Working Papers No. 48/00

A Bibliometric Study of Finnish Science

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ISSN 1239-0259
VTT, GROUP FOR TECHNOLOGY STUDIES
Printing office Lars Eriksen Oy, Espoo 2000

Foreword

This report is one of the background studies commissioned by the expert group, appointed by the Ministry of Trade and Industry and the Ministry of Education, to assess the impact of the Government Additional Appropriation to Research Work, effective in 1997-99. The study was made as a joint effort by Olle Persson from Umeå University and Terttu Luukkonen and Sasu Hälikkä from VTT Group for Technology Studies.

The authors are grateful to Göran Marklund, Ingrid Petterson and Anna Sandström at NUTEK, Stockholm, for their kind assistance in providing additional data for international comparisons. The authors greatly appreciate the comments obtained throughout the work from the assessment expert group.

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Abstract

This study is the most comprehensive bibliometric report of Finnish science carried out, and it is based on a long time series. It uses many types of bibliometric indicators to describe the scentific and technological activities of the Finnish research base. It draws attention to

- publication activities and the international visibility and impact of Finnish scientific research

- domestic and international collaboration patterns, and

- indicators of technological innovation activities.

The major findings of the report include the following. The report gives a very positive picture of Finnish science. The policy to strengthen the internationalisation of Finnish science seems to have been effective. Finland has increased its international publishing and has improved the international visibility and impact of its research publications. Overall, Finnish scientific publications are well above the world average in impact. The positive trend in the international impact of Finnish science is associated with a dramatic increase in international collaboration. Today, 40 % of the Finnish publications are co-authored with researchers from other countries, while the corresponding figure was only half that in 1986. Researchers from EU countries have become major collaboration partners for Finnish researchers. Twenty percent of Finnish papers are co-authored with researchers from the EU-countries, and the share has grown significantly faster than the share of papers co-authored with researchers from North America. EU research collaboration and the EU Framework Programme for research and development have probably played an important role in the increase of scientific collaboration with other EU countries.

The report further shows that, in the Finnish national research system, the Helsinki region dominates. To some extent, there has been a decentralisation process, which has reduced this dominance a little. The decentralisation of research into small units, however, is not advantageous for research impact - and quality, which impact is expected to reflect. Regions that produce small numbers of papers do less well in impact than other regions.

The study of Finnish US patents shows that Finland is active in producing technological innovations and has impact in telecommunications, industrial process equipment, and wood and paper. To some extent, Finland appears to be strong technologically and economically in the same fields (especially in telecommunications and wood and paper). However, in other fields, such as biotechnology and pharmaceuticals, the number of patents is increasing but is relatively small considering the strong national research base. The technological innovation base is much more nationally oriented than the Finnish science base, but there is a steady trend toward internationalisation in this area too.

When using bibliometric indicators, and particularly Science Citation Index (SCI) based data, we focus on basic research in natural sciences and medicine. The SCI uses scientific journals as source material, and publishing in journals plays a major role in basic science, while it is not true for applied areas of research or in fields such as the social sciences or humanities. In Finland, as in the other Nordic countries, medical fields dominate the country's publications in SCI based journals. This reflects particularly the fact that medical scientists have adopted the publication habits that fit the underlying assumptions of the SCI to a larger extent than other scientists have. Their frequent publications in the SCI based journals also reflect a greater degree of internationalisation of their fields of research compared with other fields.

The report also uses patent data, which is more relevant for industrial research. The report utilises the US patent system, which is used most in international comparisons and is expected to provide a filter for measuring the importance of the patents. As a drawback, Finnish firms take fewer patents in this system than in the European or national system.

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1 Introduction

In Finland, R&D expenditures have increased dramatically in the last two decades and today they make up around three percent of Finland's GDP. This development is matched by a growing number of people and organisations engaged in R&D activities and in higher education. On the basis of the growth in the R&D endeavour, we can expect a sizeable increase in the output, too.

This report focuses on the output of Finland's growing R&D effort. We will use indicators generated from literature databases, which help monitor the growth and impact of Finnish science in relation to other countries. We can also analyse collaboration patterns among Finnish scientists across sectors, regions and organisations and across the borders of the country. Collaboration is important for information flows within the R&D system. It promotes the creation of new knowledge with a broader base.

In basic scientific research, knowledge production is reported in various types of documents such as journal articles, conference proceedings, research reports and books. There is, however, a substantial amount of knowledge that is not made public in documents. Non-documented knowledge is hard to study on a large scale and regular basis. In basic research, it is in the self-interest of researchers and research departments to report their research findings to the widest possible audience in order to ensure priority and recognition for the findings as well as to legitimise their performance to the research funding agencies. Furthermore, the editorial process of scientific publishing provides a filter that is expected to improve the quality of the knowledge presented.

In applied research and development, less knowledge is made public in documents. In many instances, it is in the self-interest of industrial actors not to publish since it could be beneficial for their competitors. On the other hand, sometimes firms do publish their research results to prevent competitors from patenting, or to attract eminent researchers to collaborate with the them. Publishing papers or patenting may thus reflect the business strategies of corporations rather than knowledge outputs. Still, assuming that publication and patenting strategies stay fairly similar over the years, the counting of papers and patents of industrial actors may reveal interesting trends in research and development activities.

In addition to the fact that documents are a partial indicator of knowledge outputs, there is no database that can fully cover the output of scientific documents produced by a country. Instead, databases cover segments of the publication markets. The task is to evaluate the extent to which such segments are relevant for analysing R&D activities. The scope of coverage is good in the *Science Citation Index™ (SCI*), since the most influential journals in the life sciences, natural sciences and engineering sciences are included. However, a large number of journals are not covered by the SCI. In addition, books and other types of documents are not included at all. The SCI thus reveals a segment of the publication market, a segment which can be assumed to be relevant for scientific research and in which it is of importance to be visible. There are also technical aspects about the coverage which have to be considered. A minimum criterion is that a document database must register all author addresses. This criterion is fulfilled only by the SCI.

If we look for patent databases, there are several possible candidates for representing national technological activities. Most patent databases, however, are heavily biased towards one country, which makes international comparisons less relevant. The US patent system represents the largest market for technological innovations and as such should be a representative base for comparing countries outside the USA. Another advantage is that the US patent system has developed standardised procedures, which are applied equally to all patent applications. It tends to filter out technologically trivial patents from non-US countries. Again, we are talking about a segment of the patent market, but maybe about the most relevant segment for studying and comparing the technological activities of countries.

Papers and patents contain a lot of information. When authors publish, they tell what they did, with whom they did it, and when and where the research was done. This also holds true for patents. Furthermore, the databases are fairly standardised and various classification systems can be applied to describe the contents of the papers and patents.

To sum up, bibliometric indicators may reveal interesting information about knowledge producers and their interactions. These indicators give a partial view in the sense that they reflect knowledge that is made public in certain segments of the publication market. Still, they are the best alternative when it comes to studying the volume and impact of basic research on a large scale.

In this report we will try to answer three major questions:

- How does Finnish science and technology compare with other nations in activity and impact?
- Which are the major actors in Finnish science?

- How is research collaboration developing in Finland and with foreign countries?

2 Design of the study

In this study we have used the following four sets of data (See Appendix 1 for a full description):

1. Detailed information about all Finnish papers in the Science Citation Index (SCI) 1986-1998

This dataset was constructed by downloading Finnish records from the SCI. All Finnish addresses were standardised according to main organization, sector, city and geographical region. In order to define scientific fields, articles were classified by the subject content of the journal in which they were published.

2. Detailed information on all Finnish US-patents 1986-1998

All Finnish patents, either by inventor or assignee, were downloaded from the web server of the US patent office. The inventor and assignee addresses were standardized according to country and the patents were assigned to technical fields using the International Patent Classifications.

3. International summary data for papers based on the Science Citation Index(NSIOD)

This dataset was made by the *Institute for Scientific Information (ISI)* and can be used to make international comparisons. It is based on the SCI and has the number of papers and citations for all countries covering the period of 1981-1998. The paper and citation counts can also be distributed by subfield. We were able to use this dataset by courtesy of NUTEK in Sweden.

4. International summary data for patents based on the US-patents (CHI-data)

This data set has been produced by *Computer Horizons Inc (CHI).* For all countries it contains the number of US patents as well as the number of times other US patents have cited them in 1981-1998. This enables us to compare the patenting activity and the impact of Finnish patenting activity on other countries. The patents are classified into technical fields using the International Patent Classifications.

Various types of bibliometric measures are used in connection with these data sets. When counting papers one has to consider what to do when they are co-authored by several sectors, organizations, cities, authors or any other type of unit. If such papers are counted as one paper for each unit, we are using *whole counts*. For example, if a paper has been produced by two organizations, or classified into more than one subject category, each occurrence will be considered as one whole paper.

When whole counts are used, the data should be read as the number of papers in which a particular unit occurs. This procedure leads to double counting. We can avoid the double counting by dividing the number of papers into fractions according to the number of units that have produced them, that is, by using *fractional counts.* The sum of all fractions will be equal to the actual number of papers in the data set. This allows us to measure the percentage of all papers that has been produced by a particular unit.

There are several types of citation measure used. The NSIOD counts the number of times a paper has been cited by all other papers in the database. If the cited papers have been published by authors from several countries, the citations are not fractionalized, and all papers are also counted as whole counts. On the other hand, the CHI database uses fractional counts of patents and citations to patents. If a patent is co-invented by two countries and has been cited by ten other patents, each of the two countries will get half a patent and five citations. Although, we cannot manipulate these two types of data set in our study, we should keep in mind that whole counting hides the fact that the output and impact of a nation are increasingly the result of international collaboration. The difference between whole and fractional counts for a given unit, be they countries, institutions or individuals, is a measure of the degree of collaboration. For example, if the whole count gives an institution 100 papers and the fractional count 50 papers, we can say that the difference is the effect of collaboration.

The number of times papers and patents of a country are cited can be compared with the number of times all papers or all patents in the database are cited. A *relative citation impact* can thus be calculated by dividing the citations per paper for a country by the average number of citations per paper for all papers (the world output). In both the NSIOD and the CHI data, the citing year window is 1981-1998. This means that papers and patents published in 1981 have a much longer time period and a greater chance of being cited than those that are published towards the end of the period. Since one normally has to wait several years before a paper or a patent gets most of its citations, data for the last few years fluctuate. When comparing countries using fairly large numbers of papers and patents, even the short-term impact is interesting, since it can indicate trends in the relative standing of nations.

In this report, we use the *journal impact factor* as an alternative measure of impact, because we have no citation data for individual Finnish papers. The journal impact factor is calculated by dividing the number of times the articles of a journal are cited by the number of the articles the journal publishes. First of all, it is of importance to publish in a journal with a certain level of reputation, which is fairly well indicated by the citation impact of the journal. Secondly, provided we have a fairly large number of papers, the mean journal impact of the papers should be a reasonably good predictor of future citation impact of the papers. Still, we have to consider the fact that some units, even whole countries, may perform significantly better or worse than expected, given the journal impact factor.

When calculating the journal impact factor, the cited and citing time window may vary. In the *Journal of Citations Reports (JCR),* which is frequently used to rank journals by impact, the citing year is one year and the cited years the two previous years. In this longitudinal study we will use journal impact factors taken from a database called *Journal Performance Indicators on Diskette* (JPIOD). Here the journal impact factors are based on the average number of times the articles published in the journals in 1981-96 have been cited during the same time period.

3 Findings

The presentation of our findings is structured in the following way. We will start by comparing the output and impact of Finnish papers with those of other countries. Then we will examine the development of Finnish collaboration with other countries by analysing internationally co-authored papers. We will also study Finnish papers by region, sector and organisation. Finally, we will examine collaborative networks within Finland.

Technological activities are analysed by drawing on patent data. We will present data on the growth and impact of Finnish patents in relation to other countries, and we will also study collaboration by looking at internationally co-invented patents.

Most of the results from the study will be presented in figures in the text that follows. In addition, we also refer to tables in Appendix 2, which the reader may consult in order to get more information and explanations.

3.1 Overall output and impact of papers in all fields

Finnish scientific production shows a positive growth in terms of papers and their citation impact. Finland's share of world output has increased from 0.59 % in 1981 to 0.92 % in 1998. With the exception of Denmark, all the other Nordic countries show growth in publication numbers. This growth is strongest for Finland and Sweden (Figure 1; Table 1, Appendix 2). The Nordic countries serve as relevant benchmarks for Finland since they are relatively small countries, they have similar research profiles by scientific field, and the academic systems and traditions are quite similar.

Finland is the only Nordic country showing a marked increase in the relative citation level, particularly in the 1990s (Figure 2). Since 1991, the relative citation impact of Finnish papers (citations/paper for Finland divided by citations/paper for the world) has been above the world average, and in the late 90s, it was well above the world average and close to that of Sweden. Sweden's citation level is, however, decreasing.

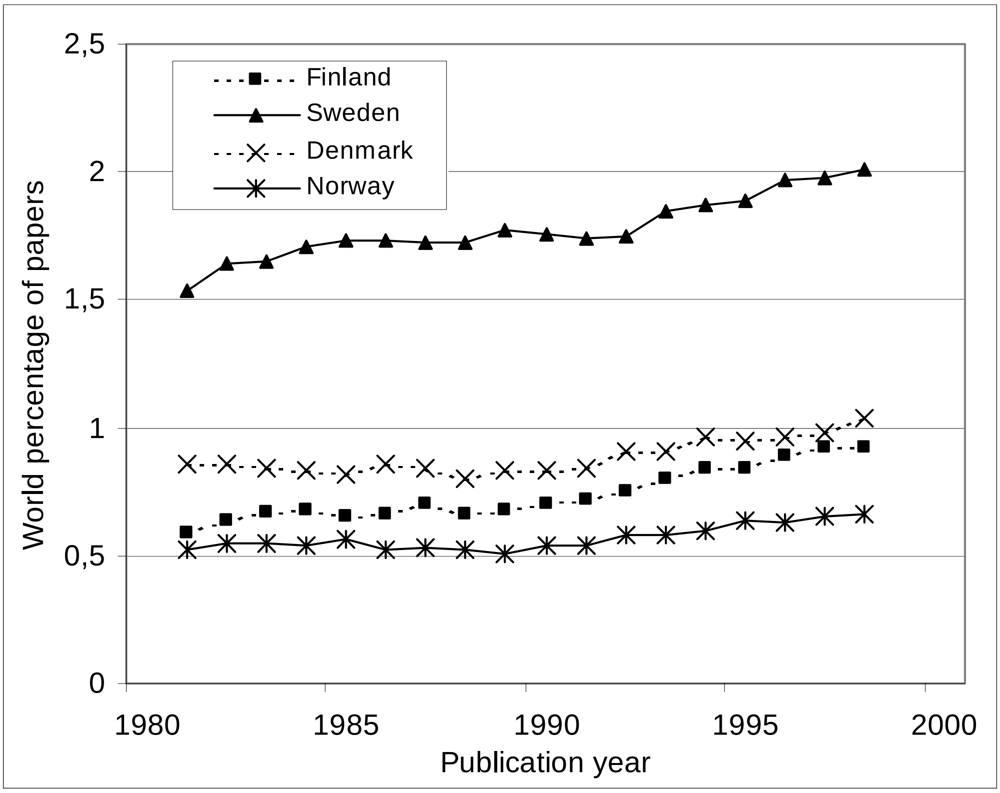

Figure 1. World percentage of papers published by the Scandinavian countries

Note: Based on Table 1 in Appendix 2

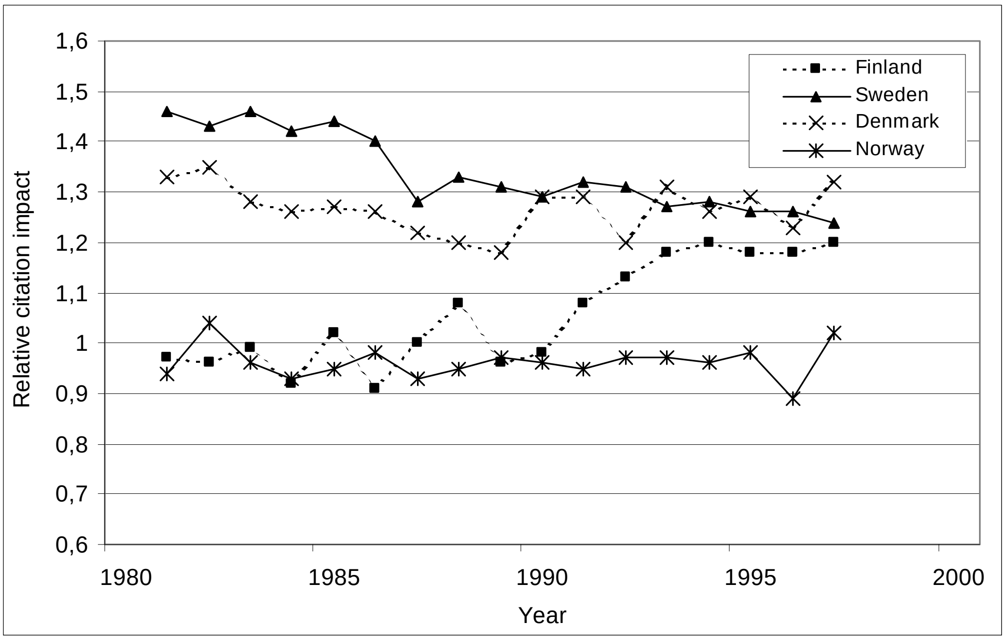

Figure 2. Citation impact of the Scandinavian countries relative to the world average

Note: Based on Table 1 in Appendix 2. World average is equal to 1.

