrastructure strategy and infrastructure funding mechanisms.
- National and international mobility continue to remain low.
- The innovation chain does not work: there are no mechanisms in place to translate research-driven ideas into practical applications.
- Most research work is done by postgraduate students; there are not enough scientists and researchers at the postdoctoral level.
- Funding is fragmented and too heavily oriented to applications-driven research, particularly in engineering fields.

Opportunities

- Women are more actively encouraged to enter natural sciences and engineering fields.
- EU and other international funding sources are used more effectively.
- Cooperation and recruitment is increased with BRIC countries (Brazil,

Russia, India, China) and other emerging countries.
- New innovative uses are developed for domestic natural resources.
- The potential of natural sciences and engineering is used more widely in solving the grand challenges facing society.

Threats
- Industrial activities are relocated from Finland.
- Research infrastructures and their creative research environments are eroded in the absence of adequate funding.
- Finland decides to opt out of major international research infrastructures.
- An inadequate recruitment base means that there is insufficient infusion of talent into natural sciences and engineering fields.
- Academic research at research institutes is threatening to dry up.

Development proposals

Position of basic research
- Funding for basic research must be strengthened in order to facilitate and promote new innovative breakthroughs and high-risk research projects.
- Strategic Centres for Science, Technology and Innovation should give greater focus to the delivery of long-term, sustainable research. Part of the funding for Strategic Centres' research programmes should be provided through open calls, without specifying research subjects in advance.

Mobility and international engagement
- Finnish scientists and researchers must be encouraged to more active international mobility.
- Increased support must be made available for the recruitment of foreign PhD-level researchers into Finland.

Research infrastructures
- A workable decision-making and funding mechanism must be established for research infrastructures.
- All research infrastructures, including those that are not on the national or EU roadmap, must be included in the development of a national research strategy.
- The costs associated with the maintenance and upgrading of local infrastructures must be covered from research organisations' core budgets.

Demonstrating the importance of natural sciences and engineering research
- Steps are needed to enhance the appeal of natural sciences and engineering fields. It is important to share information more widely in schools and throughout society about their role in addressing and resolving major global challenges.
- National forums must be established in transdisciplinary fields for the exchange of views on strategic orientations in these fields, including infrastructure decisions and the coordination of doctoral training programmes and tenure track systems.

2.4 Health research

Finnish health research enjoys a strong international position

Finnish health research is high quality, high impact and international. In several branches, health research has achieved an internationally recognised position. Key areas of strength include research that takes advantage of new biomedical technologies, cancer research, clinical diabetes research, and the newest forms of epidemiological research. Studies into different stages of the life span, such as child research and research into ageing-related neurodegenerative diseases, are other noteworthy examples. There is also a strong tradition of research into disease prevention. Finnish nutrition research is internationally very highly rated, while research in the field of pharmacy has made important advances with its studies on the effectiveness of pharmaceutical treatments, for instance. There are, however, also some fields that face significant development challenges. Finland has long been a pioneer in register-based research, but it has now been losing its international advantage. There are also many threats to the positive development of clinical research. The development of dentistry, another field that meets high international standards, is crucially hampered by the shortage of academic researchers and teachers with a doctorate, a result of short-sighted and poorly thought-out science policy decisions since the 1990s.

The field of health research has been affected by growing competition in the past ten years. In the future, it is important that funding reflects the high international standards, the high impact and diversity of research in this field. Given the right set of circumstances, Finnish health research has the potential to achieve significant and internationally high-quality results.

Development of framework conditions for research lacks long-term, sustainable approach

The chief weakness of the Finnish health research environment is the lack of long-term sustainability. Science policy in the area of health research is neither systematic nor consistent. Research funding is short-term and fragmented. This significantly hampers any attempt to create a strong research team, which can easily take ten years. Flexible and appropriate funding channels can speed up the process in which results from basic research are translated into improving treatments. On the other hand, clinical practice can set new challenges for basic research. For the advance of science, it is paramount that adequate resources are made available for researcher-driven basic research.

The university and research institute environment is currently fragmented. Universities and government research institutes should work more closely together to pool their limited resources and make the best possible use of their respective strengths in research. Government research institutes make a very significant contribution to Finnish health research. However, in the wake of the restructuring of sectoral research it is evident that the long-term sustainable research has suffered. Budgets have been slashed and research funding has been cut. Part of the funding has been reallocated to development. There is a growing demand now for fast-track evidence to support informed decisions and policy-making. This takes away from the time that could be devoted to more in-depth, anticipatory research, which is needed for longer-term strategies and which therefore needs to be supported. One specific development effort is the research consortium launched in 2011 to bring together a number of research institutes in the health field (SOTERKO). This consortium conducts research programmes that network research teams from both universities and research institutes.

Independence of junior researchers key to research reinventing itself

The graduate school system set up in Finland has amply demonstrated its value and efficacy. There have been several graduate schools in the health research field networked among a number of universities. If the funds for graduate school positions are not earmarked in universities' core budgets, there is a risk that universities' commitment to supporting networked graduate schools will be eroded. The biggest losers might be smaller fields such as pharmacy, dentistry and nursing science, which have needed national coordination in order to achieve sufficient critical mass and quality. It is important that in the future too, the allocation of doctoral student positions between different doctoral programmes is based on scientific evaluation. A key goal behind the reform of the graduate school system is to ensure that the doctoral thesis is completed during the four-year programme. Decisions on the allocation of teaching resources and content requirements for doctoral theses must be taken with this objective in mind.

It is difficult for postdoctoral researchers to secure funding at an early enough stage for them to set up their own research team, which ordinarily is a necessary step to become a recognised member of the scientific community. All this is further complicated by the ever-rising costs of doing research. Universities should have more research teams built around specific subjects or research questions as well as nationally and internationally well-networked research teams with newly graduated PhDs, more experienced scientists and docents. New teams could then grow out of these core groups as the research progresses.

In recent years, the main focus in the development of the research career has been shifted to the postdoctoral stage. Universities have developed various career packages, and the tenure track system in particular is an important development, particularly as it facilitates the formation of new research teams. The system ensures that there is sufficient competition and at the same time offers a clear path to permanent employment and a clear career outlook for the most talented researchers. However, the model does still need some fine-tuning, and it is important that the differences between individual disciplines are taken into account.

Forms of international cooperation in flux

Finnish health research is international both in scope and relevance. One clear indication of this is the large number of co-authored international publications. The contribution and collaboration of Finnish researchers as partners in international projects is very much in demand. Indeed, international cooperation is a good way for smaller research teams to find their own research niche and to network with other teams for continued success in international competition.

It is commonplace to emphasise the interdependence between mobility and career success in research. However, postdoctoral researchers today are increasingly reluctant to move abroad, or indeed to move at all for a research spell, mainly because of family reasons. Academy of Finland funding opportunities and the centralised pool of postdoctoral researchers maintained by foundations are important incentives in encouraging research abroad. However, the process of obtaining the necessary funding is laborious and time consuming. It is important that junior researchers have access to flexible funding mechanisms and that their mobility is encouraged.

The forms of international cooperation have changed and diversified in the 2000s. Instead of spending one long period working abroad, researchers can now make a few short visits instead and continue their international collaboration via computer link. Involvement in major international projects is an excellent way to build up international networks. Especially in fields where the standard of Finnish research has significantly improved, foreign research environments are no longer as attractive as they used to be.

Maintenance and replacement of diverse infrastructures have decisive impact on research standards

Funding for the maintenance and replacement of equipment and data infrastructures is crucial to high-level research. Researchers in Finland have quite excellent access to population-level registers and other data that put them in a unique position to produce high-quality research. Funds are often available for the collection of new datasets, but at the moment there is no regular source of funding for the maintenance of long-term follow-up data. The hardware and equipment needed for research at the highest level is very expensive and needs replacing every so often. The funding available for high-level research infrastructures is still inadequate to secure the development and maintenance of a competitive research infrastructure.