A word of caution, the citation figures for the last two years are unstable, since the papers have been there to be cited only for one or two years. However, if we compare the first five-year period with the last, Finland shows a significant increase in relative impact and is closing the gap with several leading nations (Figure 3). We can thus conclude that the Finnish positive trend is quite stable.

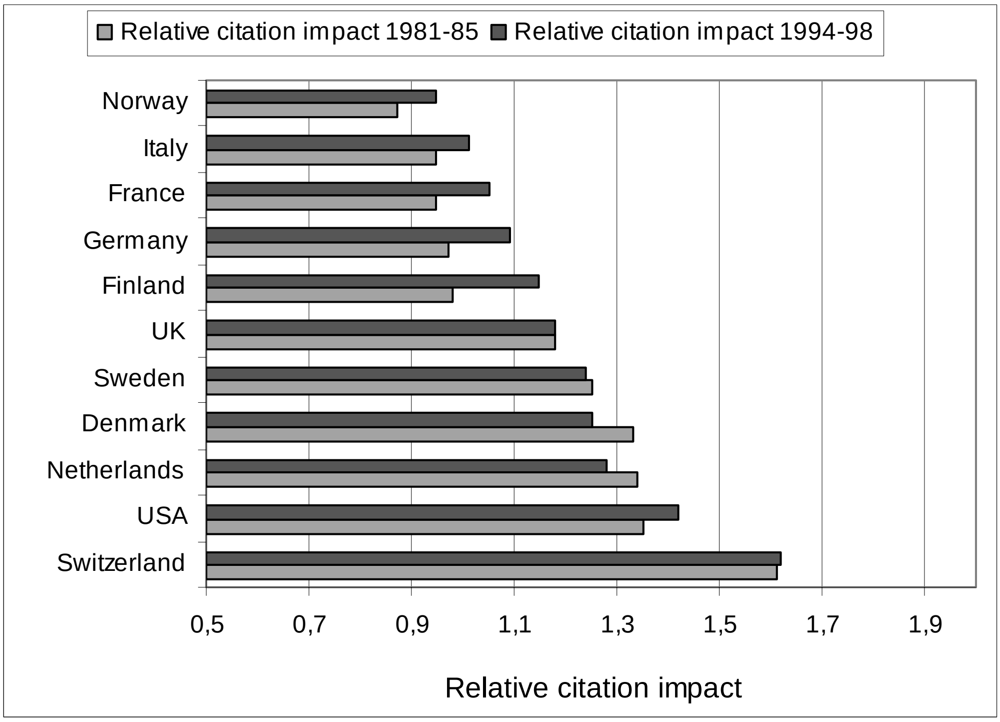

Figure 3. Citation impact relative to the world in 1981-85 and 1994-98

Note: Based on Table 2 in Appendix 2

One explanation for the rise of the relative citation impact of Finland is that Finnish papers are published in journals with a higher impact. Figure 4 shows that this is the case. The relative impact of the journals in which Finnish papers are published, shows a similar increase when compared with the growth of relative citation impact. Several international evaluations carried out on Finnish science have emphasised a need to publish in internationally highly-ranked journals. This has also been the policy of, for example, the Academy of Finland, which is the Finnish Research Council system. Another explanation for the increased impact of journals used for publication in Finland is international collaboration, which usually is associated with both higher journal impact (see figure 4), and higher citation impact (see for example, Glänzel, Schubert and Czerwon, 1999).

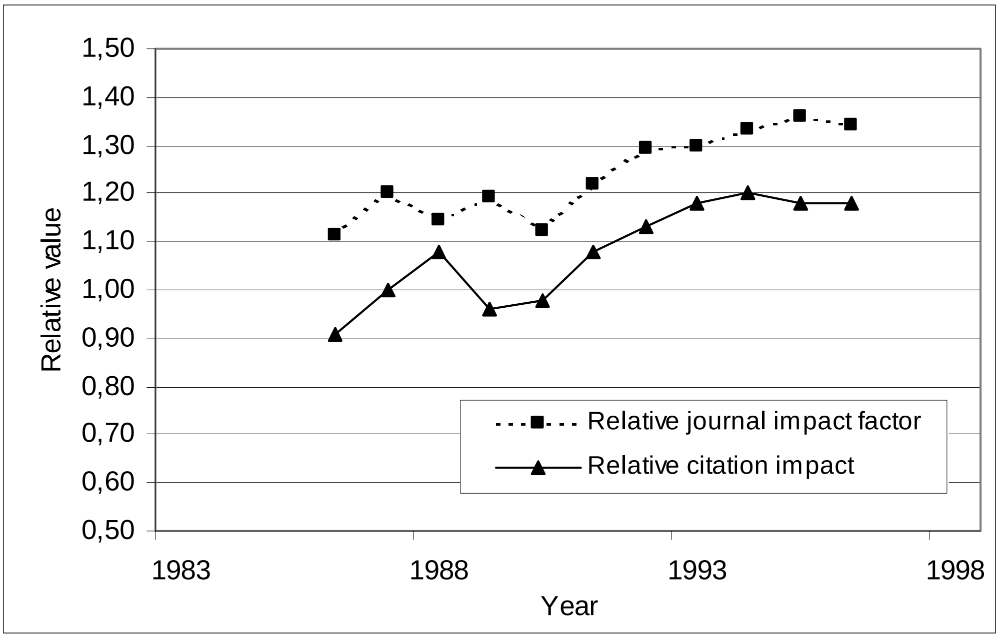

Figure 4. Relative journal impact factor and relative citation impact for Finnish papers 1986-1996

Note: Based on Table 3 in Appendix 2

3.2 Papers and citation impact by subfield

As will be seen from the analysis below, medical sciences dominate Finnish scientific publications as reflected by the SCI. This is not unique for Finland, but similar for all Nordic countries, in which papers in clinical medicine represent about 40 percent of all papers. The dominance of the medical sciences in the ISI databases is due to several factors. One of them is the fact that the majority of the source items in the SCI (and other ISI databases) are scientific journals. Medical scientists have publication habits that correspond to the underlying assumptions of the SCI: they publish in refereed journals and a great deal in Anglo-American journals, which have a dominance in the SCI. In many other fields books, reports and, in general, publishing in non-English languages is much more prevalent, and therefore, the SCI covers the publication activity of such fields only to a limited degree. A good example is engineering and technology, a field in which reports and conference proceedings are quite common and poorly, if at all, covered by the SCI. In addition, in this field, many important research findings are not published at all.

The implication of the varying coverage across subfields is that comparisons between countries should primarily be made at the subfield level, where publication activity and citation impact are measured relative to world output and impact.

Considering subfields with at least 100 Finnish papers in 1981-1998, several show *a high and a growing relative impact as measured by their citation rates* compared with the world average in each field. Among the top fields are a number of medical specialities but also physics (Table 4, Appendix 2). Several of the top ranked fields have also significantly increased their relative impact during the last five years of the period studied. Since the field classification used here is based on the NSIOD-data set, which has quite lot of subfields, the classification of single journals might have significant effects on the citation impact of a given field. Ideally one should first evaluate the list of journals included before making definite conclusions about the strength of a subfield. It is also important to stress that journal subsets do not necessarily overlap with research departments within a discipline. It is a well-known fact that research departments often publish papers in several journal subfields and also in the multidisciplinary category.

3.3 International collaboration

The dramatic increase in scientific collaboration is a well-documented trend, which is especially obvious when one looks at the share of internationally co-authored papers. Generally speaking, relatively small science nations have a higher share of internationally co-authored papers compared to larger nations (Luukkonen, Persson, Sivertsen, 1992). In 1998, 40 percent of the Finnish papers were internationally co-authored, which means that 60 percent had only Finnish authors (Table 5, Appendix 2). In 1986 the share of internationally co-authored papers was only 19 percent. In Sweden, 22 percent of papers were internationally co-authored in 1986 and 40 percent in 1996. Thus, in fifteen years international knowledge co-production has doubled in both countries.

If we take a closer look at the geographical distribution of the papers, we can conclude that the share of papers co-authored with the EU countries has grown much faster than with North America (USA and Canada). Today, collaboration with the EU countries is twice as frequent as with North America (Figure 5). There is also a growth of papers that have authors from both the EU countries and North America.

Several studies have confirmed that the citation impact of internationally co-authored papers is generally much higher than that of papers produced by a single country (see e.g. Glänzel, Schubert and Czerwon, 1999). The same tendency can be found in this study. If we multiply the Finnish papers by the journal impact factor, the mean impact level is generally higher for internationally co-authored papers. To put it slightly differently, if the distribution of papers is weighted by the journal impact factor, the contribution of national papers to the total impact decreases (Table 6, Appendix 2).

However, in terms of journal impact, it seems to pay more to collaborate with North America than with the EU. This is found by dividing the corresponding percentages in Table 6 and 5 for 1998. For the EU we get 21.4/19.2=1.11 and for North America 11.0/7.7=1.41. This is also evident when comparing Figure 5 and Figure 6, since in Figure 6 the curve for papers co-authored with North America comes closer to the EU curve. We cannot interpret this finding by concluding that papers with an American co-author are of higher quality *per se*. Rather, it is likely to do with the journal markets and the fact that papers co-authored with American authors are often published in US journals. These are more highly-cited than other journals because of the larger US readership. There is a general phenomenon of a home-country bias in citation (Frame and Narin, 1988).

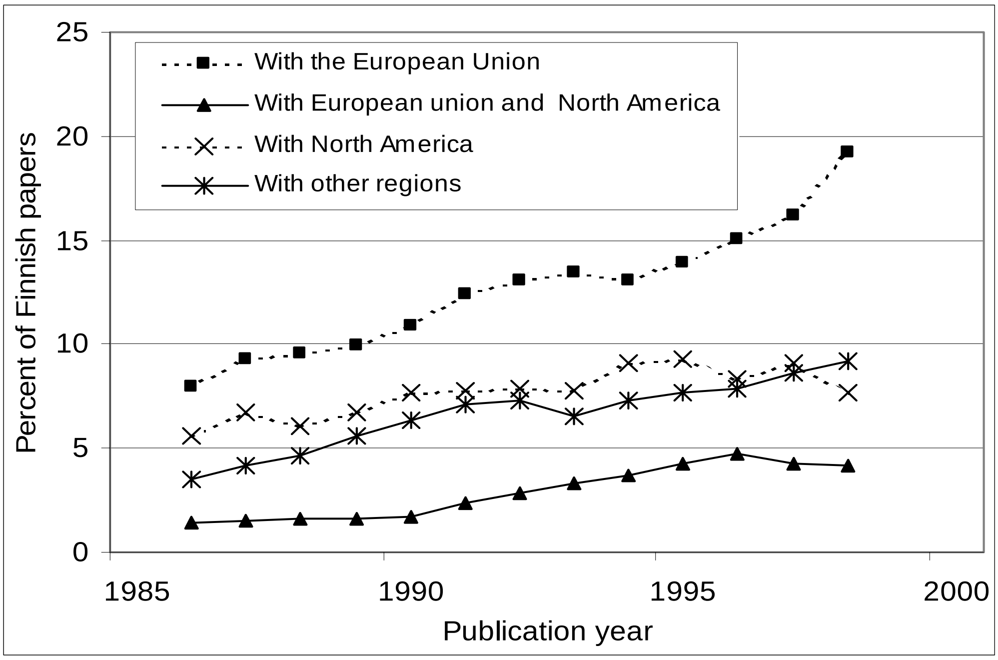

Figure 5. Percent of Finnish papers co-authored with different country groups

Note: Based on Table 5 in Appendix 2.

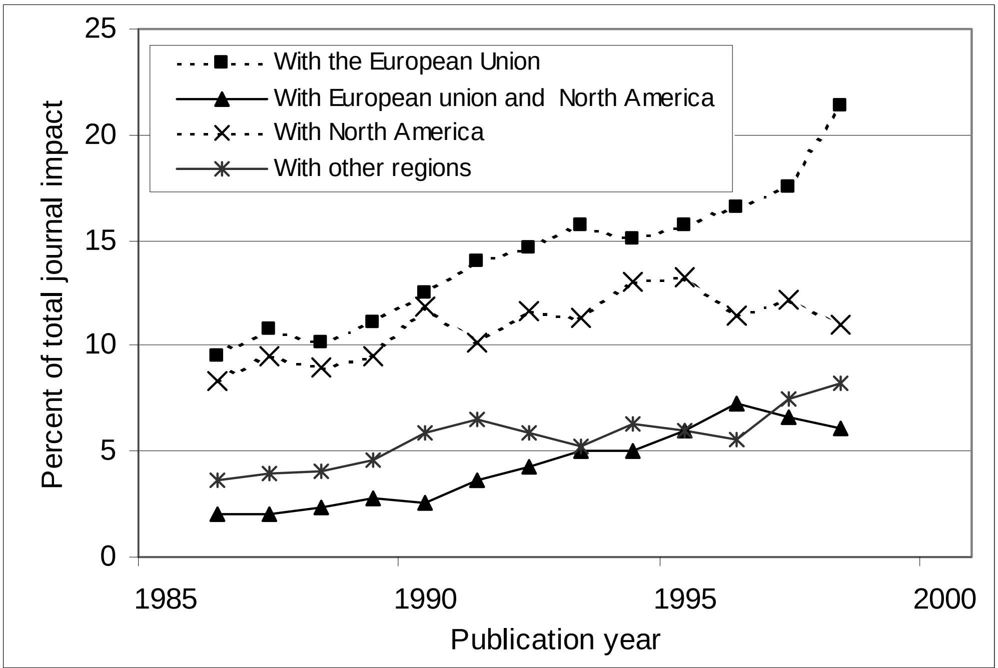

Figure 6 . Percent of Finnish total journal impact by country group of the co-author

Note: Based on Table 6 in Appendix 2.

With regard to collaboration with individual countries (Table 7, Appendix 2), Finnish international collaboration is growing fast with many countries. About ten percent of all Finnish papers are co-authored with authors from the US, but there has been a stagnation since 1995. Sweden occurs as collaborator in about 5 percent of Finnish papers. Collaboration with the EU-countries is dominated by Sweden, the UK, Germany, France, the Netherlands and Denmark.

Finland's collaboration with Spain, Portugal and Greece has increased dramatically. This is not surprising taking into account that there was very little collaboration with these countries at the beginning of the study period (see Table 7, Appendix 2). Collaboration has grown quite remarkably also with Austria, Italy, France, the Netherlands, and Belgium (Figure 7). Growth in collaboration with EU countries can be explained by an increased participation by Finland in projects financed by the EU.

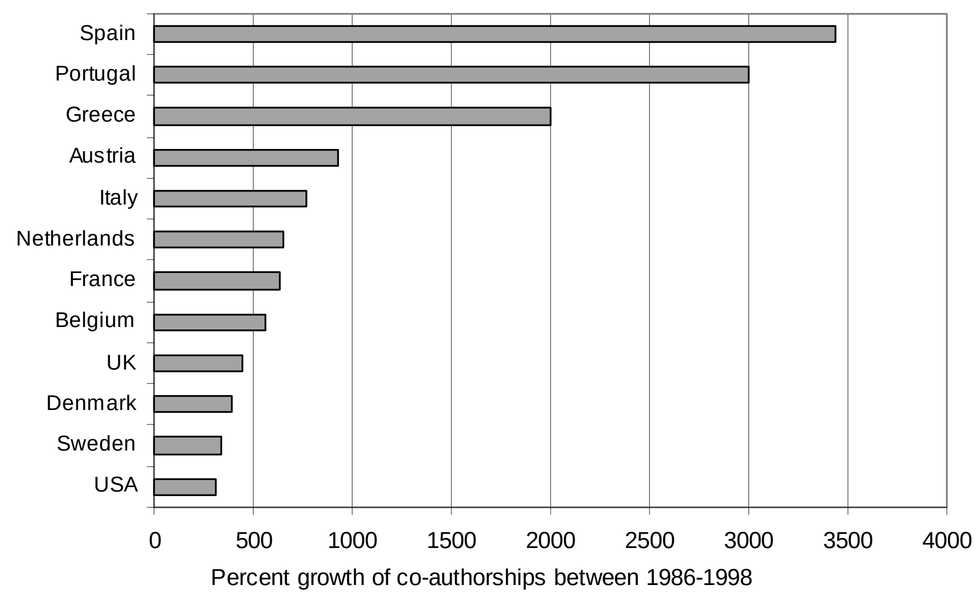

Figure 7. Growth of Finnish papers co-authored with EU-countries and the USA

Note: Based on Table 7, Appendix 2.

3.4 Finnish papers by geographical region

The regional distribution of research activities in a country has become a major policy question. The socio-economic development of a region is influenced by its ability to attract research activities and higher education institutions. There are arguments against a development towards regionalisation. One of them concerns economics of scale, namely that the decentralisation of research will lead to higher costs, at least infrastructural ones, and to lower research quality. These questions can be studied to some extent by bibliometric data.

When studying papers by geographical region we can conclude that there is a decentralisation, however weak, at work in terms of knowledge output (Figure 8). About half of the Finnish publications come from the Uusimaa (Helsinki) region, but this region has lost about 3 percentage units to other regions, most of it to south western part of Finland. The northern Ostrobothnia (Oulu) region has also lost somewhat, while most other regions have increased their shares a little. We are using fractional counts, so that co-authorship among the regions will not influence paper counts.