A strong research infrastructure also provides an important platform for industry cooperation in the development of new research equipment, for instance. Furthermore, high-quality research infrastructures pave the way to commoditising and commercialising research services, which can create additional resources for the development and maintenance of research infrastructures.

Research requires expertise in statistics and bioinformatics, but the availability of this expertise at universities and research institutes is inadequate. Mastery of the most advanced statistical methods is crucial to getting published in the most prestigious international publications. From a biostatistics point of view, not only data collection methods, but also the quality of the data collected must be given adequate attention. Bioinformatics skills and competencies have become ever more important as tools of managing and interpreting the vast amounts of data produced by new technologies. Universities and research institutes need to have facilities where postdoctoral statisticians or bioinformaticians can be full and equal members of the research team and contribute to the project's research, both through their own expertise and by acquiring the best possible expertise to support the team's analyses.

Research today takes place in an increasingly global environment. A nationally coordinated infrastructure system provides an excellent platform for participation in the European Strategy Forum on Research Infrastructures (ESFRI). Health research needs access to ever more extensive datasets that are compiled from sources in different countries. Rules governing the use of register datasets must be established for joint international projects.

Based on the findings and recommendations of an international evaluation, the Finnish biosector is currently undergoing a major restructuring programme with funding from the Ministry of Education and Culture. Conducted by Biocenter Finland in 2010–2012, this programme represents an internationally unique concept and a significant step forward that will see Finnish biocentres work more closely together to decide on their division of labour, to eliminate unnecessary overlap and to clarify their mutual responsibilities in the development and provision of technology services for the biosector. Indeed, the national coordination of infrastructure projects in the Finnish biomedical field has been highly successful. However, if centralised funding runs out, then there is a real risk that autonomous universities will descend into national and international competition instead of investing their efforts in national coordination.

Access to equipment operated by hospitals for research purposes is not easy. Research use is limited to periods when the equipment is not in clinical use, and there should also be much more support to facilitate research use.

Although register-based research and related competencies continue to remain strong, data systems and registers are beginning to fall behind developments internationally. The processing of research permits must be speeded up and all unnecessary bureaucracy surrounding the use of registers for research purposes removed. Work to upgrade and reform electronic patient information systems is lagging behind, and data protection issues may hamper research uses. Register-based datasets are often expensive, and it is difficult for university researchers to gain access.

The introduction and implementation of a biobank act will be hugely important to Finnish health research. It is crucial that legislation is put in place to support research that uses human-derived materials and that promotes human health and wellbeing. Furthermore, the Finnish act should be harmonised with European legislation.

Health research: strengths, weaknesses, opportunities and threats

Strengths

Development of health research

- Finnish health research enjoys a strong international position in several areas.
- Health research has built up a strong base of skills and competencies over a longer period of time. This base has allowed Finland to keep up with international advances in research technologies.

Research operating environment

- Finland has in place a comprehensive, high-quality public healthcare system and a public university system.
- Most people take a favourable view on research and are keen to participate in research projects. Recently this enthusiasm has been waning somewhat, but nonetheless remains reasonably strong.

Doctoral training and research career

- The existing graduate school system has demonstrated in value and efficacy. The standard of training provided is high.
- PhD placement rates are very high, in some fields the number of doctoral graduates is still too low.

International cooperation

- Finnish researchers contribute actively to international joint projects. Modern means of communication have facilitated research cooperation.

Infrastructures

- Research can draw on extensive population cohorts and hospital sample collections.
- A sound register infrastructure and research-minded data protection legislation allow for the use of register sources in different fields of health research.

- Patient data registers are high quality and reliable.
- Biocenter Finland has made good progress with its division of labour and activities.

Weaknesses

Development of health research

- Many fields rely on a very small number of top experts. Standards will suffer as soon as they retire or move out of the country.
- The number of researchers with a medical training has decreased. This trend undermines the prospects of translational research, which depends crucially on balanced two-way interaction between basic and clinical research.

Research operating environment

- Research funding is fragmented and lacks long-term sustainability. Changes made to funding instruments are often uncoordinated.
- The introduction of the full cost model has in real terms reduced the amount of funding available to research projects and increased bureaucracy.
- The university and research institute environment is fragmented: in many fields research teams are small.
- The amount of bureaucracy surrounding research has continued to increase.
- Academic support services designed to assist researchers with applications for international research funding, patent applications and with the use of bioinformatics and biostatistics are inadequate.

Doctoral training and research career

- Doctoral training takes too long because requirements for the doctoral degree are too extensive in international comparison.
- Compared to other countries and clinical practice, for instance, university researchers in the fields of health research are paid relatively little. This hampers the recruitment of medical doctors into doctoral programmes.
- The number of clinical researchers and the amount of clinical research have declined in Finland.
- There are not enough full-time professorships in clinical fields, and within the existing system part-time professorships do not provide sufficient opportunities to conduct research.

International cooperation

- Country differences in doctoral degree requirements present a challenge to international cooperation in doctoral training.
- Internationalisation is hampered by the failure of junior researchers to see the connection between researcher mobility and career success. Many postdoctoral researchers are reluctant to move abroad for a research spell, even if the funding were available.

Infrastructures

- There have been some complications with the use of register sources for research purposes. The content of health registers has begun to fall behind developments internationally.
- There is no regular funding mechanism for the maintenance of long-term follow-up data; funding is only available on a project basis.

Opportunities

Development of health research

- There is strong competence in the field of health research, providing a sound platform for the balanced development of basic research, clinical research and

translational and transformative[2] research. A virtuous research cycle contributes to improving public health and the efficiency of the service system (see also European Medical Research Councils EMRC 2011. White Paper II. A Stronger Biomedical Research for a Better European Future).
- Increasingly ambitious research projects pave the way to significant new breakthroughs.

Research operating environment
- Increased funding for health research has a positive effect on the quality of research, on the healthcare service system and on people's health (see also EMRC 2011 White Paper II).
- As public research funding from domestic sources becomes harder to come by, it is important to apply for funding from the European Research Council (ERC) and other international sources. A more active involvement in the preparation of EU research programmes will help to increase the prospects of securing more EU funding to Finland.

Doctoral training and research career
- Nordic and European-wide cooperation is increasing in doctoral training, but this requires sustainable funding as well as efforts to develop mentoring and guidance systems.
- The tenure track system and the new opportunities created by the system for career advancement after the postdoctoral stage give better opportunities to concentrate on research.

International cooperation
- International cooperation can help small research teams identify their specialised niche in research and network with other teams in order to strengthen their research capacity and to compete internationally.
- FiDiPro Fellow funding[3] facilitates the internationalisation of Finnish research environments.

Infrastructures
- Involvement in European-wide infrastructure projects is vitally important for the quality of Finnish health research. Successful integration with ESFRI projects would help to secure international research funding in Finland.
- A biobank and tissue act would give scientists access to samples and allow them to combine register data for research purposes. It would also include a research-friendly consent process.

Threats

Development of health research
- In the absence of appropriate infrastructures or personnel resources, Finnish health research is at risk of being excluded from the main streams of development.

Research operating environment
- The changes made to the status of government research institutes threaten to undermine their position in the research and innovation system. The reforms of research institutes and universities may cause particular lines of research to dry up.

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2 According to the National Institutes of Health, transformative research is exceptionally innovative and/or unconventional research that is inherently risky but that at once has the potential to create or overturn fundamental paradigms (http://commonfund.nih.gov/TRA/, accessed 30 March 2012).

3 Funding through the Finland Distinguished Professor Programme intended for top scientists past the postdoctoral stage but still in the earlier stages of their research careers.

Doctoral training and research career

- The main threat stemming from the overhaul of the doctoral training system is that networked graduate schools are fragmented between several universities. National restructuring threatens to hamper inter-university cooperation and jeopardise benchmarking in doctoral training, for instance.

International cooperation

- Health research remains aloof of EU and other international developments.
- Finland fails to attract enough high-level foreign scientists.