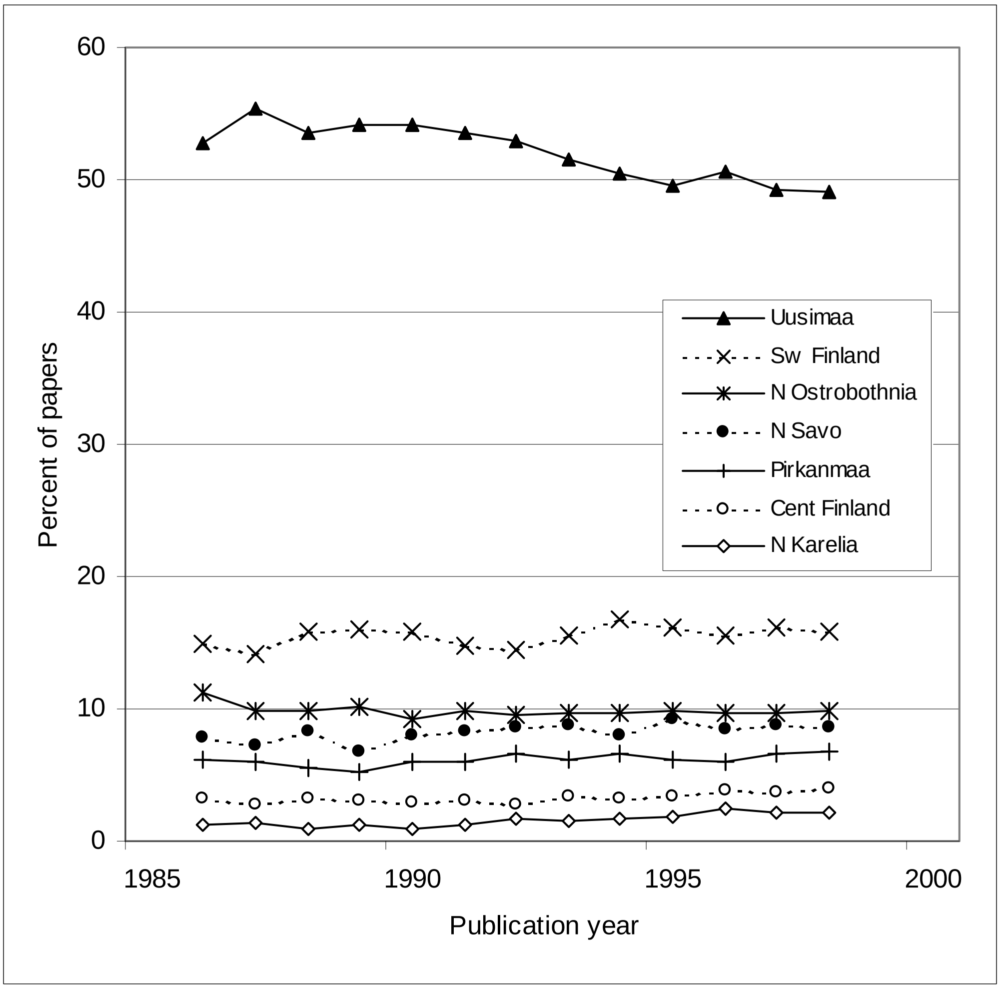

Figure 8. Percent of Finnish papers by region 1986-1998.

Note: See Table 8, Appendix 2. Source: Inforsk/VTT data based on SCI CDE.

With regard to the impact of papers, we have no measure of actual citation impact by region. We can use the journal impact factor, which for large sets of papers can be a reasonably good estimate of citation impact. Since regional research profiles may vary a great deal by field, we are only looking at trends. From Table 9 (Appendix 2) we can conclude that regions with the largest number of papers show a positive trend in average journal impact factor. For smaller regions (smaller in terms of scientific papers), the value fluctuates considerably, and it is probably an effect of a single or a few papers with a high impact factor. However, the impact level is generally lower among smaller regions. Size and impact are thus positively correlated. Consequently there is a risk of a loss of research impact, and eventually also research quality, when research activities are decentralised to very small units.

It seems that a volume of 250 or more papers per year is needed to reach a fairly high and stable impact level.

Another aspect of the regional dimension is collaboration among regions. In 1986-1998, 15 percent of Finnish papers had authors from two or more Finnish regions. This is about half as much as the share of Finnish papers co-authored with other countries in the same period. In that sense, intranational collaboration plays a minor role compared to international collaboration. Furthermore, the average journal impact of papers co-authored among Finnish regions is only slightly higher (10.8) than papers produced by only one region (10.6). By contrast, internationally co-authored papers have an average journal impact factor of 12.60. In conclusion, in terms of citation impact intranational collaboration does not pay as much as international collaboration.

We can expect that smaller regions have a higher tendency to collaborate with other regions than larger regions because researchers in small regions have most of their national colleagues in other regions, and vice versa for the large regions. A simple way to measure collaboration is to compare whole counts with fractional counts of papers by region. The more there is interregional collaboration, the lower is the fractional value compared with whole counts. Table 9 shows that for smaller regions, fractionalisation reduces the number of papers more than for larger regions. The smaller the region, the more it collaborates with other regions (Table 10, Appendix 2). In terms of impact, small regions will probably gain from collaborating with the larger regions since the latter have a higher journal impact (Table 9, Appendix 2).

3.5 Finnish papers by sector

In this study we have classified the institutional addresses of the Finnish papers into the following categories:

- Academia: Universities and other higher education institutions, with university hospitals included.
- Research institutes: Aside from public research institutes, this class includes some private research organisations that are not profit-oriented but owned either by foundations or by several companies together.
- Other: Non-profit organisations other than the ones mentioned above (hospitals that are independent of universities, associations, federations, foundations, administrative organs (other than research institutes) such as ministries,

municipalities, also municipal laboratories that do not research but do inspection, schools other than universities

- Industry: Firms including some small private, profit-oriented research organisations and consulting firms

Figure 9 gives the relative share of Finnish papers by sector. The education sector dominates with 77 percent of the papers, followed by research institutes with 12 percent. Industry answers for about four percent and the sector labelled 'others', containing mostly non-academic hospitals, have six percent of all Finnish papers. The miscellaneous category, that is with organisation unknown, which has published 0.2 percent of the papers, has been excluded from the analysis. The most obvious trend is the growth of the research institute sector, which has increased from 9 to 14 percent.

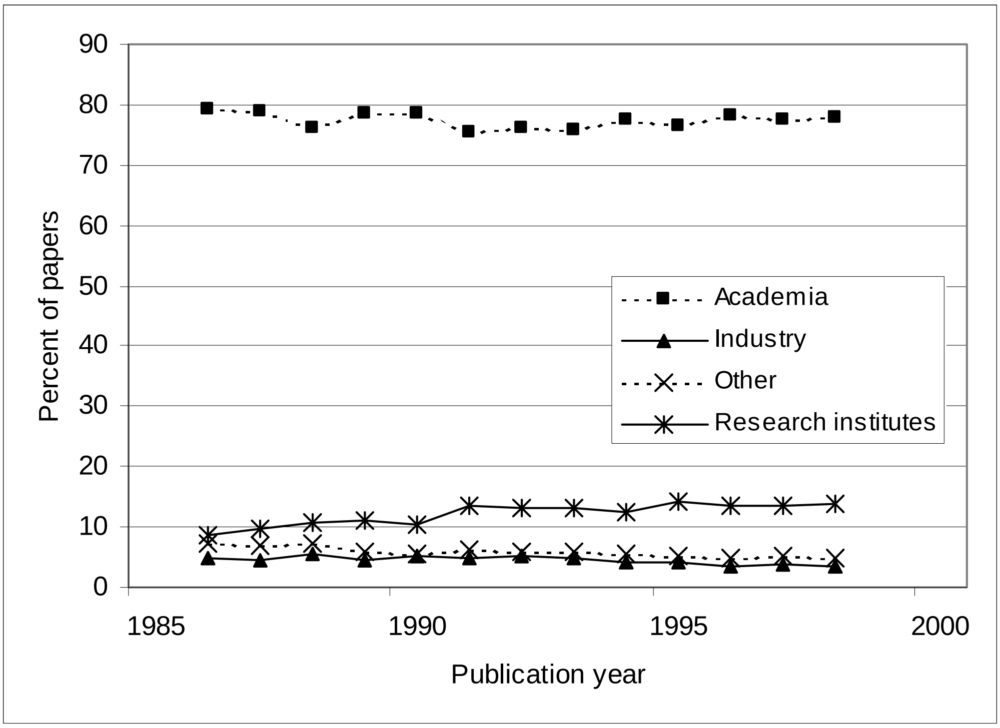

Figure 9. Percent of papers by sector

Note: Based on Table 11, Appendix 2

If we have a look at the research profiles by sector, the education sector is relatively more active in the natural sciences while industry is more active in engineering (Table 12, Appendix 2). One would expect universities to be strong in basic research and industry in applied research. The research institutes are somewhere in between, with a stronger position in engineering compared to academia, but less strong compared to industry. Since the category ’others’ mostly covers non-academic hospitals they have, and should have, a high activity in life sciences.

The mean journal impact factor is generally higher for publications authored by the academic sector in all fields. Variation by sector is quite low in life sciences, while in engineering and materials as well as in natural sciences, universities score much higher than industry and research institutes (Table 13, Appendix 2). Again, the dimension of basic and applied is the explanation, with basic science journals having higher impact factors. The different levels of journal impact by field cannot as such be interpreted as an indication of quality, since they reflect different citation habits and citation frequencies of fields.

Research policy makers in Finland, as in many other countries, have attempted to stimulate cross-sector collaboration. Figure 10 shows that there is indeed an increase in cross-sector collaboration (Table 14, Appendix 2). In 1986 the "inter-sector links per paper" ratio was 0.17 while in 1998 the corresponding figure was 0.20. However, most growth appears to have taken place between the academic sector and the research institutes.

Collaboration between academia and industry is more or less constant in absolute numbers, and decreasing relative to the whole Finnish paper output. Therefore, one might conclude that academic and industrial collaboration has not increased. However, we know from other sources of information that research collaboration between universities and industry has strongly increased in Finland in the 90s (Statistics Finland 1993 and 1999). This is evident in the fact that the funding of university research by industry has grown a great deal. The same is true for Tekes (National Technology Agency) funding, which usually has a condition that, in the projects to be funded, there is university - industry collaboration. Recent data from the Second Community Innovation Survey also confirms that there is considerable university-firm collaboration in R&D in Finland (see Luukkonen & Hälikkä, 2000). We can thus conclude that this increase in collaboration has resulted in publishing in non-SCI source journals or in non-publishable outcomes.

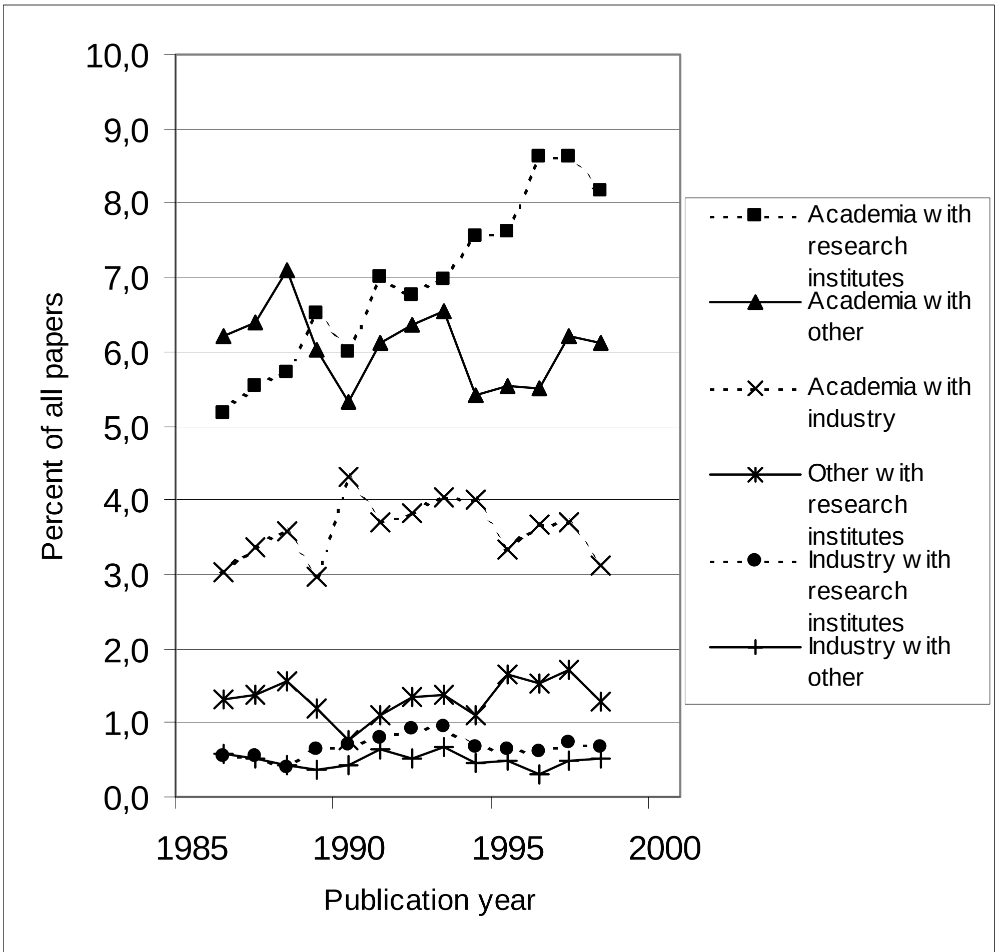

Figure 10. Percent of all Finnish papers co-authored across sectors

Note: Based on Table 14, Appendix 2. The classes are not exclusive.

However, when industry publishes papers, it publishes most of its papers in collaboration with academia. In 1986, 44 percent of the papers from industry were co-authored with the academic sector while in 1998 the figure was 56 percent and had thus increased. Most industrial papers are written by researchers in pharmaceutical companies and it follows that they dominate the collaboration between academia and industry.

3.6 Papers by main institution

So far we have studied numbers of papers and interregional and cross-sector collaboration. A large array of institutions are represented among the publishing organisations. In all, 940 organisations had produced at least one paper in 1986-1998. However, the distribution is very skewed. The most productive ten institutions account for 80 percent of the papers, 25 of the most productive for 90 percent, and 50 institutions account for 95 percent of the papers. The rest are occasional producers of papers with, at maximum, 4 papers per year. 500 institutions published only one paper.

Table 15 (Appendix 2) lists major Finnish institutions in the order of their publication output. In the university sector, the University of Helsinki has a leading role. The volume of output by the University of Helsinki is about as large as that of the Universities of Turku, Oulu and Kuopio taken together.

Orion Corporation (medical company) and Alko Limited (state monopoly of alcohol) dominate the industry sector (Table 15, Appendix 2). Neste Corporation (state-owned oil company), Farmos Group, Wallac and Leiras rank next. Among this group, aside from Neste, all other companies are involved in biomedical research.

Among the research institutes, the National Public Health Institute, again an institute in medicine, has a leading role followed by the Technical Research Centre of Finland and the Institute for Occupational Health. There is also a group of institutions that have a substantial output outside the above mentioned sectors. These include the Social Insurance Institute, The Red Cross and a number of medical institutions.

The mean journal impact factor varies by publishing institution (Table 16, Appendix 2). The National Public Health institute has the lead in life sciences and in the multidisciplinary category while Helsinki University scores quite high in the natural sciences. There might be specific research profiles that determine the impact figures and one should not pay too much attention to them unless we narrow down the study to specific subfield. If we limit the analysis to subfields, there does not seem to be systematic variation in impact by size (defined by the number of papers produced) (Table 17, Appendix 2). Physics is strong at Helsinki University but also quite strong at Åbo Academy, which has twenty times fewer papers. In biology and chemistry there are apparently no visible size effects.

We may assume that, in large samples of papers, actual citation impact will vary in a similar manner as does the journal impact factor. However, we must stress that we have studied publication activities at a fairly high aggregation level. There is probably much more variation at lower levels, at the level of departments or research groups and in smaller subfields. An important conclusion is, however, that it is hard to rank institutions without being able to control for research profiles or type of research activity. In order to discover centres of excellence, one should probably search for research groups which score highly in actual citation impact as compared with other national and foreign groups in specific research areas.

We strove to control for the influence of size on productivity and impact. Figures 31 - 33 and Table 22 in Appendix 3 give numbers of publications and average impact levels by academic institution in medical and non-medical fields. Number of person-years as reflected by the Kota database of the Ministry of Education has been used as a proxy for size.

These data show first that in medicine the trend upwards in publication numbers and relative citation impact hold for all universities despite size. The figure, which only includes journals with an impact factor higher than 10.0, attempts to control for the journal coverage change in the SCI. The database drops out journals that have low impact factors and includes new one with higher ones. Figure A33 shows that the upward trend is even more pronounced than when the data included all SCI journals, and that the position of the University of Helsinki was even more pronounced.

In non-medical fields, papers per staff are quite stable, but impact per staff fluctuates, probably because the journal impact factors vary a great deal from field to field. The data show that with a few exceptions, the University of Helsinki is publishing more than the other universities and has higher journal impact even when its size has been taken into account. The University of Kuopio publishes more in non-medical fields, but this is presumably due to one outstanding institute, the Virtanen institute in molecular biology.

Universities play an important role in research collaboration (Figure 10). The strong position of the universities is also quite clear when we look at a map of collaboration among institutions (Figure 11). The universities are in the centre closely interacting with the National Public Health Institute and the Institute for Occupational Health, both research institutes in the medical field. In the periphery there is a set of non-academic organisations. The medical sector is on the top of the map, while companies are found at the bottom right part, relatively close to the technical universities. In the bottom left part we find research institutes in agriculture and forestry. To a large extent this map is biased towards medicine and life sciences since these fields dominate the Finnish output.