Infrastructures

- Funding for Biocenter Finland is cut or discontinued.
- Funding for the Finnish Information Centre for Register Research (ReTki) cannot be organised on a sustainable basis.

Development proposals

Development of health research

- A balance must be maintained in developing basic research and clinical research in order to smooth the passage from translational to transformative research. A virtuous cycle of research approaches contributes to improving public health and the healthcare service system.
- It is important to highlight the key role that health research plays in informed policy-making. Research knowledge must be put to more effective use in the prevention of diseases and in health promotion at different stages of the life cycle. Special attention must be given to the social determinants of health, for instance marginalisation. With population ageing, it is inevitable that ageing-related research will gain increasing importance in policy-making.

Research operating environment

- Finland needs to have a dedicated health research strategy that is based on a comprehensive review and analysis of structures and funding. An integral part of the Finnish research and innovation system is formed by universities and government research institutes and their close collaboration. In the health research field, much important work is also done by university hospitals, where research is funded through the so-called EVO mechanism (transfers from the Ministry of Social Affairs and Health), now renamed as central government funding for university-level health research. Quality-based EVO funding for scientific research should be restored to its original level. Structural reforms are often carried out on a very narrow basis, without giving sufficient thought to their impacts on research. Structural changes prepared in consultation with scientists and researchers and the pooling of resources contribute to improving the framework conditions for research.
- To ensure that the research and innovation system functions properly, universities and government research institutes should be reformed in close consultation with the research community, the Government, ministries and the Research and Innovation Council. It is particularly important that researchers active in the field are represented in the preparatory working groups.

Doctoral training and research career

- Funding opportunities in the health research field need to be developed to further facilitate researchers' efforts to set up their own teams and take up leadership of those teams.
- In clinical fields, full-time professorships have increasingly given

way to part-time professorships, which within the existing system do not provide sufficient opportunities to conduct research. However, full-time professorships are an important condition for high-quality research. In major medical disciplines as well as in fields where research needs special development, every university that offers medical training must have at least one full-time professorship. Medical faculties and university hospitals must work closely to develop the job descriptions of part-time clinical professors so as to ensure that they can devote enough time to research. These development efforts require that adequate resources are made available to research and education.

International cooperation

- Small research teams must be encouraged to network internationally. International cooperation can help these teams find their own specialised research niche and network with other teams in order to strengthen their research capacity and compete internationally.
- Steps are needed to make it easier for researchers, particularly those with families, to move abroad and to return to Finland on completion of their research spell.
- The structure of Academy of Finland funding applications should be brought more closely in line with their international counterparts. This will reduce the workload of researchers who have applied for funding through the Academy and who are planning to apply for international funding.

Infrastructures

- The continuing development of infrastructures in Finland and the production of the necessary research services require strategic policy-making on Finland's involvement in international infrastructures. University core funding is not enough for the necessary investments.
- Biocenter Finland must continue in its role to develop and coordinate national infrastructure services for health research.
- Register research must be supported by identifying its main obstacles in Finland and by developing the Finnish Information Centre for Register Research. It should be possible for researchers to obtain the permissions they require from one and the same authority. At the same time, in line with the 2011–2016 education and research development plan[4], steps are needed to promote the free use for research purposes of any data collected with public funds. In the health research field, this applies at least to the medical and other data compiled by Statistics Finland, the National Institute for Health and Welfare, and the Social Insurance Institution. Furthermore, it is important that Nordic and other international cooperation in register research is developed.
- Finland needs a clinical trials centre to provide the services needed for researcher-driven clinical trials at cost price. This was the recommendation of the panel evaluating clinical research in Finland and Sweden.[5]

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4 Ministry of Education and Culture 2011. Education and research in 2011–2016. A development plan. Reports of the Ministry of Education and Culture 2012:3.

5 Academy of Finland 2009. Clinical Research in Finland and Sweden. Evaluation Report. Publications of the Academy of Finland 5/09.

3 ACADEMY FUNDING FOR RESEARCH PROJECTS AND PROGRAMMES INTO THE GRAND CHALLENGES FACING HUMANKIND AND SOCIETY

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Summary

The Academy of Finland's roadmap of the grand challenges facing humankind and society ties in closely with Nordic and European discussions on research policy. The analysis presented in this chapter aims to provide the Academy with an overview of how its funding reaches research projects and programmes in areas that address the six grand challenges identified by the Academy's Board. The data used for the investigation relate to funding awarded to Academy research projects and programmes in 2007–2010, a total of some 436 million euros. The analysis reflects and takes account of the inherent complexity of research projects. Specifically, the aim is to see how and to what extent the themes related to grand challenges are addressed in Academy-funded research projects and to examine the interactivity, focuses and coverage of the research projects.

The results show that the grand challenges have a strong presence in Academy-funded research projects. The inference drawn from this is that research in these areas is of a high standard because it has been rated highly in international peer reviews. The data also suggest that researchers in Finland are keen to engage in work that has social relevance. The themes related to the grand challenges are often multidisciplinary, yet the research teams working on those themes tend to have a rather narrow disciplinary base. One factor that may have a bearing on this is the amount of funding awarded to individual research projects. It was discovered that the projects funded were primarily focused on the themes of The Northern Climate and Environment and Sustainable Energy.

3.1 Background

In June 2011, the Board of the Academy of Finland identified six grand challenges facing humankind and society: these were **The Northern Climate and Environment; Sustainable Energy; Dialogue of Cultures; Knowledge and Know-how in the Media Society; A Healthy Everyday Life for All; and The Ageing Population and Individuals**. Scientific research is a necessary, but not a sufficient condition for resolving these challenges. The challenges singled out by the Academy can be taken to represent Finland's response to initiatives in the European Research Area and innovation policy. Indeed, the identification of these challenges can help direct the focus of research to problems that are most crucial to society and also improve European researchers' opportunities for global cooperation.

The purpose of the analysis here is to provide the Academy with the tools it needs to define and carry out its role in addressing and resolving these problems. The aim is to gain a clearer understanding of the strengths, weaknesses and areas of development in Finnish science and research within the six areas identified by the Academy's Board as grand challenges for humankind and society.

Another objective is to see how Academy funding for research projects and programmes is connected with the themes relevant to the grand challenges and to explore the interactivity of research addressing these challenges.

Given the inherent complexity of research projects, some of the results they produce are inevitably unpredictable. It follows that an analysis of funding decisions alone will not allow us to draw any definite conclusions about how closely individual research projects are focused on specific grand challenges. Other relevant concerns with regard to research into the grand challenges are coverage and adequacy, on which no data are currently available. For this reason, the outcomes and impacts of Academy-funded projects are excluded from the analysis.

The grand challenges can be understood as research themes that cut across disciplinary boundaries: these are the themes that research needs to tackle in order to resolve the problems that are crucial to the future of humankind and society. However, these challenges have been identified in relatively general terms, giving each Research Council the latitude to define them in closer detail from their own respective vantage points.

The identification of grand challenges serves the purpose of giving increased exposure to the relevant problems and by the same token of improving the prospects of resolving them. However, even the most optimistic view of science does not envision that the grand challenges facing humankind and society can be resolved by means of science alone. What science and research can do, however, is help find ways in which public and private stakeholders in society can tackle and intervene in the problems identified. In some disciplines, the projects funded are not necessarily focused on any of the challenges specified, even though the projects' themes might be central to the Research Councils' funding decisions.

One particular challenge with respect to the channelling of Academy funding is that this is the first ever assessment of its kind that focuses on the performance of individual Research Councils. For this reason, the present report is explorative by nature and seeks to develop new research tools.

3.2 Material

The material for this analysis was drawn from Academy of Finland databases during spring 2012. It comprises 1,373 research projects funded by the Academy. The examination is limited to general research grants, Academy Projects and to national

Table 1. Number of research projects and funding awarded from 2007 to 2010

Year	Project funding		Programme funding		Total	
	N	€ million	N	€ million	N	€ million
2007	331	88.1	69	15.8	400	104.0
2008	313	90.9	77	16.8	390	107.8
2009	221	89.2	96	26.1	317	115.2
2010	222	97.5	44	12.0	266	109.5
Total	1,087	365.7	286	70.7	1,373	436.4

research programme funding in 2007–2010. Excluded from the analysis are Academy research posts, researcher training, funding for researcher mobility based on bilateral agreements, international calls for research programmes and contributions to funding international organisations (Table 1).

The Academy has four Research Councils: the Research Council for Biosciences and Environment, the Research Council for Culture and Society, the Research Council for Natural Sciences and Engineering and the Research Council for Health. The analysis here applies the same classification of disciplines as that on which the Research Councils are structured. The analysis allows us to make some limited observations about the state and quality of scientific research in Finland from a multidisciplinary perspective.

3.3 Criteria applied and foundations for interpretation

The allocation of Academy of Finland funding to different areas of research that touch upon the grand challenges has been assessed by analysing public descriptions of research projects in relation to the contents of the grand challenges. One of the strengths of these public descriptions is that they constitute a homogenous dataset. On the other hand, their succinct delivery of information is a source of some difficulty for interpretation; the translations of these descriptions may also involve problems (Finnish, Swedish and English). Nonetheless, it has been possible to use a consistent set of content criteria to evaluate all projects under each Research Council. The analysis is based on the more detailed interpretations provided by the Research Councils in spring 2012 about how the grand challenges relate to specific research themes. Based on these detailed interpretive analyses, we have been able to provide assessments of the specific significance of the grand challenges to each Research Council.

Research projects administered by a given Research Council were first evaluated by one reviewer on the team. This reviewer assessed the projects of all four Research Councils. Next, applying the same criteria, a second reviewer independently assessed the work of the first reviewer and might have proposed some changes. These proposals were subsequently considered by all four reviewers on the team. In general, the review process was organised to ensure maximum compatibility across the Research Councils, giving due consideration to the differences in the nature of the disciplines they represent.

The reviews highlighted some significant differences in the emphases and interpretations of the Research Councils. In their own interpretative analyses, the Research Councils have assigned widely diverging meanings to the same grand challenges. For the Research Council of Natural Sciences and Engineering, for instance, the challenge of Sustainable Energy has always been connected to new energy sources, smart electrical networks or nuclear, nano- and biotechnology applications, whereas for the Research Council for Biosciences and Environment it may have been connected to such issues as Arctic regions, land use and Northern wetlands. For the Research Council for Health and the Research Council for Culture and Society, then, the same challenge may have been related to obesity or cellular energy balance in the middle-aged population. Similarly, views differed on the challenge of The Ageing Population and Individuals: the Research Council for Natural Sciences and Engineering stressed the role of practical technologies designed to help older people in their everyday life, the Research Council for Biosciences and Environment the biochemistry of degenerative nervous diseases, while the Research Council for Health emphasised population-level lifespan studies. For projects under the Research Council for Culture and Society, on the other hand, ageing may have been taken to refer to the individual's mental or social growth at different stages of life.

The connections of individual research projects with the grand challenges (see below) were assessed for each challenge on a five-point scale; in addition, a 0 option was available for cases where the necessary information for an assessment was missing altogether, for instance because project descriptions were not available in electronic format for all of the research projects. The scores on the 1–5 scale were defined as follows:

1 = based on the description, the project is unambiguously not connected to the grand challenge in question;

2 = based on the description, the project is probably not connected to the grand challenge in question;

3 = based on the description, the project may or may not be connected to the grand challenge in question, or the description is not clear or accurate enough to warrant a reliable assessment;

4 = based on the description, the project is clearly connected to the grand challenge in question;

5 = based on the description, the project is unambiguously and directly connected to the grand challenge in question.

On this scale, both scores 1 and 2 and scores 4 and 5 are clearly quite close to each other. Score 3, on the other hand, is clearly more far removed from both these scores and sometimes based on a slightly different train of reasoning. Analyses of unclear cases scored at 3 have been elaborated for each Research Council in collaboration with Academy of Finland science advisers. In other words, score 3 is by no means a "don't know" option, but a deliberate view, arrived at in consultation with experts, on how the research project relates to the scale.

The scale and criteria applied in the analysis give rise to several important restrictions with respect to understanding the analysis. Since the scale is designed primarily for the classification of research projects, the indexes produced on the basis of this scale must be regarded as indicative only. Furthermore, it must be separately stressed that for the same reason, statistical comparisons between the four Research Councils are not possible. The calculation of statistical indicators (e.g. means, correlations) from the results would be meaningless because the assessments of how individual research projects are connected to the grand challenges are not exact measurements, but overall judgments based on a harmonised set of criteria.

3.4 Academy-funded research projects and grand challenges

Interconnectedness

Interconnectedness refers here to interactivity and collaboration among research projects and thematic areas in the research community. As well as interacting with one another, they are also interconnected with their environment. From a knowledge accumulation point of view, it is impossible to predict in advance how research projects will develop and unfold, and the accumulation of evidence and knowledge may lead to a realignment of objectives in individual studies during

Table 2. Number of research projects and research funding by Research Council in 2007–2010

Research Council	Project funding		Programme funding		Total	
	N	€ million	N	€ million	N	€ million
Biosciences and Environment	198	81.4	39	10.1	237	91.4
Culture and Society	243	95.4	67	17.8	310	113.2
Natural Sciences and Engineering	421	126.0	112	28.9	533	154.9
Health	225	63.0	68	14.0	293	77.0
Total	1,087	365.7	286	70.7	1,373	436.4

their funding term. On the other hand, projects that do not clearly focus on any specific grand challenge may still produce results that are significant to one or more of the challenges. One source of difficulty with the present dataset is presented by projects that are clustered into council-specific consortia or consortia that cut across Research Council boundaries. Annual Academy funding for research consortia totals around 30 million euros. There are also marked differences in the total number of projects under the four Research Councils as well as in the breakdown of funding allocated to these projects, as is clear from Table 2. The number of research projects and the level of overall funding allocated to Research Councils do not as such measure the number of disciplines under the Research Councils in question or the overall volume of research conducted under these Research Councils. However, the amount of funding allocated to each Research Council may affect the areas the research will be focused on.

Research consortia: interactivity

About one-third of all Academy-funded projects have come under the umbrella of a research consortium. Detailed figures are shown in Tables 3 and 4. However, there are marked differences between the four Research Councils. Almost half of funded projects in the natural sciences and engineering fields have been part of a research consortium, whereas only one-quarter of those in the field of health research were. In the biosciences and environment field and in the culture and society field, no more than one-fifth of funded projects were part of a research consortium. Because the research consortia set up in some disciplines have been highly successful with their applications for Academy funding, the data raise the question as to whether the current

Table 3. Number of consortium projects and funding by Research Council in 2007–2010

Research Council	Project funding		Programme funding		Total	
	N	€ million	N	€ million	N	€ million
Biosciences and Environment	18	4.2	29	7.8	47	12.0
Culture and Society	21	5.3	40	9.1	61	14.4
Natural Sciences and Engineering	154	38.2	90	22.2	244	60.4
Health	8	1.7	65	13.0	73	14.6
Total	201	49.4	224	52.1	425	101.4

Table 4. Number of consortium projects and annual funding from 2007 to 2010

Year	Project funding		Programme funding		Total	
	N	€ million	N	€ million	N	€ million
2007	59	11.6	27	4.9	86	16.5
2008	61	11.9	74	15.2	135	27.1
2009	29	8.9	79	20.0	108	28.9
2010	52	17.0	44	12.0	96	29.0
Total	201	49.4	224	52.1	425	101.4

application system favours consortia-type applications, therefore favouring some research fields at the expense of others.