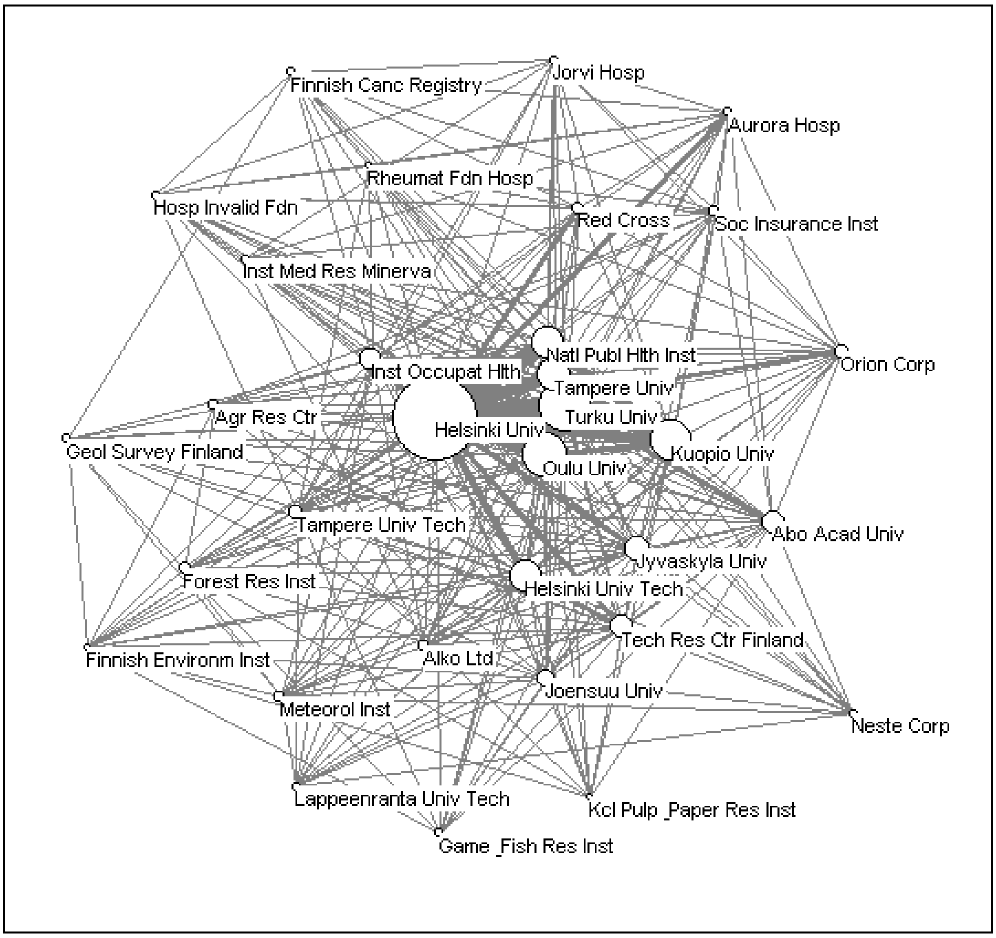

Figure 11. Collaboration among main institutions

Note: The location of institutions on the map is estimated by applying a Multi-Dimensional-Scaling algorithm to a collaboration matrix. The size of the circles is proportional to the number of papers. The thickness of the lines between circles indicates the number of co-authored papers. Only institutions with more than 4 papers are included.

Quite another set of nodes and interactions appear if we specify the network to be the field of Materials Science & Engineering (Figure 12). Not surprisingly, the technical universities and industries now dominate. Since universities collaborate intensively with each other, there are many opportunities for indirect linkages between firms and universities.

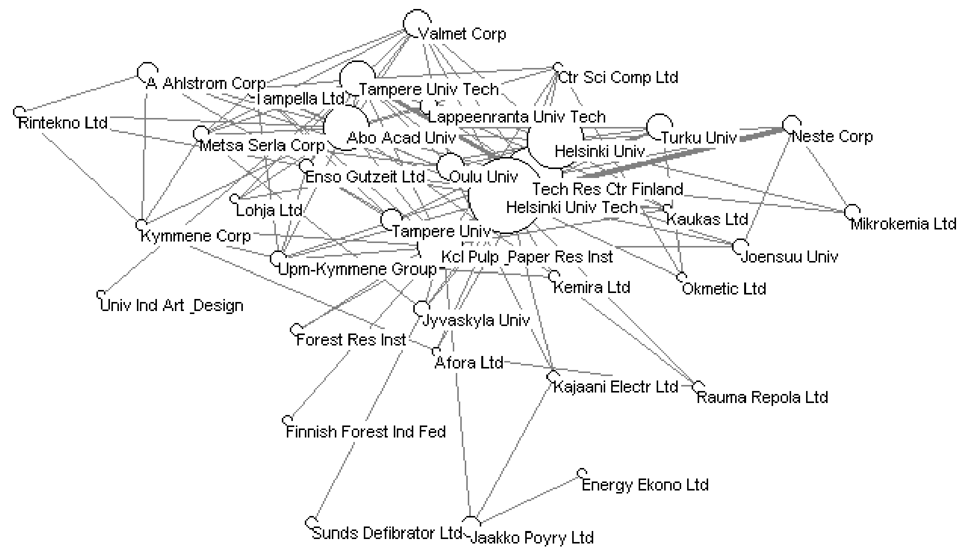

Figure 12. Collaboration among main institutions in Materials Science & Engineering

Note: The location of institutions on the map is estimated by applying a Multi-Dimensional-Scaling algorithm to a collaboration matrix. The size of the circles is proportional to the number of papers, and the thickness of the lines between circles indicates the number of co-authored papers. Only institutions with more than 4 papers are included.

3.7 Overall output and impact of patents

If papers in the SCI represent output from basic research, patents in the US patent system mirror the output of technological innovations. The patent data from the CHI are based on the country of the inventor of patents issued in the US patent system. In 1986-1998, there were 4400 patents with at least one inventor with a Finnish address (Table 18, Appendix 2). This is 0.3 percent of all patents. Compared to Sweden, the SCI-paper/US-patent ratio is just about the same: for Finland 0.9/0.3=3.0, while for Sweden 1.9/0.6=3.1.

The most dynamic field of the last few years is telecommunications, which has by far the greatest number of patents. This is not surprising considering the exceptional success of the Nokia Group. Telecommunications technology shows an impressive trend upwards. However, it is a rapidly developing field, and companies in many countries patent intensively in this field.

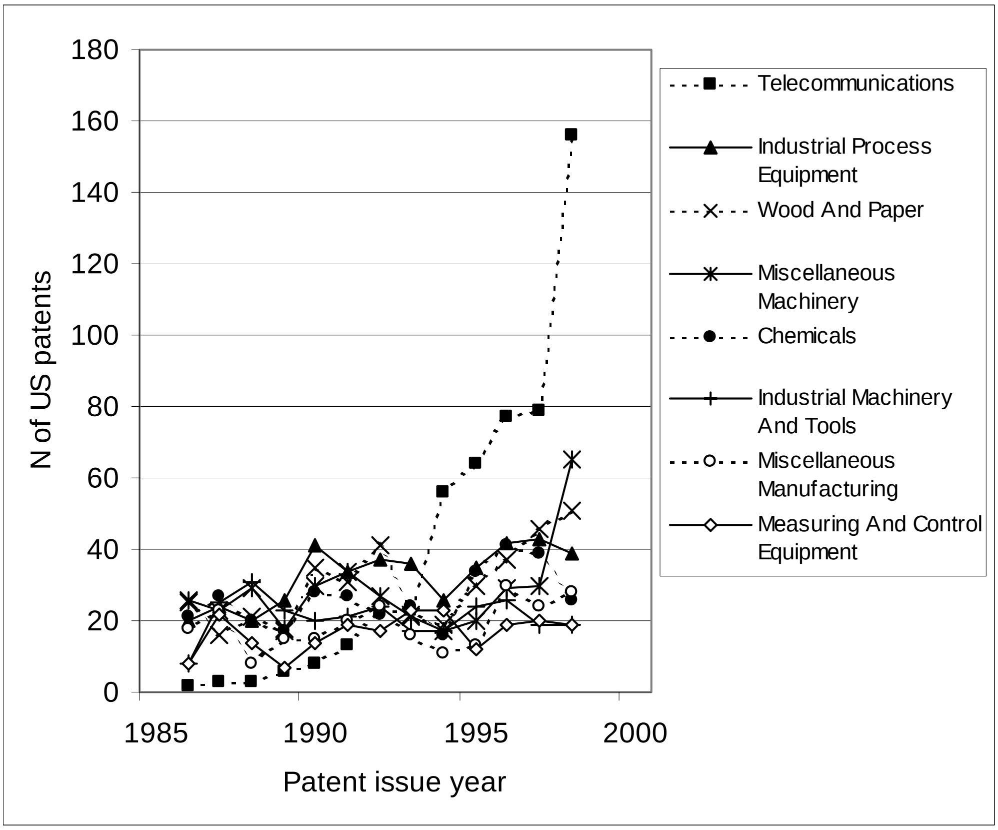

Figure 13. Number of patents with a Finnish address in the US patent system, 1980-1998

Note: Based on Table 18, Appendix 2

If we relate the share of Finnish patents in a field to the share of all US-patents in the same field, we find that Finland has the highest shares in the fields of wood and paper, medical equipment, industrial process equipment, glass, clay and cement (the relative activity index (RA) in Table 18, Appendix 2).

The impact of the patents, that is, other patents citing them, is above the world average in telecommunications and wood and paper (Table 19 Appendix 2). Electrical appliances and components is a field with a high impact, though a somewhat lesser activity. The patent impact fluctuates a great deal in many fields, since these are small, and particular patents may have sudden citation peaks.

3.8 International collaboration in patents

For a US patent, there may be inventors from several countries, in the same way as a paper may be internationally co-authored. Figure 14 shows that collaboration with the EU countries is growing. However, Finnish inventors collaborate with a North American inventor twice as often. In 1998, for patents taken by Finnish inventors, 3.5 % were co-invented with an EU and 7.7% with a US inventor. According to a corresponding study in Sweden, Swedish inventors had taken 4.6 % of their patents with an EU and 5.8 % with a North American inventor. Thus, for Finland, the balance is somewhat more in favour of the US. One must recall that we are counting patents with inventors having a Finnish home address. The company that owns the patent might be located elsewhere, for example a Nokia R&D unit in the USA.

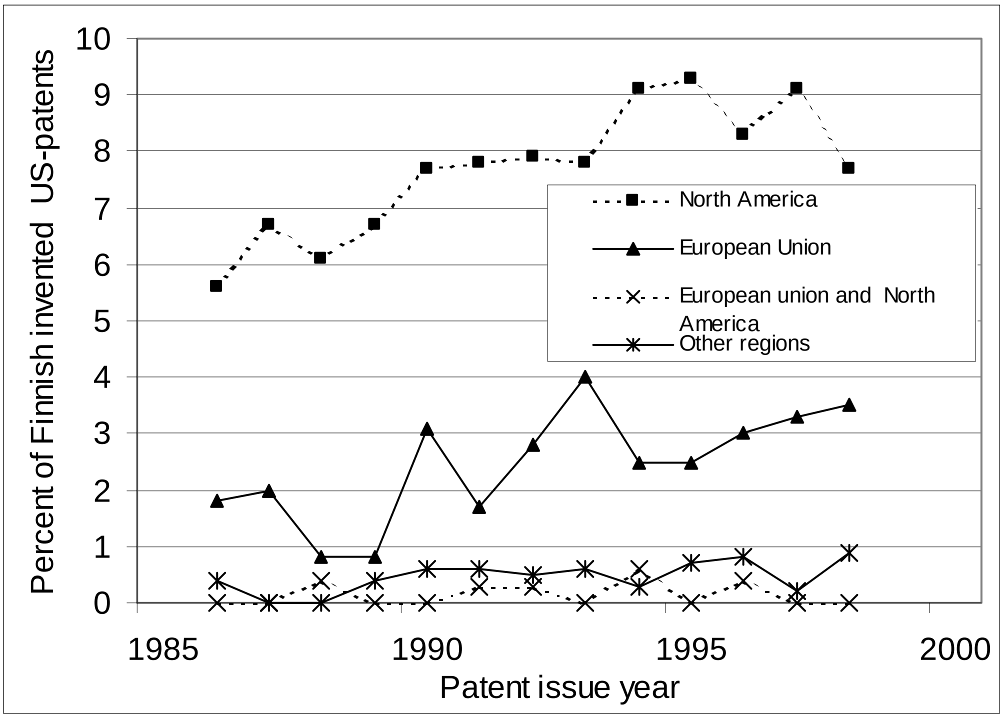

Figure 14. Percent of Finnish invented US-patents 1980-1998 co-invented with other regions

Note: Based on Table 20, Appendix 2

A patent has both inventors and assignees. The assignee, mostly a company, owns the patent, while the inventor is either a company's employee or a collaborator from the outside, such as a university. If we study the extent to which patents with a Finnish assignee address have inventors from other countries we can get one indication of the internationalisation of a Finnish company. We find that an increasing share of the patents assigned to companies in Finland are invented by inventors with a foreign address. The national inventor base is still strong, around 90 percent, but it is tending to decrease. The share of patents with Finnish inventors who have assignees located outside Finland was about 10 percent at the end of the period (Table 21, Appendix 2). This proportion fluctuates somewhat. The interpretation of this piece of information is more difficult since the assignee can be a Finnish company with premises abroad or a foreign company that has inventor-employees in Finland.

For Sweden, the share of Swedish inventors in Swedish owned patents is about the same as for Finland, but the share of patents that have Swedish inventors but foreign assignees is about 20 percent.

4 Conclusions

The above set of bibliometric indicators provides a positive picture of Finnish science. Seen from the point of view of the international journal market, Finland has strengthened its position both in terms of papers produced and their citation impact. However, Finland continues to be a little behind Sweden and Denmark in terms of citation impact, though it has almost caught up with Sweden. The positive trend in Finnish citation impact is associated with publications in journals with higher impact factors. In some subfields, Finland is well above the world average in citation impact.

Much of the growth of Finnish papers and citation impact seems to be associated with a dramatic increase in international collaboration, which has doubled in relative terms since 1986. Today, 40 % of the Finnish papers are co-authored with other countries. The EU region has become the major source of collaborators for Finnish researchers, since 20 % of Finnish papers are co-authored with researchers from EU countries, and the share has grown significantly faster than the share of papers co-authored with researchers from North America. In terms of impact, it pays more to collaborate internationally than not, especially with North America. Thus, to some extent, the positive trend in the output and impact of Finnish scientific publications can be explained by international collaboration. Increasing international collaboration and a positive trend in output and impact can reflect a longer-term policy to reinforce international orientation in Finnish science and to improve scientific standards.

When it comes to technological innovations, the study of Finnish-US patents shows that Finland has strong activity and impact in telecommunications, industrial process equipment, and wood and paper. In other patent fields, such as biotechnology and pharmaceuticals, the number of patents are increasing but are relatively few considering the strong national research base. We have also found that Finnish inventors tend to collaborate increasingly with foreign inventors, but the share of patents co-invented with foreigners is much lower compared to papers, and we cannot find an EU effect of the same kind as in papers. The national inventor base for Finnish patents is still very strong although there is a steady trend towards internationalisation.

In this study we have made reference to a similar study of Swedish papers and patents. When it comes to internationalisation, there are many similarities. Finland has become an important actor internationally in the research world in the last decade. Apparently this development has also been favourable in terms of research quality.

In the Finnish national research system, the Helsinki-region dominates with some 50 % of all papers, but there has been a decentralisation of activities, which has reduced this dominance somewhat. When it comes to impact, measured by the journal impact factor, the largest regions show a positive trend at a fairly high impact level, while papers from smaller regions have lower impact and a positive trend is harder to see. Interregional collaboration in Finland will not have significant quality effects in contrast to international collaboration.

We also have studied numbers of papers, their citation impact, and cross-sector collaboration. The university sector dominates the output with 77 % of the papers, the research institutes publish 12 % and industry about four percent. The most significant change is the growth of papers by research institutes. Collaboration between universities and research institutes has particularly increased. The number and proportion of papers co-authored by the universities and industry have stagnated. However, we know from other sources that this collaboration has increased. The results of this collaboration are either published in the so-called grey literature, or more likely they remain unpublished. Nevertheless, when industry does publish in scientific journals, it does so to a large extent in collaboration with universities. In general the university sector produces papers with higher journal impact, especially in engineering and materials and natural sciences. This is probably a reflection of the basic research orientation of universities, while industry and institutes are more oriented towards application.

When we study the publications by single organisations, we find a pattern parallel to that in sectors and regions. Concentration on Helsinki is obvious. The University of Helsinki produces more papers than the Universities of Turku, Oulu and Kuopio together. Similarly, there are a few big producers of papers in the industry sector (Orion Corporation, Alko Ltd and Neste Corporation) and in the research institute sector (National Public Health Institute, Technical Research Centre of Finland and Institute of Occupational Health). When it comes to impact, we do not find major differences between the major actors. The collaboration networks among organisations are, because of size, dominated by universities, which interact intensively with each other. Universities have collaboration with researchers in other sectors, too, depending on their specific research profiles.

When using bibliometric indicators, and particularly SCI-based data, we introduce a bias towards basic research, since publishing and publishing in journals plays a major role in it. Using this information, we have witnessed a significant growth and impact of Finnish basic research combined with, and to some extent explained by, a fast growing internationalisation. It appears that international integration is a much stronger force at work than intranational integration, be that among regions or sectors.

When it comes to technological innovations, we have seen positive trends for Finland. Finland appears to be strong technologically and economically in the same fields, for example in wood and paper, and telecommunication. However, in our data there are no obvious connections found between scientific and technological activities in the sense that we could say that the fields in which Finnish science is strong are the same in which it is strong technologically or economically. The most probable reason for this lack of match may simply be the fact that our data on scientific publishing primarily reflects what is happening in basic, mostly academic research. In applied research the interactions and the match of academic and industrial activities are probably much closer.