Focus of research projects

It seems that Academy-funded projects are most heavily clustered in the themes of The Northern Climate and Environment and Sustainable Energy (Table 5). These grand challenges include projects and research consortia from all four Research Councils. The same applies to research themes related to the A Healthy Everyday Life for All challenge. In the case of the other grand challenges, it is clearly harder to identify research projects that cut across disciplinary boundaries. So is this tendency of gravitation a sign of a weakness that can be corrected through a more careful allocation of research funding? This should not be interpreted as either a weakness or strength, because the areas under the Research Councils evidently relate to solvable scientific issues. More importantly, how the challenges are divided between the four Research Councils is less important than having projects that aim to resolve problems relevant to the grand challenges. These can cut across disciplinary boundaries and can thus contribute to the solving of grand challenges from different perspectives. In other words, major consortia could produce a larger number of interdisciplinary projects than is currently the case.

The breakdown of research projects between the four Research Councils furthermore shows that certain challenges are hardly covered at all in certain Research Councils. For instance, themes related to the challenges of Knowledge and Know-how in the Media Society and Dialogue of Cultures are covered neither

Table 5. Number of research projects addressing grand challenges (scores 4 or 5) and their percentage of all projects by Research Council

	The Northern Climate and Environment	Sustainable Energy	A Healthy Everyday for All	Dialogue of Cultures	Knowledge and Know-How in the Media Society	The Ageing Population and Individuals
Biosciences and Environment (N=237)	107 (45%)	21 (8%)	19 (8%)	2 (1%)	0 (0%)	3 (1%)
Culture and Society (N=310)	19 (6%)	10 (3%)	66 (21%)	87 (28%)	49 (16%)	11 (4%)
Natural Sciences and Engineering (N=533)	133 (25%)	226 (42%)	124 (23%)	36 (7%)	141 (26%)	37 (7%)
Health (N=293)	2 (1%)	1 (0%)	159 (54%)	3 (1%)	1 (0%)	56 (19%)

in projects funded by the Research Council for Biosciences and Environment nor in projects funded by the Research Council for Health. Nonetheless, even these rarer combinations might yield new and significant multidisciplinary research settings if calls were specifically targeted to themes related to the grand challenges.

An index was formed to describe the extent to which grand challenge themes are addressed in individual research projects. For each of the six grand challenges, each research project was given a score from 1 to 5, and the sum was then divided by 6. In all, there were 233 projects with the lowest index score of less than 1.5; 553 projects had an index score of 1.5–2; and 417 projects had a score of 2.0–2.5. It is particularly interesting to see which Research Councils attracted the most projects with an index score of 2.5 or higher, which numbered 170 in all. The figure for the Research Council for Health was 3; the Research Council for Biosciences and Environment 10; the Research Council for Culture and Society 29; and the Research Council for Natural Sciences and Engineering 129. In other words, this analysis also clearly underscores the different nature and key role of the Research Council for Natural Sciences and Engineering projects in addressing grand challenges.

Project coverage

The inherent differences between disciplines are clearly reflected in Table 6. As described above, projects in the biosciences and environmental and in the health research fields in particular gravitate towards two challenges. In the more multidisciplinary fields of cultural and social research and natural sciences and engineering research, then, the range of challenges covered is clearly wider. Furthermore, the existence of a few more broadly based consortia that address multiple challenges in the field of the Research Council for Natural Sciences and Engineering means that the number of projects tackling more than two challenges is clearly higher in this than in other Research Councils.

Indeed, the breakdown of Research Council funding to research projects could also be analysed by counting projects that come under a consortium umbrella as separate, single projects. In this case, the Research Council for Natural Sciences and Engineering would no longer seem to have a significantly higher number of research projects addressing several grand challenges at the same time. On the other hand, since funding is allocated separately to all projects that form a consortium, this would not in other respects be a meaningful approach.

Table 6. Number of grand challenges addressed in Academy-funded research projects by Research Council in 2007–2010

Grand challenges	0	1	2	3	4	5	6	Total
Biosciences and Environment	105 (44.3%)	112 (47.3%)	20 (8.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	237 (100%)
Culture and Society	113 (36.5%)	156 (50.3%)	39 (12.6%)	2 (0.6%)	0 (0%)	0 (0%)	0 (0%)	310 (100%)
Natural Sciences and Engineering	58 (10.9%)	295 (55.3%)	146 (27.4%)	25 (4.7%)	9 (1.7%)	0 (0%)	0 (0%)	533 (100%)
Health	115 (39.2%)	136 (46.4%)	40 (13.7%)	2 (0.7%)	0 (0%)	0 (0%)	0 (0%)	293 (100%)
Total	391 (28.5%)	699 (50.9%)	245 (17.8%)	29 (2.1%)	9 (0.7%)	0 (0%)	0 (0%)	1,373 (100%)

Table 7. Breakdown of funding between projects addressing grand challenge themes and other projects by Research Council in 2007–2010

	Funding for projects clearly addressing at least one challenge, € million (percentage of total funding)	Funding for projects that do not clearly address any challenge, € million (percentage of total funding)	Total funding, € million (percentage of total funding)
Biosciences and Environment (N=237)	47.5 (52%)	43.9 (48%)	91.4 (100%)
Culture and Society (N=310)	71.4 (63%)	41.7 (37%)	113.2 (100%)
Natural Sciences and Engineering (N=533)	136.4 (88%)	18.6 (12%)	154.9 (100%)
Health (N=293)	44.9 (58%)	32.1 (42%)	77.0 (100%)
Total (N=1,373)	300.2 (69%)	136.3 (31%)	436.4 (100%)

The best overview of the breakdown of Academy funding to research projects addressing grand challenge themes is obtained by looking at total funding volumes and breakdowns in each Research Council (Table 7). This shows that in the Research Council for Natural Sciences and Engineering, a larger than average proportion of funding (88%) goes to projects addressing grand challenge themes. In the other Research Councils, the corresponding proportions are considerably lower, i.e. in the Research Council for Culture and Society and in the Research Council for Health less than two-thirds, and in the Research Council for Biosciences and Environment only around one-half. On the other hand, this finding is directly attributable to the fact that in the field of the Research Council for Natural Sciences and Engineering, a larger proportion of research projects addressed at least one or more grand challenge themes.

Overall then, we find that more than two-thirds of all Academy-funded projects included in the dataset addressed at least one grand challenge theme. This is true despite the fact that for many years the projects included in the analysis have not been specifically designed to focus on these themes. This may be indicative of the ability of research teams to identify relevant problems or of the science policy orientations of the research funding agency.

3.5 Key observations

It is evident from these data that themes related to the grand challenges have strong prominence in Academy-funded projects. This can be interpreted to mean that research in these areas is of a high standard because it has been rated highly in international peer reviews. The data also suggest that researchers in Finland are keen to engage in work that has social relevance. However, there are apparent differences between individual disciplines in terms of how they seek to answer the questions related to grand challenges. It seems that projects tend to cluster in two areas, viz. The Northern Climate and Environment and Sustainable Energy. In other words, projects addressing the grand challenges seem most closely connected to the Natural Science and Engineering and the Biosciences and Environment Research Councils.

At the time of filing their applications, the projects and research teams investigated here had no knowledge of the Academy's definition of grand challenges. They may, however, have been influenced by what they knew from earlier successful project applications, as documented for instance in a report on the impact of Academy research funding (Suomen Akatemia, 2006). According to this report, high-risk funding should be targeted to well-credentialed researchers and their multidisciplinary initiatives on the interface of different research areas. Both basic and applied research is expected to yield social impact. Seen from this perspective, grand challenges in the future may shape notions of which themes can produce relevant and high-impact research.

It is an important asset for the national research system that researchers who have been awarded funding are working with problems that are relevant to the grand challenges in the fields of research under all Research Councils. This seems to hold whether or not there is underlying research programme steering the course of research. Academy of Finland research programmes are based on researchers' own definitions of research areas, which seems to have resulted in individual projects becoming more closely connected to the grand challenges. On the other hand, it may be considered a weakness, so far at least, that projects have shown limited interest in European and Nordic grand challenges. Indeed, international contact and exchange do not appear as a strength of Academy-funded research projects, which possibly reflects the nature of Academy Research Councils primarily as national sources of research funding.