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Appendix 1. A more detailed description of the data material

There are two types of bibliometric data that can be used for a study of the output of national R&D efforts, papers and patents. We have constructed one data set for Finnish papers and one for Finnish patents. We have also used ready-made indicators produced in the US for both papers and patents. These four data sets are described below.

Finnish papers in the Science Citation Index

The 1986-1999 *Science Citation Index*™ CD-ROM editions (SCI-CDE) were used to download all source items (genuine articles, notes, letters, reviews etc) with the word "Finland" in the address field. In all 83.771 records were found. Since the annual discs refer to the update period of the database rather than the publication year of the articles, the SCI-CDE period of 1986-1999 covers publication years 1986-1998 fully.

Each record has a set of fields, which starts with a tag, e.g. "TI" and ends with a spike "|" (Example 1). To improve the quality of the data and to enable various types of aggregation and analysis we had to produce new fields. These fields are shown in bold text in Example 1.

The address field ("CS") contains all author addresses. All Finnish addresses were standardised and converted into a new field. The NX-field gives the main organisation, sector, t city and geographical region. The GL-field has all country names of the addresses.

FN-	Science Citation Index (Jan 98 - Dec 98)
GA-	124WQ |
TI-	Reaction of 1-Naphthyl Amine with Methyl Ketones - A Possible Route to the One-Pot Syntheses of Substituted 1,2-Dihydrobenzo(H)Quinolines|
LA-	English|
AU-	Leis J; Pihl A; Pihlaja K; Karelson C|
GL-	**ESTONIA; FINLAND|**
NX-	**TURKU UNIV TURKU EDU SW FINLAND|**
CS-	UNIV TURKU/DEPT CHEM/FIN 20014 TURKU//FINLAND; TARTU STATE UNIV/DEPT CHEM/EE 2400 TARTU//ESTONIA|
NI-	**ACT CHIM HU CHEMISTRY|**
FI-	**2.53 DY CHM NATURAL|**
JN-	ACH-MODELS IN CHEMISTRY, 1998, V135, N4, P573-581|
DT-	Article|
NR-	9 | |

Example 1. A downloaded record from SCI-CDE

In order to be able to identify research fields, the journal name ("JN") was classified into journal subject categories using different systems. The field entitled FI gives the journal categories used in one of the products of the ISI called *Journal Performance Indicators on Diskette* (JPIOD) and the journal categories taken from another classification created by *SPRU*, which has some 20 subfields and four major fields. In addition this field also gives the journal impact factor (JIF) obtained from JPIOD-1996. JIF is the average number of citations per paper for a given journal. The time window for calculating JIF may vary, both in terms of cited and citing years. In this study we have used a citing window starting in 1981 and ending in 1996.

When analysing our data we decided to test another classification system taken from *National Indicators on Diskette* (NSIOD), which has about 100 categories (See the NI field). This enables us to make some comparisons between the Finnish papers taken from SCI-CDE and the corresponding NSIOD-data.

Finnish patents in the US patent system

The www-server of US Patent Office (www.uspto.gov) was used to retrieve Finnish patents. In all we found 5.175 patents issued in 1986-1998 with a Finnish assignee and/or inventor. The patents at the USPTO-server were downloaded as screen dumps meaning that we got the text versions of the front-pages of issued patents. We then converted these front pages into field delimited records.

The TP-field was added to the patent records (Example 2), based on the international classifications (ICL) used by Computer Horizons (CHI) for their national patent indicators. This enabled us to get a match between Finnish patents and international data in about the same way as we had for papers.

AA- US patent front page|
NO- 2|
PN- 4,632,778|
PY- 1986|
TI- Procedure for ceramizing radioactive wastes|
IN- Lehto Jukka K. (Helsinki, FI); Miettinen Jorma K. (Helsinki, FI); Heinonen Olli (Helsinki, FI)|
AS- Imatran Voima Oy (FI)|
PF- 1983|
TP- POWER GENERATION AND DISTRIBUTION|
IC- G21F 9/28, G21F 9/12, G21F 9/16|
UC- 588/10; 588/7; 588/9; 976/DIG 383; 976/DIG 385|
CP- 2,616,847/Apr., 1951/Ginell/252/629/; 3,093,593/Jun., 1963/Arrance/252/629/; 3,249,551/May, 1966/Bixby/252/629/; 4,297,304/Oct., 1981/Scheffler et al./252/629|
CD- Not Found||

Example 2. A downloaded record from USPTO

National Science Indicators (NSIOD)

ISI's National Science Indicators on Diskette (NSIOD) is a database of summary publication and citation statistics in 1981-1998 reflecting research performance by over 170 countries. It gives a data set of 105 fields in the sciences, social sciences, and arts and humanities corresponding to ISI's *Current Contents*® (*CC*®) categories. The database contains counts of publications and citations taken from the peer-reviewed journals indexed by the ISI from 1981 to 1998.

International Technology Indicators Database (CHI-data)

Computer Horizons (CHI) uses the US Patent system to count patens by technological field and the country of the inventor. This database also includes the number of patens citing patents The number of patents as well as patent citations are fractionalised by country. If a patent has been co-invented by two Swedish, one Finnish and one US inventor, that patent would be counted as half a patent for Sweden and one fourth of a patent for Finland and one forth for the USA.

The CHI-patent database uses the International Classification System (ICL) to group the patents into some thirty field of technology. Only the first listed ICL-code is used by the CHI.

A Swedish twin study

There is a similar study of Swedish papers and patents covering the years 1986-1996, reported by Olle Persson, that will be made avialable by Nutek (www.nutek.se).

Software

To analyse bibliometric raw data one usually needs specialised software, at least to start with. Typically we have a large number of cases and a set of variables that can take a large number of values. For example, taking 100.000 records by main organisation will produce a file of almost double size. Adding a field classification to each main organisation will increase the file further. Not many standard software packages can deal with such tasks easily enough. We also need special software to identify specific units in each field, to classify units into sectors or research fields, to calculate fractions of papers, to build co-authorship data and so forth. A beta version of a bibliometric toolbox called Bibexcel was found quite helpful in this task. Bibexcel can also be used to visualise the data using maps.

Appendix 2. Tables

Table 1. Finnish output of papers and their relative citation impact in all fields of science.

Note: Relative citation impact is the number of citations per paper for Finland compared to the number of citations per paper for all countries (World). A value of 1.20 means that the Finnish papers are cited 20 percent above the world average. Percent of all papers should be read as the percent of all papers, which have at least one Finnish author address. The paper and citation counts are not fractionalalised according to the number of countries involved in producing the papers.

Source: National Indicators based on SCI/SSCI produced by ISI

	Relative citation impact				Percentage of all papers			
Year	Finland	Sweden	Denmark	Norway	Finland	Sweden	Denmark	Norway
1981	0.97	1.46	1.33	0.94	0.59	1.54	0.86	0.52
1982	0.96	1.43	1.35	1.04	0.64	1.64	0.86	0.55
1983	0.99	1.46	1.28	0.96	0.67	1.65	0.84	0.55
1984	0.92	1.42	1.26	0.93	0.68	1.71	0.83	0.54
1985	1.02	1.44	1.27	0.95	0.65	1.73	0.82	0.56
1986	0.91	1.40	1.26	0.98	0.66	1.73	0.86	0.52
1987	1.00	1.28	1.22	0.93	0.70	1.72	0.84	0.53
1988	1.08	1.33	1.20	0.95	0.66	1.72	0.80	0.52
1989	0.96	1.31	1.18	0.97	0.68	1.77	0.83	0.51
1990	0.98	1.29	1.29	0.96	0.70	1.76	0.83	0.54
1991	1.08	1.32	1.29	0.95	0.72	1.74	0.84	0.54
1992	1.13	1.31	1.20	0.97	0.75	1.75	0.91	0.58
1993	1.18	1.27	1.31	0.97	0.80	1.85	0.91	0.58
1994	1.20	1.28	1.26	0.96	0.84	1.87	0.96	0.60
1995	1.18	1.26	1.29	0.98	0.84	1.89	0.95	0.64
1996	1.18	1.26	1.23	0.89	0.89	1.97	0.96	0.63
1997	1.20	1.24	1.32	1.02	0.92	1.98	0.98	0.65
1998	1.03	1.21	1.45	1.24	0.92	2.01	1.04	0.66

Year	Number of citations Finland	Sweden	Denmark	Norway	Number of papers Finland	Sweden	Denmark	Norway
1981	38875	154226	78645	33751	2640	6940	3897	2348
1982	41791	159847	79245	38833	2954	7593	3988	2531
1983	46264	168526	75188	36726	3166	7789	3979	2587
1984	43822	169502	72357	34716	3212	8053	3887	2520
1985	48062	180243	75528	38488	3283	8708	4137	2797
1986	43633	175494	78652	37278	3437	9029	4471	2734
1987	51025	160771	74646	36097	3626	8935	4356	2753
1988	51804	165287	69879	36061	3558	9272	4323	2813
1989	46732	167029	70744	35323	3785	9887	4656	2826
1990	48662	161838	75700	36443	3990	10088	4731	3077
1991	52424	155271	72993	34379	4247	10283	4950	3162
1992	55201	148496	71059	36832	4712	10987	5716	3661
1993	54597	136318	69645	32710	4923	11402	5625	3591
1994	49847	118892	60152	28555	5474	12154	6254	3902
1995	39151	93125	47851	24525	5755	12890	6474	4338
1996	26205	62173	29807	14149	6125	13642	6658	4366
1997	13240	29410	15622	7940	6408	13758	6833	4502
1998	1980	4993	3107	1706	6623	14439	7448	4725

Table 2. Relative citation impact for a set of countries in 1981-85 and 1994-98

Country	Relative citation impact 1981-85	Relative citation impact 1994-98
Switzerland	1.61	1.62
USA	1.35	1.42
Netherlands	1.34	1.28
Denmark	1.33	1.25
Sweden	1.25	1.24
UK	1.18	1.18
Finland	0.98	1.15
Germany	0.97	1.09
France	0.95	1.05
Italy	0.95	1.01
Norway	0.87	0.95

Source: National Indicators based on SCI/SSCI produced by ISI

Table 3. Relative journal impact factor and relative citation impact for Finnish papers in 1986-1996

Note: The calculation of relative journal impact factor (RJIF) is based on SCI-CDE downloads and JPIOD-1996. Fisrt, the mean journal impact factor (MJIF) is calculated by multiplying the number of papers by the corresponding journal impact factor, and then the sum of these products are divided by the number of papers. Finnish RJIF is the ratio of MJIF for Finnish papers and MJIF for all papers (World). The relative citation impact is taken from Table 1.

Year	Relative journal impact factor	Relative citation impact
1986	1.11	0.91
1987	1.20	1.00
1988	1.14	1.08
1989	1.19	0.96
1990	1.12	0.98
1991	1.22	1.08
1992	1.29	1.13
1993	1.30	1.18
1994	1.33	1.20
1995	1.36	1.18
1996	1.34	1.18

Table 4. Fields by size and impact

Source: National Indicators based on SCI/SSCI produced by ISI

Field	Relative impact 1994 - 1998 (compared with the average citation level of all papers in field)	Relative activity (percent of all papers in field)	Relative impact increase (1994-1998 compared with 1981-1998)*	Number of Finnish papers
General & Internal Medicine	1.92	0.88	1.00	634
Physics	1.76	0.75	1.34	1129
Pharmacology/Toxicology	1.72	1.12	1.41	196
Research/Lab Med & Med Techn	1.56	1.60	1.39	431
Animal Sciences	1.55	1.19	1.42	556
Gastroenterol and Hepatology	1.49	0.85	1.19	230
Orthopedics & Sports Med	1.46	1.64	0.93	352
Pediatrics	1.44	1.36	1.05	436
Cardiovasc & Respirat Syst	1.43	0.96	1.51	668
Dentistry/Oral Surgery & Med	1.42	2.80	1.34	449
Dermatology	1.37	1.37	0.99	239
Endocrinol, Nutrit & Metab	1.36	1.71	1.28	720
Experimental Biology	1.36	0.70	1.48	144
Instrumentation/Measurement	1.35	1.07	1.13	297
Neurology	1.32	1.34	1.31	494
Veterinary Med/Animal Health	1.31	0.57	1.12	210
Urology	1.30	0.74	1.30	213
Clin Immunol & Infect Dis	1.29	1.75	1.22	464
Molecular Biology & Genetics	1.27	1.17	1.59	675
Oncology	1.27	1.03	1.22	348
Biotechnol & Appl Microbiol	1.27	0.92	0.84	187
Oncogenesis & Cancer Res	1.25	1.32	1.19	728
Environment/Ecology	1.24	1.57	1.20	1239
Environmt Med & Public Hlth	1.22	2.74	1.08	485
Food Science/Nutrition	1.22	1.06	1.11	320

Table 4. cont

Field	Relative impact 1994 - 1998 (compared with the average citation level of all papers in field)	Relative activity (percent of all papers in field)	Relative impact increase (1994-1998 compared with 1981-1998)*	Number of Finnish papers
Medical Res, Diag & Treatmt	1.21	1.29	1.19	1085
Endocrinol, Metab & Nutrit	1.20	2.68	1.14	475
AI, Robotics & Auto Control	1.20	0.71	1.13	175
Agricultural Chemistry	1.16	0.71	1.26	152
Info Technol & Commun Syst	1.15	0.84	1.16	135
Cardiovasc & Hematology Res	1.14	1.07	1.44	689
Rheumatology	1.13	2.73	1.30	271
Anesthesia & Intensive Care	1.09	1.73	1.07	401
Pharmacology & Toxicology	1.08	1.15	1.33	913
Mathematics	1.07	0.57	1.10	320
Clin Psychology & Psychiatry	1.07	1.84	1.60	313
Engineering Mgmt/General	1.07	0.99	1.24	157
Organic Chem/Polymer Sci	1.06	0.49	1.47	459
Multidisciplinary	1.06	0.54	0.94	264
Appl Phys/Cond Matt/Mat Sci	1.05	0.58	1.08	1420
Optics & Acoustics	1.05	0.78	1.17	318
Hematology	1.05	0.71	1.31	137
Chemical Engineering	1.04	0.89	1.65	351
Spectrosc/Instrum/Analyt Sci	1.02	0.97	1.28	767
Elect & Electronic Engn	1.01	0.63	1.07	360
Ophthalmology	1.01	1.14	1.07	200
Medical Res, Organs & Syst	1.00	1.66	1.10	1723
Microbiology	0.99	0.93	1.11	712
Agriculture/Agronomy	0.99	1.08	1.24	295
Materials Sci and Engn	0.98	0.86	1.44	834
Public Hlth & Hlth Care Sci	0.98	1.14	1.34	408
Computer Sci & Engineering	0.98	0.84	1.34	180

Table 4. cont

Field	Relative impact 1994 - 1998 (compared with the average citation level of all papers in field)	Relative activity (percent of all papers in field)	Relative impact increase (1994-1998 compared with 1981-1998)*	Number of Finnish papers
Environmt Engineering/Energy	0.98	0.69	0.91	129
Biochemistry & Biophysics	0.97	0.70	1.17	951
Biology	0.96	0.84	0.96	251
Medical Res, General Topics	0.95	1.71	1.06	1363
Animal & Plant Sciences	0.93	0.65	1.39	191
Otolaryngology	0.91	1.85	0.92	264
Inorganic & Nucl Chemistry	0.91	0.51	1.17	157
Psychiatry	0.90	1.75	1.55	396
Radiol, Nucl Med & Imaging	0.90	0.89	1.29	334
Mechanical Engineering	0.90	0.27	1.70	124
Cell & Developmental Biol	0.89	0.67	1.00	301
Physical Chem/Chemical Phys	0.88	0.58	1.28	714
Surgery	0.88	0.68	0.98	294
Chemistry	0.87	0.39	1.47	325
Reproductive Medicine	0.86	2.29	1.02	726
Neurosciences & Behavior	0.85	1.28	1.25	1676
Plant Sciences	0.84	1.29	1.25	873
Aquatic Sciences	0.84	1.08	1.14	410
Psychology	0.83	0.60	1.12	442
Earth Sciences	0.77	0.64	1.26	511
Space Science	0.76	1.13	1.23	448
Chemistry & Analysis	0.76	0.49	1.29	442
Immunology	0.63	1.16	0.97	670
Physiology	0.59	1.07	1.18	249
Economics	0.49	0.67	1.53	222
Entomology/Pest Control	0.45	0.87	0.92	170

*An index figure. For example, 1.20 means a twenty-percent growth in relative citation level.

Table 5. Percent of Finnish papers co-authored with different country groups

Source: Inforsk/VTT database based on SCI CDE.

	Country region					
Year	Finland	European Union	European Union and North America	North America	Other regions	Papers
1986	81.4	8.0	1.4	5.6	3.5	3868
1987	78.3	9.3	1.5	6.7	4.2	3908
1988	78.0	9.6	1.6	6.1	4.6	3895
1989	76.1	9.9	1.6	6.7	5.6	3488
1990	73.4	10.9	1.7	7.7	6.3	3765
1991	70.3	12.4	2.4	7.8	7.1	3957
1992	68.9	13.1	2.8	7.9	7.3	4303
1993	69.0	13.4	3.3	7.8	6.5	4785
1994	66.8	13.1	3.7	9.1	7.3	5192
1995	64.8	13.9	4.3	9.3	7.7	5555
1996	63.9	15.1	4.7	8.3	7.9	5909
1997	61.7	16.2	4.3	9.1	8.6	6359
1998	59.8	19.2	4.2	7.7	9.2	6131
Total	68.95	13.19	3.13	7.84	6.89	61115

Table 6. Percent of Finnish total journal impact by country group of the co-author

Note: The total journal impact is calculated by adding the journal impact of each paper.