It is not possible to make a direct inference from the data studied here whether the amount of funding awarded by the Academy to address the grand challenges of humankind and society is adequate. If funding were more closely focused on these challenges, this might have the effect of restricting academic freedom. Scientists and researchers define their own problems, and rarely take up grand challenge themes as they stand.

The Academy's emphasis on grand challenges does not signify the restriction of academic freedom in any way. To underline this, the Research Councils operate independently, although closely following the criteria for funding decisions laid down by the Board of the Academy. The criteria allow for the consideration of discipline-specific methods and approaches and thus a council-specific way of working is possible for each Research Council.

Each Research Council places a premium on the tools that will allow for the most efficient use of the funding resources available. In the research areas that have a lower number of projects working on grand challenge themes, the funding is fragmented to smaller projects. More comprehensive research coverage of the themes related to grand challenges under the various Research Councils may imply a need for more integrated practices.

All in all, the grand challenges facing humankind and society have a strong presence in the Academy-funded research projects and programmes. Since the grand challenges identified by the Academy are by definition multidisciplinary, the fragmentation of project funding between relatively small research questions is somewhat surprising. The Research Councils' practices offer much scope for research programmes that promote multidisciplinary cooperation and that cut across disciplinary boundaries.

Bibliography

Academy of Finland. (2007). Research fields hosted by Research Councils. Retrieved from www.aka.fi/en-GB/A/For-researchers/How-to-apply/Guidelines/Research-fields-hosted-by-Research-Councils/

European Commission. (2006). Creating an innovative Europe. Report of the Independent Expert Group on R&D and Innovation appointed following the Hampton Court Summit and chaired by Mr. Esko Aho. Retrieved from http://ec.europa.eu/invest-in-research/pdf/download_en/aho_report.pdf

European Commission. (2007). The European Research Area: New Perspectives. Retrieved from http://ec.europa.eu/research/era/pdf/era_gp_final_en.pdf

European Commission. (2009). Preparing Europe for a New Renaissance. A Strategic View of the European Research Area. First Report of the European Research Area Board. Retrieved from http://ec.europa.eu/research/erab/pdf/erab-first-annual-report-06102009_en.pdf

European Commission. (2009). The Evaluation of the Sixth Framework Programmes for Research and Technological Development 2002–2006. Retrieved from http://ec.europa.eu/research/reports/2009/pdf/fp6_evaluation_final_report_en.pdf

European Commission. (2010). The Communication Europe 2020 Flagship Initiative – Innovation Union. Retrieved from http://ec.europa.eu/research/innovation-union/pdf/innovation-union-communication_en.pdf

Nordforsk. (2011). A Nordic Contribution to the Grand Challenges Debate. Retrieved from www.nordforsk.org/files/a-nordic-contribution-to-the-grand-challenges-debate

Suomen Akatemia. (2006). Suomen Akatemian tutkimusrahoituksen vaikuttavuus. Suomen Akatemian julkaisuja 11/06. Retrieved from www.aka.fi/Tiedostot/Tiedostot/Julkaisut/11_06%20Tutkimuksen%20vaikuttavuus.pdf

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Scientific research is a necessary, but not alone a sufficient means of tackling the grand challenges facing humankind and the wide-ranging problems they entail: climate change, environmental and energy issues, health and wellbeing, and cultural dialogue. In order to respond effectively to global change, research must be prepared to take greater risks and venture into new lines of inquiry. Multidisciplinary approaches have great significance in addressing the grand challenges facing humankind, coupled with new problem-driven fields that play an ever-increasing role alongside traditional scientific disciplines.

Welfare and wellbeing in Finnish society are based upon knowledge and know-how. Given its high level of education and high level of skills and competencies, Finland is well placed to reinvent itself and find sustainable solutions for the good life. The added value of funding scientific research comes not only from the new knowledge and new applications it generates, but also from the experts who pick up their training in science and arts research. All this paves the way to building an ecologically, socially and economically sustainable society.

In its programme dated 22 June 2011, the Finnish Government has committed itself to the target of spending 4% of GDP on research, development and innovation. In 2011, the ratio was 3.73%, higher than the average for OECD countries. Given the climate of economic uncertainty that is continuing to affect R&D funding, it is unlikely that investment in R&D will be increased over the next few years ahead, and therefore the 4% target will probably not be attained. In 2012, public R&D funding is estimated to come in at 1.0% of GDP.[1] Government is by far the most important source of funding for high-social-impact research, as private-sector R&D funding is quite heavily focused on the development side.

International competitive funding is of growing importance to Finnish research at a time when core funding for universities and national competitive research funding look set to stagnate. Making more systematic use of international funding opportunities will help improve the framework conditions for research and help Finland develop its scientific competencies. However, competition for international research funding is also getting tougher.

In 2010, the number of R&D personnel per one thousand employed persons in Finland was 23. This figure is higher than in any other OECD country and more than twice as high as in the EU27 group on average. However, it is noteworthy that most Finnish R&D personnel do not have postgraduate training. In 2009, the proportion of R&D employees with postgraduate training was just 18%, less than in the countries with which comparisons were made (Ireland, Sweden, Norway and Austria). The proportion has, however, increased since 2003. The level of qualifications held by research personnel obviously has major relevance to the quality and impact of scientific research.

[1] GDP 2012 based on Ministry of Finance forecast.

The content and extent of researcher training warrants careful examination. The need for PhDs and PhD employability vary from one branch to the next. Only a small proportion of PhDs find permanent employment in research and teaching positions at universities or research institutes. PhD-level research qualifications have wide currency even outside the field of scientific research in various positions of expertise and management. The ability to critically analyse problems, to collect and analyse data and to draw conclusions is an important skill in virtually all areas of society, not least in business and industry.

In recent years, many of the countries included in this comparison[2] have stepped up their investment in scientific research. Many of them have reformed their university systems, restructured the funding of universities and increased competitive research funding in order to strengthen their research capacities. This has also implied escalating international competition in research, which is reflected in the development of publishing volumes and citation impacts, for instance.

Publication and citation figures for Finnish science and research have remained quite stable over the past few years. In 2008–2010, a total of 15,674 scientific publications were published in Finland, 6% more than in the mid-2000s. Relative to population, this is the third highest figure among the countries included in the comparison, after Switzerland and Sweden. However, Finnish publication numbers have been falling after 2006–2008.

In 2008–2010, Finnish publications received 6% more citations (relative citation impact 1.06) than the world average. This is slightly more than in 2003–2005, when Finland's relative citation impact (1.01) was around the world average. The relative citation impacts for all of the countries included in the comparison have ranked above the world average since 2005–2007.

One way to analyse the proportion of high-quality research is to look at publications that rank among the top 10% of most cited publications in the world. In 2008–2010, 9% of Finnish publications ranked among the world's top publications. This is roughly the same figure as in the world on average.

International co-publishing has increased significantly in Finland over the past 20 years. International co-publications receive significantly more citations than national publications.

Publication numbers in Finnish science and research and citations to Finnish research publications are at a good level. Indices for the countries included in the comparison have remained more or less unchanged: changes at country level happen very slowly. Nonetheless, it is interesting to consider why Switzerland, for instance, continues to have such strong success: is there something about Swiss science and research funding or about university practices in Switzerland that could be imported and applied to Finland? Switzerland has long been known for its high level of research funding and for its relatively small number of university students. Furthermore, Swiss universities and research institutes have in recent years given increasing emphasis to international recruitment and to obtaining international funding. It is difficult to significantly raise funding levels or to sharply cut back on student numbers, but it might be rather

[2] Austria, Denmark, Finland, Ireland, Netherlands, Norway, Sweden and Switzerland.

easier to place greater importance on recruitment and international funding.