Source: Inforsk/VTT database based on SCI -CDE.

	Country region					
Year	Finland	European Union	European Union and North America	North America	Other regions	Papers
1986	76.6	9.5	2.0	8.3	3.6	3851
1987	73.8	10.8	2.0	9.5	3.9	3883
1988	74.2	10.2	2.4	9.0	4.1	3862
1989	71.9	11.1	2.8	9.5	4.6	3472
1990	67.1	12.5	2.6	11.9	5.9	3732
1991	65.8	14.0	3.6	10.1	6.5	3939
1992	63.6	14.6	4.3	11.6	5.9	4278
1993	62.9	15.7	5.0	11.3	5.2	4750
1994	60.6	15.1	5.0	13.0	6.3	5130
1995	59.0	15.7	6.0	13.3	6.0	5486
1996	59.0	16.6	7.3	11.4	5.6	5779
1997	56.2	17.5	6.6	12.2	7.5	6134
1998	53.3	21.4	6.1	11.0	8.2	5802

Table 7. Number of Finnish papers co-authored with other countries

Note: Numbers refer to the number of papers co-authored with a country, and these numbers are not fractionalised according to the number of countries involved in a paper. Growth is the percentage change between 1986 and 1998. N.a. in the growth column means not available because of zero values.

Source: Inforsk/VTT database based on SCI CDE.

	Year													
Country	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Growth
All papers	3868	3908	3895	3488	3765	3957	4303	4785	5192	5555	5909	6359	6131	159
USA	248	291	268	257	320	360	413	480	604	690	717	799	783	316
Sweden	132	154	177	137	176	190	242	263	332	352	415	432	446	338
UK	78	100	106	104	131	158	197	199	201	255	323	357	345	442
Germany	98	85	81	73	96	136	181	200	198	283	328	370	381	389
France	38	39	47	47	62	87	112	113	150	208	198	229	241	634
Netherlands	29	49	54	55	57	53	81	88	110	153	163	210	188	648
Denmark	46	47	34	48	65	57	105	124	108	155	152	154	179	389
Russia	0	0	0	0	1	13	103	109	142	194	208	224	240	n.a.
Italy	28	36	28	36	40	39	77	78	96	133	160	195	214	764
Switzerland	39	52	41	49	52	65	79	78	104	126	132	142	160	410
Norway	31	24	31	43	51	41	81	68	79	119	139	165	152	490
Canada	34	46	49	42	46	57	73	66	79	106	83	117	115	338
Japan	15	21	21	26	24	55	76	86	104	87	100	110	124	827
Spain	5	4	14	6	30	30	61	54	78	105	116	131	172	3440
Poland	15	25	24	38	51	38	59	69	72	78	87	95	73	487
Hungary	17	26	22	27	30	43	49	42	56	68	70	110	95	559
Belgium	18	22	20	21	18	21	48	46	54	75	92	80	101	561
Austria	7	18	11	11	15	24	41	37	35	56	69	72	65	929
Australia	12	10	20	10	17	23	14	30	29	25	48	53	77	642
USSR	17	39	38	55	92	85	6	0	0	0	0	0	0	n.a.
Estonia	0	0	0	0	0	3	22	24	42	47	55	68	58	n.a.
Greece	2	1	4	7	9	8	25	29	32	49	49	40	40	2000
China	4	2	5	7	11	15	23	16	17	28	33	54	42	1050
Portugal	1	2	2	2	7	4	27	22	22	43	43	35	30	3000
Brazil	4	9	9	7	5	2	15	20	31	37	37	35	28	700
Czech Repub.	0	0	0	0	0	2	11	3	34	48	44	49	44	n.a.
India	6	8	4	2	3	7	6	7	15	22	28	37	44	733
Israel	5	5	3	6	2	2	12	17	20	20	26	36	32	640

Table 8. Papers by region in 1986-1998. Percent of all Finnish papers (fractional counts)

Source: Inforsk/VTT database based on SCI CDE.

	Year													
Region	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Papers
Uusimaa	52.8	55.4	53.5	54.2	54.1	53.6	53.0	51.5	50.5	49.6	50.6	49.3	49.1	34973
Sw Finland	15.0	14.1	15.8	16.0	15.8	14.8	14.4	15.5	16.8	16.1	15.6	16.2	15.9	11385
N Ostrobothnia	11.2	9.9	9.9	10.2	9.3	9.8	9.5	9.7	9.7	9.8	9.7	9.7	9.9	7259
N Savo	7.8	7.3	8.3	6.8	8.0	8.3	8.6	8.7	8.0	9.2	8.5	8.8	8.6	6350
Pirkanmaa	6.1	6.0	5.5	5.3	6.0	6.0	6.6	6.1	6.6	6.1	6.0	6.6	6.7	5028
Cent Finland	3.3	2.8	3.3	3.1	2.9	3.1	2.8	3.4	3.2	3.4	3.9	3.7	4.0	2528
N Karelia	1.3	1.4	0.9	1.3	1.0	1.3	1.7	1.6	1.7	1.9	2.4	2.1	2.2	1312
Inner Tavastia	0.2	0.5	0.5	0.6	0.6	0.8	0.8	0.6	0.7	0.8	0.7	0.6	0.7	566
Lapland	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.4	0.6	0.5	0.6	0.7	0.8	420
S Karelia	0.4	0.4	0.4	0.3	0.3	0.4	0.6	0.4	0.6	0.6	0.5	0.6	0.6	432
Paijat-Hame	0.6	0.5	0.8	0.6	0.5	0.4	0.4	0.3	0.3	0.4	0.3	0.4	0.3	442
E Uusimaa	0.4	0.3	0.3	0.4	0.3	0.3	0.2	0.7	0.4	0.4	0.3	0.3	0.1	285
Cent Ostrobothnia	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.1	273
S Savo	0.2	0.1	0.1	0.2	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.3	179
Satakunta	0.1	0.3	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.2	0.1	159
Kainuu	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	145
Kymenlaakso	0.1	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	129
Ostrobothnia	0.1	0.2	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	101
S Ostrobothnia	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	82
Aland	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	18
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	72066

Table 9. Average journal impact by region, 1986-1998.

Source: Inforsk/VTT database based on SCI CDE.

	Year													
Region	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Uusimaa	10.3	10.8	10.2	10.6	11.0	10.7	11.7	11.6	11.0	11.2	11.0	11.6	11.7	11.1
Sw Finland	9.3	9.7	9.7	10.3	10.4	10.6	11.3	10.8	10.3	11.2	10.7	11.5	11.4	10.7
N Ostrobothnia	9.4	10.7	11.4	10.6	11.4	11.1	12.7	12.2	12.0	11.7	11.2	11.9	11.4	11.4
N Savo	8.6	11.0	9.7	8.9	10.1	10.1	11.0	12.1	11.2	11.6	11.4	12.2	12.6	11.1
Pirkanmaa	9.7	10.6	9.4	9.0	10.0	8.8	10.3	10.4	10.4	10.8	11.2	11.2	10.6	10.4
Cent Finland	9.2	8.4	8.3	8.6	8.1	9.2	9.3	9.2	9.7	9.2	8.6	10.2	10.6	9.3
N Karelia	8.0	8.0	7.4	7.2	9.0	9.1	7.8	9.4	8.6	7.2	7.7	7.5	7.9	8.0
Inner Tavastia	5.0	5.7	6.0	6.1	5.4	9.7	5.4	11.1	9.0	6.5	5.9	7.9	7.7	7.3
Lapland	7.5	6.0	10.0	8.8	7.1	6.7	12.3	12.1	6.4	9.3	7.8	10.4	6.9	8.5
S Karelia	7.4	7.4	5.9	6.9	7.1	9.5	5.4	7.8	6.9	5.2	4.7	7.7	6.9	6.7
Paijat-Hame	7.9	6.5	7.0	9.9	9.0	9.0	8.7	9.6	11.8	9.1	7.2	11.9	7.5	8.8
E Uusimaa	6.2	6.1	7.9	6.2	7.0	6.1	5.9	7.3	9.8	6.4	6.3	5.9	4.4	6.8
Cent Ostrobothnia	9.0	5.5	7.2	5.2	3.8	4.6	5.1	4.3	3.4	5.2	3.7	5.9	4.7	5.3
S Savo	7.3	7.3	8.0	9.2	9.5	10.5	7.1	11.2	5.1	9.2	6.9	10.6	9.0	8.6
Satakunta	3.6	4.4	6.4	5.0	4.8	5.2	6.9	7.6	6.3	8.3	8.2	13.8	6.1	7.1
Kainuu	4.5	6.5	3.9	5.6	4.4	11.7	5.4	4.5	13.6	13.0	10.0	14.3	18.9	10.6
Kymenlaakso	4.9	5.6	12.1	6.8	10.2	6.8	11.7	6.9	15.9	10.1	5.3	19.1	12.5	10.3
Ostrobothnia	3.7	10.1	8.2	6.5	5.2	6.0	7.4	16.2	4.7	10.2	8.7	18.4	8.1	9.3
S Ostrobothnia	12.6	11.5	9.5	15.5	7.2	6.1	28.8	6.9	21.0	11.5	6.7	17.5	8.9	12.2
Aland	0.0	0.0	0.0	6.3	36.8	4.4	5.9	20.4	16.4	0.0	14.8	12.7	0.0	18.1
Total	9.7	10.4	10.0	10.1	10.5	10.4	11.2	11.2	10.8	11.0	10.6	11.4	11.3	10.7

Table 10. Tendency for interregional collaboration

Note: The lower the fractional/whole count ratio, the more the region collaborates with other regions.

Source: Inforsk/VTT database based on SCI CDE.

Region	Whole counts	Fractional count	Fractional/Whole counts
Uusimaa	34973	31584	0.9
Sw Finland	11385	9530	0.8
N Ostrobothnia	7259	6018	0.8
N Savo	6350	5071	0.8
Pirkanmaa	5028	3781	0.8
Cent Finland	2528	2053	0.8
N Karelia	1312	1029	0.8
Inner Tavastia	566	393	0.7
S Karelia	420	295	0.7
Lapland	432	288	0.7
Paijat-Hame	442	263	0.6
E Uusimaa	285	205	0.7
S Savo	273	141	0.5
Satakunta	179	105	0.6
Cent Ostrobothnia	159	103	0.7
Ostrobothnia	145	77	0.5
Kymenlaakso	129	63	0.5
S Ostrobothnia	101	42	0.4
Kainuu	82	41	0.5
Aland	18	11	0.6
All papers	72066	61093	0.8

Table 11. Percent of papers by sector (fractional counts)

Source: Inforsk/VTT database based on SCI CDE

	Sector				
Year	EDU	IND	OTH	ROR	Papers
1986	79.12	4.90	7.19	8.79	3860
1987	78.98	4.52	6.95	9.55	3901
1988	76.30	5.59	7.24	10.87	3884
1989	78.47	4.55	5.96	11.02	3482
1990	78.75	5.36	5.55	10.34	3761
1991	75.60	4.81	6.20	13.39	3951
1992	76.08	5.04	5.83	13.06	4298
1993	75.84	4.87	6.02	13.27	4774
1994	77.67	4.32	5.50	12.51	5183
1995	76.60	4.21	5.07	14.12	5545
1996	78.33	3.44	4.77	13.46	5898
1997	77.37	3.70	5.27	13.66	6342
1998	77.91	3.44	4.87	13.78	6122
1986-1998	77.44	4.41	5.75	12.40	
Papers	47240	2687	3510	7566	61002

Note: EDU: Higher education institutions with university hospitals included

ROR: Only organisations that are independent of universities. This class includes also some private research organisations that are not profit-oriented but owned either by foundations or by several companies together

OTH: Organisations other than ones mentioned above (hospitals that are independent of universities, associations, federations, foundations, administrative organs (other than research institutes) such as ministries, municipalities, also municipal laboratories that do not research but do inspection, schools other than universities

IND: Firms including some small private, profit-oriented research organisations and consultant agencies.

MIS: Organisation unknown

Table 12. Publication activity of sectors by major field.

Source: Inforsk/VTT database based on SCI CDE.

Note: Percent of papers that a sector has in different fields. See Table 11 for definitions of sectors.

	Sector				
Field	EDU	IND	OTH	ROR	Total
Engineering & Materials	3.16	14.50	0.82	5.17	3.88
Life	69.67	58.36	92.71	69.24	70.82
Multidisciplinary	8.89	14.24	4.34	14.01	9.55
Natural	18.28	12.90	2.13	11.58	15.75
Total	100.00	100.00	100.00	100.00	100.00

Table 13. Mean journal impact of papers by sector and major field

Source: Inforsk/VTT database based on SCI CDE. See Table 11 for definitions of sectors.

	Sector				
Field	EDU	IND	OTH	ROR	Total
Engineering & Materials	4.2	2.3	3.6	2.9	3.5
Life	11.8	10.7	10.9	11.7	11.6
Multidisciplinary	10.5	6.8	10.1	8.2	9.7
Natural	9.2	7.5	6.7	8.0	9.0
Total	11.0	8.5	10.7	10.3	10.7

Table 14. Co-authorships among sectors by year

Source: Inforsk/VTT database based on SCI CDE. See Table 11 for definitions of sectors.

	Pair							
Year	EDU with IND	EDU with OTH	EDU with ROR	IND with OTH	IND with ROR	OTH with ROR	Total pairs	Total papers
1986	117	240	199	23	21	51	651	3860
1987	131	249	216	20	22	54	692	3901
1988	139	275	222	17	15	61	729	3884
1989	103	210	227	13	22	42	617	3482
1990	162	200	226	16	27	29	660	3761
1991	146	242	277	25	31	43	764	3951
1992	164	273	291	22	40	58	848	4298
1993	192	312	333	32	45	65	979	4774
1994	207	280	392	23	35	57	994	5183
1995	184	307	423	27	35	92	1068	5545
1996	217	325	508	18	36	91	1195	5898
1997	234	393	547	31	47	108	1360	6342
1998	191	375	499	31	41	79	1216	6122
Total	2187	3681	4360	298	417	830	11773	61002

Table 15. Number of papers by institution in all fields (whole counts)

Source: Inforsk/VTT database based on SCI CDE. Institutions with fewer than 50 papers excluded.

Education	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	1626	1600	1593	1401	1541	1526	1633	1768	1964	2013	2236	2384	2312	23597
Turku Univ	522	541	544	533	545	541	598	690	807	835	874	1019	961	9010
Oulu Univ	476	453	437	417	410	467	450	553	555	658	648	698	710	6932
Kuopio Univ	299	357	346	278	331	397	403	492	489	564	596	644	628	5824
Tampere Univ	261	249	259	226	242	263	312	285	329	343	348	434	412	3963
Helsinki Univ Tech	163	164	157	193	215	227	258	243	318	351	413	395	395	3492
Jyvaskyla Univ	120	131	119	101	108	128	136	160	183	202	233	252	252	2125
Åbo Acad Univ	91	77	70	77	104	94	99	157	185	153	197	207	197	1708
Joensuu Univ	50	50	36	45	46	60	74	76	111	130	137	157	152	1124
Tampere Univ Tech*	27	2	4	2	0	2	10	84	95	78	108	97	108	617
Lappeenranta Univ Tech	3	8	7	7	7	12	26	21	27	31	24	34	39	246
Industry	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Orion Corp	44	42	49	27	47	56	69	56	64	47	53	85	63	702
Alko Ltd	31	41	51	30	34	29	41	44	49	38	23	17	6	434
Neste Corp	9	13	14	21	12	13	21	40	28	24	20	29	10	254
Farmos Group	22	29	30	28	58	17	3	0	1	0	0	0	0	188
Leiras Ltd	10	13	2	14	11	13	13	14	22	22	16	16	16	182
Wallac Ltd	11	13	15	10	15	12	15	18	15	18	8	13	11	174
Nokia Group	2	4	3	0	4	11	6	6	11	12	15	14	28	116
Valio Ltd	7	3	7	3	11	3	10	12	6	7	9	19	12	109
Outokumpu Ltd	15	10	13	4	9	4	12	4	8	9	8	7	6	109
Kemira Ltd	3	3	5	6	4	4	9	13	6	6	8	11	7	85
Imatran Voima Ltd	4	4	8	1	4	2	13	9	11	8	7	6	3	80
Cultor Ltd	0	0	0	5	8	5	7	4	4	6	11	9	5	64
Yhtyneet La-boratoriot Ltd	4	5	3	2	2	8	4	7	7	8	2	4	3	59
Valmet Corp	5	2	3	1	6	6	4	5	3	4	4	3	12	58
Labsyst Ltd	7	8	8	6	4	7	6	4	0	1	4	1	0	56
A Ahlstrom Corp	2	3	4	4	4	2	2	9	6	6	5	3	3	53
Enso Gutzeit Ltd	2	4	5	2	6	6	4	2	3	5	2	7	2	50

*) The classification of papers from Tamper Univ Tech are incorrect in the SCI-records,which explains the low numbers for some years.

Table 15. cont

Research Institutes	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Natl Publ Hlth Inst	161	175	155	163	181	213	242	282	283	391	419	466	432	3563
Tech Res Ctr Finland	83	84	103	122	111	148	169	193	173	202	193	193	203	1977
Inst Occupat Hlth	121	135	123	99	84	119	114	108	111	133	134	130	143	1554
Forest Res Inst	8	25	16	19	26	24	31	52	69	84	92	77	111	634
Meteorol Inst	13	21	12	20	27	33	16	35	56	38	60	59	66	456
Agr Res Ctr	10	16	20	17	19	35	35	31	42	48	49	55	61	438
Game & Fish Res Inst	7	6	8	19	13	16	37	15	29	24	41	58	46	319
Geol Survey Finland	13	22	12	22	12	27	18	21	21	20	30	44	31	293
Inst Med Res Minerva	14	19	22	18	22	22	18	11	21	22	10	20	12	231
Finnish Environm Inst	6	4	10	10	8	15	15	9	22	28	20	25	21	193
Kcl Pulp & Paper Res Inst	25	13	20	11	17	10	12	20	29	16	16	13	9	211
Vet Med & Food Inst	14	3	11	21	14	9	16	18	16	16	16	19	19	192
Ctr Radiat & Nucl Safety	9	13	5	6	5	5	5	17	22	20	25	29	18	179
Wihuri Res Inst	7	6	9	11	4	9	10	9	7	12	11	26	15	136
Inst Marine Res	10	4	4	1	6	5	15	8	9	14	16	15	18	125
Biocity	0	0	0	0	0	5	15	13	17	26	23	13	4	116
Natl Res & Dev Ctr Wel & Hlth	5	4	5	10	2	7	11	13	13	16	19	24	31	160

Table 15. cont

Other	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Soc Insurance Inst	29	62	35	22	31	43	41	39	39	35	45	34	24	479
Red Cross	34	29	32	21	18	47	29	50	36	55	43	31	43	468
Aurora Hosp	27	43	38	20	21	22	20	27	25	26	11	13	10	303
Finnish Canc Registry	19	13	9	12	15	14	8	18	29	26	31	35	32	261
Hosp Invalid Fdn	17	23	27	24	16	15	18	24	20	12	28	9	10	243
Jorvi Hosp	15	25	15	13	19	31	11	11	12	14	20	30	22	238
Rheumat Fdn Hosp	21	12	33	19	14	9	11	15	16	13	15	23	14	215
Cent Hosp Cent Finland	16	13	17	11	9	11	11	21	18	12	12	20	16	187
Ukk Sport Inst	5	5	13	11	4	6	12	8	19	15	27	26	27	178
Cent Mil Hosp	17	19	20	12	8	16	12	10	9	10	14	18	10	175
Family Fed	2	3	2	8	8	9	10	16	12	17	22	27	23	159
Cent Hosp Paijat Hame	8	8	9	8	11	9	14	6	8	11	8	10	9	119
Lastenlinna Hosp	14	12	10	9	10	7	12	12	6	6	5	6	2	111
Def Forces	15	5	3	6	1	6	3	11	7	13	15	12	13	110
Cent Hosp N Karelia	10	4	7	6	1	11	8	11	9	8	7	14	8	104
Cent Hosp Mikkeli	7	5	5	4	7	12	14	14	3	11	4	8	9	103
Cent Hosp Cent Ostrobothnia	12	12	10	5	4	11	11	15	4	2	5	7	3	101
Assoc Folkhalsan	5	2	11	4	7	12	8	10	4	2	5	6	19	95
Vaajasalo Hosp	9	9	26	9	8	4	9	7	1	5	0	0	0	87
Deaconess Inst Hosp Oulu	10	7	3	4	6	6	10	3	5	6	8	10	5	83
Municipal Hosp Helsinki	1	0	5	7	2	4	2	2	6	11	19	8	15	82
Cent Hosp Vaasa	3	3	2	1	3	5	4	6	4	5	7	7	17	67
Municipal Hosp Turku	8	3	4	5	7	6	1	4	5	2	10	7	4	66
Cent Hosp Jyvaskyla	0	1	0	1	1	5	6	10	11	6	5	9	10	65
Cent Hosp S Ostrobothnia	6	7	3	1	2	4	1	5	5	13	6	7	5	65
Acad Finland	4	5	3	4	6	1	3	9	5	8	7	4	3	62
Meltola Hosp	6	3	4	2	6	5	3	3	8	10	8	0	4	62
Cent Hosp S Karelia	2	5	2	3	2	1	3	4	5	9	6	10	9	61
Deaconess Inst Hosp Helsinki	3	2	3	2	6	5	4	8	7	5	4	8	3	60
Maria Hosp	2	2	6	1	3	3	4	3	5	9	2	8	10	58
Kivela Municipal Hosp Helsinki	1	1	7	2	9	5	7	14	4	3	2	1	1	57
Canc Soc Finland	7	8	6	6	3	2	2	6	1	1	4	3	2	51

Table 16. Average journal impact of papers by institution and major field.

Source: Inforsk/VTT database based on SCI CDE.

Note: Cells with less than 100 papers are excluded.

	Major field			
Institution	Engineering & Materials	Life sciences	Multidisciplinary	Natural sciences
Helsinki Univ	4.9	12.3	13.8	10.2
Turku Univ		11.8	10.7	8.4
Oulu Univ	4.1	12.5	10.5	9.0
Kuopio Univ		11.4	10.9	8.0
Tampere Univ	5.0	11.8	10.4	8.7
Helsinki Univ Tech	3.8	10.0	7.5	9.1
Natl Publ Hlth Inst		14.7	15.1	
Jyvaskyla Univ		9.3	8.7	9.3
Tech Res Ctr Finland	3.4	10.4	6.0	7.5
Åbo Acad Univ	4.2	11.5	8.8	8.0
Inst Occupat Hlth		9.2	8.5	7.9
Joensuu Univ		7.9	7.2	7.6
Orion Corp		12.1		
Tampere Univ Tech	4.3	6.8	4.5	9.4
Forest Res Inst		6.2	12.1	
Red Cross		14.5		

Table 17. Average journal impact of papers by institution and subfield.

Note: Cells with less than 100 papers are excluded.

Physics	Papers	Sum of journal impact factors	Mean journal impact factor
Helsinki Univ	1883	23668	12.6
Helsinki Univ Tech	1242	12586	10.1
Turku Univ	632	6278	9.9
Jyvaskyla Univ	547	6178	11.3
Oulu Univ	463	5408	11.7
Tech Res Ctr Finland	243	1868	7.7
Joensuu Univ	199	1322	6.6
Tampere Univ Tech	161	1573	9.8
Åbo Acad Univ	108	1172	10.9
Tampere Univ	107	1091	10.2
Biology			
Helsinki Univ	3029	44746	14.8
Turku Univ	1115	15247	13.7
Oulu Univ	925	15845	17.1
Natl Publ Hlth Inst	396	7389	18.7
Kuopio Univ	371	5212.2	14
Jyvaskyla Univ	311	3130.6	10.1
Joensuu Univ	245	2339.6	9.55
Åbo Acad Univ	217	2211.4	10.2
Tampere Univ	216	3549.6	16.4
Forest Res Inst	180	1407.7	7.82
Tech Res Ctr Finland	176	3176.9	18.1
Game & Fish Res Inst	153	1165.6	7.62
Chemistry			
Helsinki Univ	911	6780.6	7.44
Turku Univ	574	4466.7	7.78
Helsinki Univ Tech	466	3499.9	7.51
Åbo Acad Univ	290	2207.7	7.61
Jyvaskyla Univ	265	1868.1	7.05
Joensuu Univ	252	2166	8.6
Oulu Univ	222	1465.2	6.6
Tech Res Ctr Finland	190	1402.3	7.38
Kuopio Univ	101	771.02	7.63

Table 18. Number of Finnish invented US patents 1980-1998

Source: CHI-data. Relative activity (RA) in the column on the right hand side is the field´s share of all Finnish patents divided by the corresponding share for all patents

Technological field	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Tot.	RA
Telecommunications	2	3	3	6	8	13	23	23	56	64	77	79	156	512	1.8
Industrial Process Equipment	20	24	20	26	41	34	37	36	26	35	42	43	39	421	2.5
Wood And Paper	25	16	21	17	35	31	41	22	19	30	37	46	51	392	5.2
Miscellaneous Machinery	26	23	29	18	30	34	27	21	17	20	29	30	65	368	1.6
Chemicals	21	27	20	17	28	27	22	24	16	34	41	39	26	342	0.9
Industrial Machinery And Tools	8	25	31	23	20	21	24	17	17	24	26	19	19	273	1.0
Miscellaneous Manufacturing	18	23	8	15	15	20	24	16	11	13	30	24	28	245	0.8
Measuring And Control Equipment	8	22	14	7	14	19	17	23	23	12	19	20	19	216	1.0
Electrical Appliances And Components	10	10	8	9	11	10	10	14	13	16	11	18	14	154	0.7
Plastics, Polymers And Rubber	5	8	11	8	8	6	8	11	12	13	4	15	11	118	0.6
Other	5	10	3	10	11	13	4	9	9	6	8	5	12	104	0.8
Medical Electronics	3	7	4	6	2	9	8	5	11	8	11	9	16	98	2.2
Fabricated Metals	1	3	11	9	9	13	13	7	2	4	7	10	10	98	1.5
Pharmaceuticals	4	7	2	3	4	3	7	2	9	7	17	11	14	91	0.8
Glass, Clay And Cement	6	6	6	6	8	13	12	5	10	6	2	2	3	84	2.3
Other Transport	7	13	10	4	5	8	4	1	5	4	3	14	7	84	1.3
Agriculture	12	11	4	4	6	7	10	4	0	2	9	2	13	83	0.9
Biotechnology	1	4	2	1	6	4	7	6	3	9	8	11	20	82	1.4
Oil And Gas	9	8	10	5	5	2	7	5	9	4	4	7	6	81	1.3
Medical Equipment	1	2	1	4	4	6	8	2	4	10	10	13	10	76	0.5
Motor Vehicles And Parts	1	5	1	9	10	4	8	4	5	5	6	7	9	73	0.4
Textiles And Apparel	4	2	1	6	5	6	8	2	7	7	6	3	6	62	0.6
Food And Tobacco	2	2	3	5	7	8	11	4	3	2	8	2	5	61	1.1
Computers And Peripherals	1	2	1	2	1	2	2	3	6	8	7	8	15	58	0.2
Semiconductors And Electronics	6	2	1	4	2	5	6	4	2	1	7	5	9	54	0.2
Power Generation And Distribution	2	3	2	1	2	2	3	4	6	4	6	4	7	45	0.8
Primary Metals	1	4	4	0	2	1	4	3	6	8	5	3	2	42	1.5
Heating And Ventilation	1	4	2	5	3	7	0	2	4	2	3	4	3	40	1.1
Office Equipment And Cameras	0	0	0	0	4	2	4	6	5	1	3	2	4	31	0.1
Aerospace And Parts	0	0	1	3	0	1	2	1	1	1	3	1	0	15	0.6
All	209	275	233	231	304	330	358	286	315	358	447	455	599	4400	1.0

Table 19. Relative citation impact of Finnish US-patents

Source: CHI-data. Relative citation impact is Finnish citation impact relative to the citation impact of all patents. The years are citing years and the values are based on citations from a given year to patens issued five years earlier.

Technological field	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Tot.	Patents
Telecommunications	0.9	0.2	0.2	0.9	0.9	0.6	0.7	0.7	0.7	0.7	0.9	0.8	1.1	0.8	512
Industrial Process Equipment	1.2	0.8	0.8	1.1	1.2	0.9	0.9	0.8	0.9	0.8	1.2	0.8	0.9	0.9	421
Wood And Paper	0.6	1.1	0.8	0.8	1.3	0.8	0.7	0.9	0.5	0.7	1.0	0.9	1.1	0.9	392
Miscellaneous Machinery	0.8	0.7	0.7	0.6	0.9	0.8	0.7	0.7	0.9	0.8	0.8	0.7	0.8	0.7	368
Chemicals	0.9	1.5	1.0	0.8	0.7	0.7	0.6	0.6	0.7	0.5	0.8	0.3	0.7	0.7	342
Industrial Machinery And Tools	0.5	1.0	0.6	0.7	0.8	0.8	0.8	0.7	0.6	0.8	0.6	0.8	0.8	0.7	273
Miscellaneous Manufacturing	0.6	1.0	0.6	0.6	0.3	0.5	0.6	0.6	0.5	0.8	0.7	0.6	0.8	0.6	245
Measuring And Control Equipment	0.7	0.5	0.9	0.6	0.7	0.8	1.0	0.8	0.9	0.5	0.5	0.4	0.3	0.6	216
Electrical Appliances And Components	0.8	1.0	1.2	0.6	0.9	0.4	0.3	0.5	0.9	0.7	0.9	1.0	1.2	0.8	154
Plastics, Polymers And Rubber	2.5	1.7	1.3	0.9	0.6	0.6	0.4	0.4	0.8	0.6	0.4	0.5	0.4	0.7	118
Other	1.0	1.1	1.0	1.0	0.9	1.1	0.9	0.5	0.7	0.5	0.6	0.6	0.3	0.7	104
Medical Electronics	1.3	1.1	0.6	1.0	0.4	0.8	0.6	0.6	0.8	0.5	0.3	0.5	0.6	0.6	98
Fabricated Metals	0.2	0.6	0.2	0.5	0.8	1.0	1.1	1.2	0.7	1.1	0.8	1.0	0.6	0.8	98
Pharmaceuticals	0.2	2.0	0.2	0.5	0.3	0.7	2.0	0.3	1.3	0.8	0.6	0.3	0.4	0.7	91
Glass, Clay And Cement	0.0	0.4	3.2	0.6	0.9	0.6	1.0	0.5	0.3	0.4	0.1	0.9	0.3	0.6	84
Other Transport	0.5	0.6	0.3	0.3	0.4	0.4	0.8	0.3	0.1	0.6	1.0	1.1	0.5	0.5	84
Agriculture	0.7	0.5	0.6	0.7	0.7	0.7	1.2	0.7	1.3	0.6	1.0	0.8	1.7	0.8	83
Biotechnology	0.0	2.0	2.9	2.8	1.0	0.6	0.2	1.3	0.6	1.3	0.2	0.8	0.7	0.9	82
Oil And Gas	0.2	0.6	1.1	0.1	0.4	0.8	0.9	0.8	0.5	0.7	0.7	0.2	0.3	0.6	81
Medical Equipment	0.2	0.2	0.3	0.2	0.5	0.5	0.6	0.8	0.6	0.8	0.7	0.8	0.2	0.6	76
Motor Vehicles And Parts	0.4	0.5	0.7	0.7	1.1	0.2	0.3	0.5	0.6	0.4	0.5	0.4	0.5	0.5	73
Textiles And Apparel	0.3	0.5	1.0	0.4	0.7	1.0	1.2	0.4	1.0	0.8	1.2	1.0	0.5	0.8	62
Food And Tobacco	0.0	0.8	0.0	0.4	0.6	0.6	1.2	0.7	1.2	0.6	1.1	1.1	1.0	0.8	61
Computers And Peripherals	0.0	0.2	0.7	0.6	0.2	0.1	0.2	0.9	0.6	0.4	0.9	0.9	0.8	0.6	58
Semiconductors And Electronics	0.0	0.5	0.4	0.8	0.6	0.7	0.8	0.6	0.6	0.4	0.5	0.5	1.1	0.6	54
Power Generation And Distribution	0.0	0.0	0.7	0.2	0.5	0.2	0.5	0.8	1.6	0.9	1.4	1.2	0.6	0.8	45
Primary Metals	0.6	0.0	0.1	0.2	0.0	0.2	0.0	0.2	0.7	0.8	1.3	0.4	0.4	0.4	42
Heating And Ventilation	0.0	0.0	0.0	0.4	0.2	1.2	0.4	0.3	0.6	0.6	0.1	0.2	0.5	0.4	40
Office Equipment And Cameras	0.1	0.8	0.6	0.0	0.6	0.0	0.4	0.5	0.6	0.7	0.5	0.1	0.2	0.4	31
Aerospace And Parts	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.5	1.4	0.2	1.5	1.2	0.7	0.7	15
All	0.6	0.7	0.7	0.6	0.7	0.6	0.7	0.6	0.7	0.6	0.7	0.7	0.8	0.7	4400

Table 20. Percent of Finnish invented US-patents in 1980-1998 co-invented with other regions

Note: Based on USPTO downloads

Year	Domestic	European Union	European Union and North America	North America	Other regions
1986	97.4	1.8	0.0	5.6	0.4
1987	95.3	2.0	0.0	6.7	0.0
1988	97.1	0.8	0.4	6.1	0.0
1989	96.1	0.8	0.0	6.7	0.4
1990	93.6	3.1	0.0	7.7	0.6
1991	96.0	1.7	0.3	7.8	0.6
1992	94.3	2.8	0.3	7.9	0.5
1993	92.9	4.0	0.0	7.8	0.6
1994	90.6	2.5	0.6	9.1	0.3
1995	93.3	2.5	0.0	9.3	0.7
1996	92.2	3.0	0.4	8.3	0.8
1997	92.3	3.3	0.0	9.1	0.2
1998	92.4	3.5	0.0	7.7	0.9
Total	93.7	2.6	0.1	7.84	0.5

Table 21. Finnish US-patents by country address of assignee and inventor in 1986-1998

Note: Based on USPTO downloads

Issue year	Percent of patents with Finnish assignees that have Finnish inventors	Percent of patents with Finnish inventors that have non-Finnish assignees
1986	97.8	3.9
1987	97.1	11.1
1988	94.3	8.5
1989	93.6	8.3
1990	93.2	5.9
1991	92.9	9.1
1992	94.3	10.2
1993	89.5	9.5
1994	87.9	12.0
1995	89.8	9.6
1996	94.0	8.5
1997	91.3	7.5
1998	86.8	9.7