The results of country-level bibliometric analyses that cover all scientific disciplines are indicative only and do not allow for very far-reaching conclusions. The problems associated with bibliometric analysis were discussed in more detail in Chapter 1.5. The bibliometric results for specific disciplines indicate that there is marked variation between individual fields, but on the other hand, comparisons over different time periods also show that in fields with lower publication numbers, the bibliometric indicator values may change quite quickly. Indeed, the best and most reliable way to gain a more in-depth view of developments in a particular branch is to resort to peer reviews at university, research institute or discipline level.

External peer reviews, when conducted on a large scale, are quite heavy and expensive tools to use. The current review of the state of scientific research in Finland made use of task forces that produced SWOT analyses of the strengths, weaknesses, opportunities and threats to the development of individual disciplines (www.aka.fi/tieteentila2012 > English).

The SWOT analyses and the summaries offered by each Research Council in Chapter 2 indicate that several disciplines have many problems as well as many opportunities in common, although there are of course noteworthy differences as well. The key recommendations from the areas covered by the Academy's four Research Councils are listed at the end of this chapter.

The grand challenges facing humankind have emerged as a major focus of debate at universities, research institutes and research funding agencies, both in Finland and around the world. These challenges need to be solved, and the research addressing them must be of a high quality and high impact. It is also important that the research community is in a position to open up new lines of scientific inquiry, to achieve scientific breakthroughs and to respond to possible future problems.

How to assess the impact of scientific research is one of the most critical and hardest questions facing science policy today, and there is no single unambiguous answer. Predicting impact is extremely difficult, among other reasons because of the fundamental differences that distinguish different disciplines, differences in time spans and the difficulty of predicting potential applications.

The grand challenges and the progress of scientific research are placing new demands on the Finnish science and research system, on research funding instruments, and on researchers and policy-makers. The grand challenges further underscore the importance of multidisciplinary and interdisciplinary research approaches, and a problem-oriented way of thinking is gaining ever greater prominence in scientific research. The analysis presented in Chapter 3 goes to show that research projects funded by the Academy of Finland interface broadly with the various grand challenges in the areas covered by all four Academy Research Councils. Domestic and international collaboration among research communities, universities, research institutes and other research funding agencies is crucial to organising and coordinating research around the grand challenges.

Ways of doing science are also very much in flux: electronic access to research materials and data, multidisciplinary research approaches, a focused problem orientation and various networks of collaboration are distinctive features not just of research concerned with grand challenges, but virtually all scientific work. These changes present significant challenges for universities, research institutes and research funding agencies alike.

The Finnish higher education system is based on a dynamic interplay of research and education. It is paramount to further strengthen this interconnection and so to enhance the quality and impact of scientific research. Research-based education is indeed central to further developing research environments and funding instruments.

Improving the quality and impact of scientific research in Finland requires optimising the allocation of scarce resources, i.e. the making of choices and omissions. The Finnish science system is well accustomed to making choices since it has never been in the position to cover the whole research field at high enough quality levels. The need to make these kinds of choices and omissions is only going to increase with the grand challenges, economic uncertainty and austerity, and the growth of international competition. In order to achieve a lasting improvement in quality and impact it is paramount that institutions of higher education and government research institutes can establish a genuine division of labour not only in subjects and areas covered, but also in working methods, that they can form strong alliances and place greater emphasis on national and international cooperation. Following the university reform, universities are in a stronger position to make these decisions autonomously. This must be further supported, for instance, by means of strategic funding that is incorporated in the universities' new funding model.

At a time of scarce resources, the key to successful research lies in differentiation and division of labour. At the same time, however, it is important to recognise the importance of opening new lines of inquiry: one of the major strengths of scientific research is its ability to constantly reinvent itself. Indeed, in developing their funding instruments, it is important that research institutes, institutions of higher education and research funding agencies ensure they are well placed to detect and identify new perspectives.

The quality and impact of scientific research are primarily dependent on people: researchers, teachers and students. It is critical to the success of Finnish science and research that it is in the position to recruit the best people and the most talented students. Given their greater autonomy, universities are better placed than before to pursue an active recruitment and personnel policy. The development of national and international recruitment and the growth of mobility will open up new opportunities for institutions of higher education and research institutes. Another area of development for science and research is to improve the student selection procedures of institutions of higher education.

4.2 Recommendations

Greater focus must be placed on the recruitment of researchers and students

Why: The recruitment of research personnel and student selection are central quality issues for institutions of higher education and research institutes. The competitiveness of scientific research in Finland depends on the recruitment and training of talented researchers and students.

How: Institutions of higher education and research institutes must take steps to develop their recruitment processes and career systems so that they can attract the best possible talent. Further efforts are needed to develop the student selection and admission procedures of institutions of higher education. International recruitment strategies must be developed. In particular, the recruitment of postdoctoral researchers and early-career professors is a fast and effective way of enhancing the internationalisation of the Finnish science system.

National and international mobility must be encouraged and supported

Why: There is still only little national and international mobility at the various stages of the research career.

How: In their recruitments as well as in their personnel policy, it is important that institutions of higher education and research institutes place increasing emphasis on mobility. Research funding agencies must work closely together to identify the most effective ways of supporting and promoting mobility. Continued efforts are needed to help alleviate the practical problems hampering the mobility of researchers with families, for instance. Institutions of higher education and research institutes must develop academic support services designed to promote national and international mobility.

The position of basic research must be safeguarded with a view to cultivating new lines of inquiry and high-risk research

Why: Scientific research, the search for new knowledge and the building of a solid foundation for education are central to the future of Finland. Sustained scientific research plays a crucial part in regenerating intellectual capital, and is a vital precondition for technological development and innovation.

How: Research funding agencies must develop and introduce funding instruments that better meet the needs of research aimed at new innovative breakthroughs and risk-taking. Funding allocations by institutions of higher education and research institutes must reflect the changes that have happened in ways of doing science, including the use of virtual environments as well as the growing volume and diversity of research materials.

In line with the 2011–2015 policy guidelines by the Research and Innovation Council, public funding for research must be increased to 1.2% of GDP. Universities and research institutes must make better use of EU funding opportunities, particularly ERC funding.

Structural development of institutions of higher education and research institutes must be continued

Why: In order to strengthen the quality and impact of research in Finland it is also necessary to optimise the allocation of research resources, to make choices and omissions.

How: The university reform has put universities in a stronger position to make autonomous choices and omissions, and this must be further supported, for instance, by means of strategic funding included in universities' funding model. Implementation of the polytechnic reform must ensure that adequate money and human resources are made available for R&D. Similarly, the development of research institutes must look into both structural and funding mechanisms. The only way to clarify the division of labour between stakeholders in the national research system and to consolidate fragmented structures and intensify resource use is through cooperation across administrative branches.

Steps are needed to develop researcher training that supports a wider range of career options

Why: The demand for PhDs varies across different fields of education and different sectors of society in both numbers, quality and content.

How: Universities must consider their doctoral student numbers against the resources at their disposal. Universities must work closely together to develop doctoral programmes in such a way that they provide PhDs with the skills and competencies they need not only in research and education positions, but also in other expert positions in society and business and industry. The quality and impact of scientific research require greater flexibility on the part of both researchers and researcher training.

Continued development and efficient use of research infrastructures must be maintained

Why: Lack of funding for hardware and data infrastructures presents a significant threat to the standard of scientific research. It is imperative that Finland take steps to ensure that its researchers have access to the necessary international research infrastructures. Interesting and high-quality research environments and datasets add to Finland's appeal as a research country.

How: The continued development and efficient use of research infrastructures require closer strategy-based national and international cooperation as well as strategic decisions on how Finland shall contribute to international infrastructures and on which national research infrastructures need to be supported for the future of Finnish research. The national expert committee on research infrastructures will contribute to the aforementioned tasks.

Steps are needed to strengthen multidisciplinary and interdisciplinary research

Why: Multidisciplinary and interdisciplinary approaches will play a prominent role in resolving the grand challenges with the aid of scientific research.