Appendix 3. Note on productivity

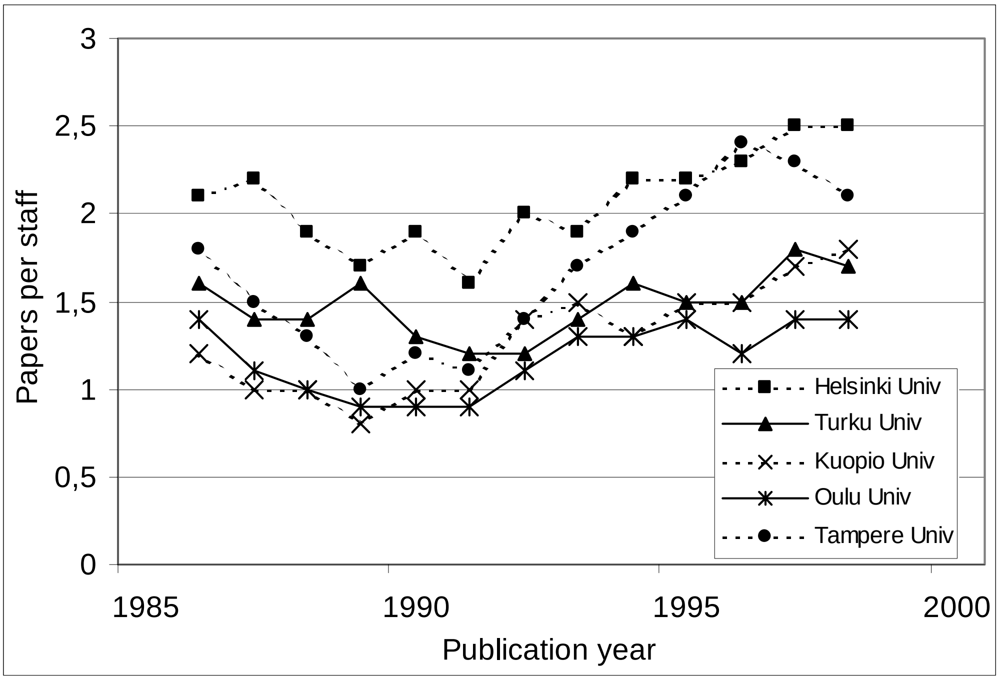

Figure A31. Papers per staff in medicine

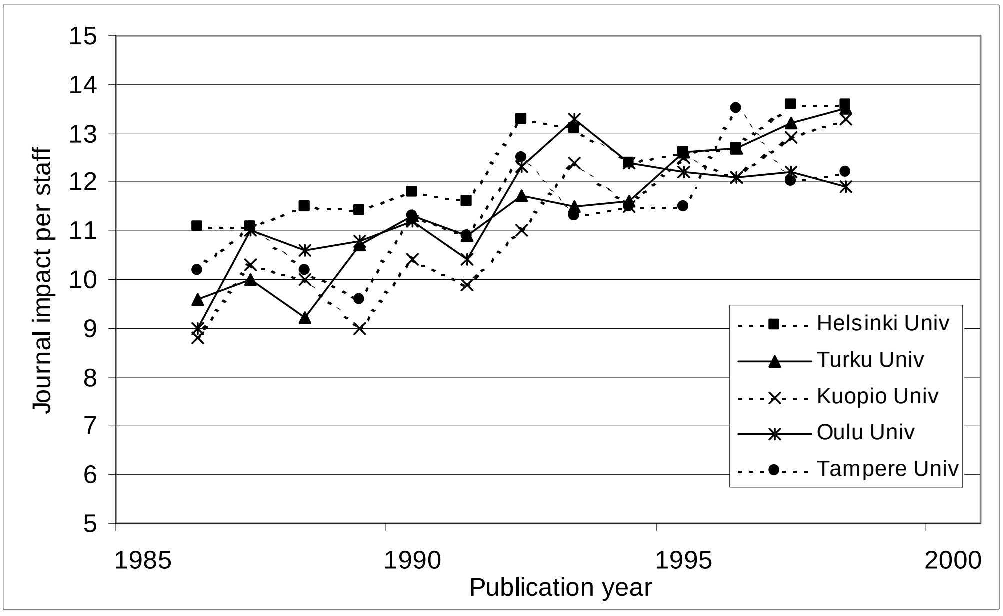

Figure A32. Journal impact per staff in medicine

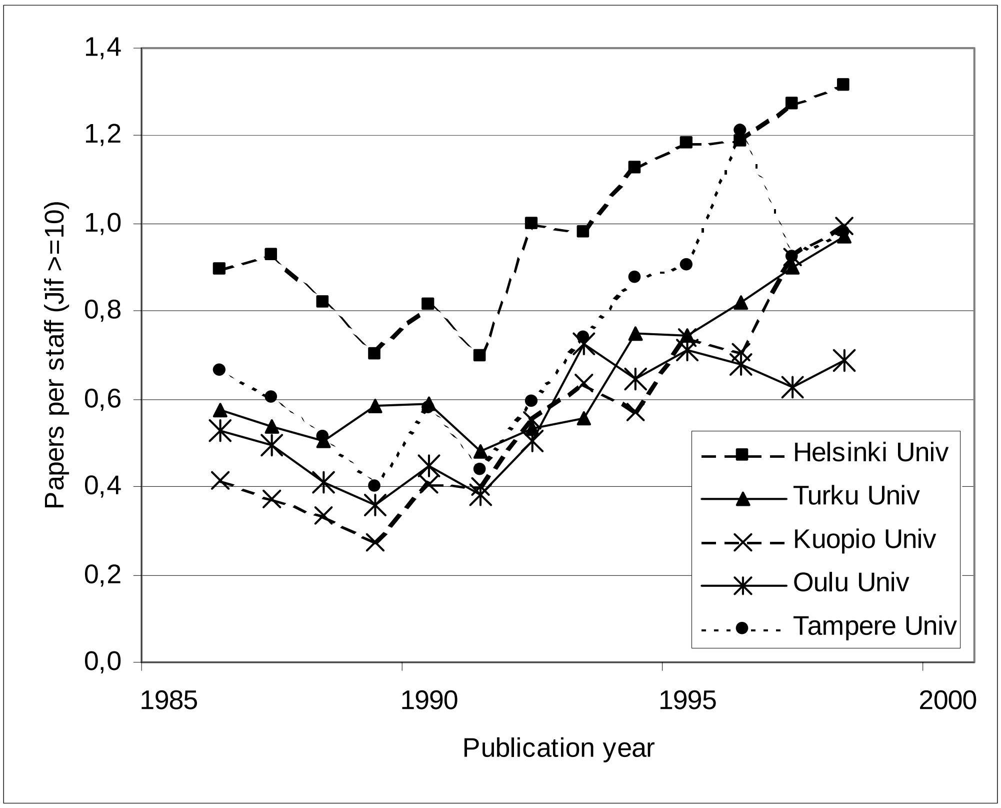

Figure A33. Papers per staff in medicine in journals with impact ≥ 10.0

Journals with a journal impact ≥ 10.0, medical fields

Medical research staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Helsinki Univ	455	443	469	463	471	486	473	472	466	489	510
Turku Univ	209	236	233	223	230	253	269	269	281	282	299
Kuopio Univ	224	247	234	261	254	256	242	249	262	294	281
Oulu Univ	207	223	244	243	238	266	239	227	242	265	291
Tampere Univ	117	124	132	143	140	144	141	142	146	124	108
Jyväskylä Univ	12	16	18	20	22	21	21	25	24	25	32
Åbo Acad Univ	6	9	10	12	11	11	11	10	11	10	11
Papers											
Helsinki Univ	407	412	385	325	385	340	473	462	526	578	605
Turku Univ	120	127	117	130	136	122	143	150	211	210	245
Kuopio Univ	93	92	78	71	103	103	134	159	150	217	199
Oulu Univ	109	110	100	87	107	102	120	165	156	189	198
Tampere Univ	78	75	68	57	81	63	84	105	128	112	131
Jyvaäkylä Univ	12	8	13	5	5	4	4	9	12	5	12
Åbo Acad Univ	4	4	4	9	6	4	6	11	13	13	16
Papers per staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Helsinki Univ	0.9	0.9	0.8	0.7	0.8	0.7	1.0	1.0	1.1	1.2	1.2
Turku Univ	0.6	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.8	0.7	0.8
Kuopio Univ	0.4	0.4	0.3	0.3	0.4	0.4	0.6	0.6	0.6	0.7	0.7
Oulu Univ	0.5	0.5	0.4	0.4	0.4	0.4	0.5	0.7	0.6	0.7	0.7
Tampere Univ	0.7	0.6	0.5	0.4	0.6	0.4	0.6	0.7	0.9	0.9	1.2
Jyväskylä Univ	1.0	0.5	0.7	0.3	0.2	0.2	0.2	0.4	0.5	0.2	0.4
Åbo Acad Univ	0.7	0.4	0.4	0.8	0.5	0.4	0.5	1.1	1.2	1.3	1.5

Table 22. Research staff, papers and journal impact

Note: Data on staff was retrieved from the Kota database of the Ministry of Education. The data give person-years.

Papers/staff was obtained by dividing the numbers of papers by person-years and journal impact/staff by dividing the sum of journal impact factors with staff.

Medical research staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	455	443	469	463	471	486	473	472	466	489	510	514	465	6176
Turku Univ	209	236	233	223	230	253	269	269	281	282	299	305	282	3371
Kuopio Univ	224	247	234	261	254	256	242	249	262	294	281	287	247	3338
Oulu Univ	207	223	244	243	238	266	239	227	242	265	291	297	265	3247
Tampere Univ	117	124	132	143	140	144	141	142	146	124	108	159	144	1764
Jyväskylä Univ	12	16	18	20	22	21	21	25	24	25	32	37	26	299
Åbo Acad Univ	6	9	10	12	11	11	11	10	11	10	11	12	12	136
Medical papers	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	964	978	905	794	874	801	928	910	1042	1083	1198	1263	1147	12887
Turku Univ	342	320	329	353	301	307	320	372	443	422	456	560	478	5003
Kuopio Univ	265	244	244	205	250	266	338	365	353	433	424	476	453	4316
Oulu Univ	295	251	248	215	224	252	256	291	325	361	361	403	384	3866
Tampere Univ	214	186	178	150	173	161	191	235	277	260	255	358	306	2944
Jyväskylä Univ	27	43	32	15	14	20	14	22	35	30	42	37	34	365
Åbo Acad Univ	13	6	7	11	11	6	14	16	22	24	26	28	36	220
Papers/Staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	2.1	2.2	1.9	1.7	1.9	1.6	2.0	1.9	2.2	2.2	2.3	2.5	2.5	2.1
Turku Univ	1.6	1.4	1.4	1.6	1.3	1.2	1.2	1.4	1.6	1.5	1.5	1.8	1.7	1.5
Kuopio Univ	1.2	1.0	1.0	0.8	1.0	1.0	1.4	1.5	1.3	1.5	1.5	1.7	1.8	1.3
Oulu Univ	1.4	1.1	1.0	0.9	0.9	0.9	1.1	1.3	1.3	1.4	1.2	1.4	1.4	1.2
Tampere Univ	1.8	1.5	1.3	1.0	1.2	1.1	1.4	1.7	1.9	2.1	2.4	2.3	2.1	1.7
Jyväskylä Univ	2.3	2.7	1.8	0.8	0.6	1.0	0.7	0.9	1.5	1.2	1.3	1.0	1.3	1.2
Åbo Acad Univ	2.2	0.7	0.7	0.9	1.0	0.5	1.3	1.6	2.0	2.4	2.4	2.3	3.0	1.6

Table 22. cont

Journal impact/Staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	11.1	11.1	11.5	11.4	11.8	11.6	13.3	13.1	12.4	12.6	12.7	13.6	13.6	12.4
Turku Univ	9.6	10.0	9.2	10.7	11.3	10.9	11.7	11.5	11.6	12.6	12.7	13.2	13.5	11.6
Kuopio Univ	8.8	10.3	10.0	9.0	10.4	9.9	11.0	12.4	11.5	12.5	12.1	12.9	13.3	11.4
Oulu Univ	9.0	11.0	10.6	10.8	11.2	10.4	12.3	13.3	12.4	12.2	12.1	12.2	11.9	11.6
Tampere Univ	10.2	11.1	10.2	9.6	11.3	10.9	12.5	11.3	11.5	11.5	13.5	12.0	12.2	11.5
Jyväskylä Univ	10.3	7.9	9.6	9.3	9.0	7.5	9.7	9.1	9.1	8.1	7.6	10.8	9.9	9.0
Åbo Acad Univ	8.2	14.3	13.3	14.3	14.2	14.0	12.6	15.2	15.3	15.0	15.7	9.4	16.4	13.9
Non-Medical staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	1529	1464	1492	1513	1558	1569	1587	1632	1593	1789	1861	1891	1776	21254
Turku Univ	528	708	675	586	604	630	750	726	708	762	795	812	785	9069
Helsinki Univ Tech	750	745	801	792	861	849	834	876	973	1151	1270	1332	1202	12436
Oulu Univ	648	699	729	752	713	728	738	721	754	854	963	954	884	10137
Jyväskylä Univ	494	551	561	583	590	581	638	650	638	735	818	840	719	8398
Åbo Acad Univ	285	361	363	400	413	422	402	389	421	469	490	497	482	5394
Kuopio Univ	91	114	119	121	117	115	119	116	125	136	146	166	153	1638
Joensuu Univ	325	368	368	372	398	406	426	392	445	473	465	499	479	5416
Tampere Univ	421	428	438	497	462	467	479	467	459	501	527	581	556	6283
Tampere Univ Tech	263	412	440	411	463	490	490	495	545	622	672	682	675	6660
Lappeenranta Univ Tech	170	195	171	188	201	218	204	230	254	261	274	289	303	2958
Lapland Univ	84	81	100	101	104	109	108	104	122	117	137	129	133	1429
Non-Medical papers	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	586	671	650	639	671	709	702	860	887	927	986	1032	1021	10341
Turku Univ	189	190	244	196	225	241	266	303	372	396	400	443	437	3902
Helsinki Univ Tech	141	177	129	179	198	210	239	221	305	307	373	350	349	3178
Oulu Univ	203	186	187	196	171	197	204	239	260	246	291	308	310	2998
Jyväskylä Univ	98	68	102	88	93	106	107	146	141	165	199	202	184	1699
Åbo Acad Univ	69	68	69	60	93	92	86	132	151	147	159	158	158	1442
Kuopio Univ	68	86	102	78	80	108	83	115	118	134	150	150	168	1440
Joensuu Univ	44	57	30	51	39	56	75	75	100	123	144	144	141	1079
Tampere Univ	38	38	36	32	41	39	57	43	56	58	67	82	93	680
Tampere Univ Tech	26	41	27	34	46	65	64	74	78	83	96	79	97	810
Lappeenranta Univ Tech	5	6	7	6	7	12	24	18	28	32	30	32	34	241
Lapland Univ					1			2	3	7	5	5	10	33

Table 22. cont

Non-Medical papers/staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.6	0.5	0.5	0.5	0.6	0.5
Turku Univ	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.4
Helsinki Univ Tech	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Oulu Univ	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3
Jyväskylä Univ	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Åbo Acad Univ	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Kuopio Univ	0.7	0.8	0.9	0.6	0.7	0.9	0.7	1.0	0.9	1.0	1.0	0.9	1.1	0.9
Joensuu Univ	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2
Tampere Univ	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Tampere Univ Tech	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lappeenranta Univ Tech	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lapland Univ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
Non-Medical Journal impact/staff	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Helsinki Univ	4.2	5.4	4.3	4.7	4.7	5.3	5.3	6.5	6.2	6.2	6.0	6.2	7.0	5.6
Turku Univ	3.5	2.5	3.9	3.6	4.0	4.6	4.2	4.3	4.9	5.6	4.7	5.8	5.9	4.5
Helsinki Univ Tech	1.6	2.1	1.2	1.7	1.9	1.7	2.1	2.1	2.5	1.9	2.1	2.2	2.2	2.0
Oulu Univ	3.1	2.8	3.3	2.8	2.9	3.3	3.7	3.8	4.1	3.5	3.2	3.8	3.8	3.4
Jyväskylä Univ	1.8	1.1	1.4	1.3	1.3	1.7	1.4	1.9	2.0	2.2	2.2	2.4	2.6	1.8
Åbo Acad Univ	1.9	1.7	1.4	1.2	1.7	1.4	1.7	3.1	2.9	2.4	2.2	2.7	2.9	2.1
Kuopio Univ	5.5	9.2	8.3	5.9	6.6	10.1	7.3	11.3	9.7	10.6	9.7	10.5	12.9	9.3
Joensuu Univ	0.9	1.2	0.6	0.9	1.0	1.1	1.1	1.7	1.8	1.8	2.4	2.0	2.1	1.5
Tampere Univ	1.0	1.9	1.2	1.1	1.6	1.6	1.8	1.4	1.6	2.2	1.5	2.3	2.2	1.7
Tampere Univ Tech	0.7	0.0	0.0	0.0	0.0	0.0	0.1	1.0	1.0	0.7	0.9	0.6	0.8	0.5
Lappeenranta Univ Tech	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.3	0.4	0.6	0.5	0.5	0.6	0.4
Lapland Univ	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.0	0.2	0.4	0.2	0.3	0.5	0.2

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This study is the most comprehensive bibliometric report of Finnish science carried out, and it is based on a long time series. It uses many types of bibliometric indicators to describe the scentific and technological activities of the Finnish research base. It draws attention to publication activities and the international visibility and impact of Finnish scientific research, domestic and international collaboration patterns, and indicators of technological innovation activities.

The report gives a very positive picture of Finnish science. The policy to strengthen the internationalisation of Finnish science seems to have been effective. Finland has increased its international publishing and has improved the international visibility and impact of its research publications. The study of Finnish US patents shows that Finland is active in producing technological innovations and has impact in telecommunications, industrial process equipment, and wood and paper. To some extent, Finland appears to be strong technologically and economically in the same fields (especially in telecommunications and wood and paper). The technological innovation base is much more nationally oriented than the Finnish science base, but there is a steady trend toward internationalisation in this area too.