How: Research funding agencies and institutions of higher education must encourage researchers to undertake sufficiently ambitious research projects, to explore new innovative lines of research inquiry, to engage in interdisciplinary cooperation and to take advantage of inter-organisational divisions of labour. Institutions of higher education must improve their recruitment practices and research funding agencies their funding principles with a view to promoting the development of multidisciplinary and interdisciplinary research.

Data collected with public funding should be made as freely available as possible

Why: Finland has internationally unique datasets that are produced with public funding. Free access to the information included in these datasets would benefit individual citizens and society as a whole. In many fields it would also give research a head start in the international competition.

How: National agencies, including the government, central government agencies, institutions of higher education and research institutes, must continue their efforts to facilitate the broader access to public data resources in readily usable format in line with the Government Programme (22 June 2011).

High-quality research and innovation cooperation must be strengthened

Why: An economically, ecologically and socially sustainable society needs a constant stream of new innovations. Sustainable scientific research and education and innovation based on such research are not mutually exclusive but, on the contrary, mutually supportive and complementary.

How: The Academy of Finland, Tekes, the Finnish Funding Agency for Technology and Innovation, and foundations must work together with institutions of higher education, research institutes, the public service system and business and industry to strengthen basic and applied research as well as experimentation and innovation. This requires the creation of internationally attractive knowledge clusters that rely heavily on high-quality basic research. Implementation of this recommendation will benefit from the instrument reform carried out by Tekes. Institutions of higher education, research institutes, the public service system and business enterprises must hire more people with a PhD training into R&D positions.

Political decision-making and public administration should make better use of scientific research evidence

Why: Public decision-making needs evidence-based support from scientific research. Research also has a major part to play in understanding and resolving the grand challenges facing humankind and society. In many fields, Finnish research is of an internationally high standard – in some areas it is world class – and Finnish knowledge and know-how can offer significant support for policy-making and administration.

How: Researcher training must place increasing focus on ensuring that researchers know how to report on their findings in a clear, accessible way and demonstrate the relevance of their research to policy-making. Research funding agencies, institutions of higher education and research institutes can pool their resources to organise events designed to highlight the benefits and opportunities offered by scientific research. The aim of this regular exchange and interaction is to strengthen the knowledge base of policy-making and to set up experiments and development projects for the practical application of scientific research evidence in public administration.

Among the recommendations offered by the Academy's Research Councils, the following warrant special mention

The Research Council for Biosciences and Environment recommends that a clear strategic plan of action be drawn up for Finland for the next few years ahead with a view to bridging the bioinformatics competence deficit in the biosciences. Long-term emphasis must be given to the qualification requirements in the biosector, opportunities for interdisciplinary cooperation, postgraduate training in bioinformatics and the international recruitment of bioinformaticians.

The Research Council for Culture and Society recommends that a common national research strategy be drawn up for the humanities and social sciences in Finland. Discipline workshops and researcher meetings are proven working methods. Organised on a regular basis, they would provide a strong structure under which to address special themes and future challenges in different fields throughout strategic planning periods.

The Research Council for Natural Sciences and Engineering recommends that steps be taken to enhance the appeal of natural sciences and engineering. Awareness about their role in addressing major global challenges must be increased throughout society, and particularly in school education.

The Research Council for Health recommends that basic research and clinical research be developed in a balanced way. A virtuous research cycle contributes to improving public health and the efficiency of the service system.

Appendix 1. Bibliometric methods

Data source

The data consist of publications found in the Thomson Reuters Web of Science databases Science Citation Index (SCI Expanded), Social Science Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Conference Proceedings Citation Index – Science (CPCI-S), and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH).[1] Publication types accepted for the analysis were articles, reviews, letters and proceedings papers. All publications and citations in the included document types in the databases above have been considered.

The analysis was performed by Postdoctoral Researcher Raj Kumar Pan and Associate Professor Santo Fortunato of Aalto University in Finland.

Fractionalisation

All papers are fractionalised among the contributing countries. When more than one country is found in the affiliation address of a paper, the affiliated countries are given an equal share of the paper and the citations received. For example, from a paper written by three organisations, two from Finland and one from Sweden, Finland is accredited with 2/3 of the publication and Sweden with 1/3. The subsequent citations received are: from m citations Finland receives 2m/3 and Sweden respectively m/3. This method is consistent with the previous report *The State and Quality of Scientific Research in Finland 2009*[2] by the Academy of Finland.

Self-citations

Self-citations are removed based on author names. If the citing and the cited article are authored by authors with the same name, the citation is excluded from this analysis.

Citation window

Citations are considered for publication year + two following years. This is also consistent with the 2009 report by the Academy of Finland. However, citations to 2009 and 2010 publications are only received until the end of 2010.

Trend lines

The results are segregated in three-year intervals and a moving window is considered (2003–2005, 2004–2006…, 2008–2010). The number of publications, citations received, relative citation index and the share in the top cited publications is calculated for each of the windows. The last two windows (2007–2009, 2008–2010) are in this respect somewhat incomplete because citations to 2009 and 2010 publications are only received until the end of 2010.

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1 Certain data included herein are derived from the Science Citation Index Expanded, Social Science Citation Index, Arts & Humanities Citation Index, and Conference Proceedings Citation Index – Science and Conference Proceedings Citation Index – Social Science & Humanities, all prepared by Thomson Reuters®, Philadelphia, Pennsylvania, USA, © Copyright Thomson Reuters ®, 2012.

2 Löppönen Paavo, Lehvo Annamaija, Vaahtera Kaisa and Nuutinen Anu (Eds.) 2009. The State and Quality of Scientific Research in Finland 2009. Publications of the Academy of Finland 10/09.

Relative citation impact

The relative citation impact is a field-normalised citation score. Each paper is normalised by the world average in fields to which the paper belongs. All papers are fractionalised by the number of countries as explained earlier.

For the country-level analysis, the relative citation impact has been calculated by using the formula of the mean normalised citation score (MNCS) indicator, introduced and described by Waltman et al[3]. For the discipline-level analysis, the used formula follows the one presented in the 2009 report by the Academy of Finland (p. 286[4]). These two formulas are, in essence, the same.

Top 10%

The calculation of the proportion of the publications of a country among the top 10% of the most cited publications follows the formula presented in the 2009 report by the Academy of Finland (p. 286). For Finland, Sweden, Norway, Denmark, Austria, Switzerland, the Netherlands and Ireland, the top most cited papers in each field are compared to the total number of papers of the country. A relative comparison is made by dividing the country's percentage by the respective world percentage. Provided a paper is assigned to more than one field, a separate comparison is made with the corresponding field average. It is therefore possible for a paper to reach the top 10% in one field but not in another field.

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[3] Waltman, L., van Eck, N.J., van Leeuwen, T.N., Visser, M.S., van Raan, A.F.J. 2011. Towards a new crown indicator: Some theoretical considerations. Journal of Informetrics 5 (1), 37–47.

[4] However, publications have not been normalised by the publication type when calculating the relative citation index and top 10% of the most cited publications.

The Academy of Finland has reviewed the state of scientific research in Finland at three-year intervals since 1997. The 2012 review studies the changes in the research operating environment and reviews the state and position of the research system in international comparison.

In addition, the Academy of Finland's Research Councils analyse the development of the operating environment and the framework conditions for research. The Research Councils also identify the strengths, weaknesses, opportunities and threats of research and make development proposals for the research fields within their remit. The Research Councils' reviews are based on the assessments of the state of different disciplines made by 42 discipline-specific task forces in autumn 2011. The task forces were attended by a total of 366 researchers.

The report also provides a thematic overview of the extent to which Academy-funded projects have dealt with themes associated with the grand challenges facing society. The grand challenges pinpointed by the Academy Board are: The Northern Climate and Environment; Sustainable Energy; Dialogue of Cultures; A Healthy Everyday for All; Knowledge and Know-how in the Media Society; and The Ageing Population and Individuals.

The report includes conclusions and presents development proposals for further strengthening Finnish scientific research and the Finnish research system.

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