IZVIRNI ČLANEK/ORIGINAL ARTICLE

Research in the fields of medicine in Slovenia – research potential, funding, and publications

Raziskave na področjih medicinskih ved v Sloveniji – kadrovska in finančna moč ter znanstvena produkcija

Stojan Pečlin,[1] Primož Južnič[2]

[1] Biomedical Research and Innovative Society, Puhova 10, 1000 Ljubljana, Slovenia

[2] Department of Library and Information Science and Book Studies, Faculty of Arts, University of Ljubljana, Aškerčeva 2, 1000 Ljubljana, Slovenia

Korespondenca/ Correspondence:
mag. Stojan Pečlin
Biomedical Research and Innovation Society, Puhova 10, 1000 Ljubljana, Slovenia
Zavod biomedicinska razvojno-inovacijska skupina, Puhova 10, 1000 Ljubljana
E-mail: stojan.peclin@gmail.com

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Abstract

Background: This study analyses funding of research from public sources, research potential (number of researchers), and scientific results (scientific papers authored or co-authored by researchers from Slovenia). Research fields of medicine are analysed in-depth and comparatively with several other research fields to gain a better understanding of differences that may be a result of long-term science policies in Slovenia. The aim of the study was to discover if relatively big differences in research potential and public funding are also reflected in the number of scientific papers and their impact.

Methods: Research potential was defined as the number of research groups and number of researchers (head count) and expressed in their capacities to research in FTE (full time equivalent). Research results data was analysed and evaluated basically as bibliometric data, that is, the number of papers published in ISI – indexed journals and their impact measured by the number of citations. Quantitative indicators used for the evaluation of research results were divided in two groups: indicators of scientific activities and indicators of scientific productivity and impact. We analysed investment from public sources into government and higher education sectors' research more thoroughly as that was the research, which was the focus of our interest. Scientific papers are mostly the result of the performance in higher education sector and government sector.

Results: Differences in research potential and public funding only partly influence the number of scientific papers but might have more to do with their impact. The results show that the number of papers published with the authorship or co-authorship of researchers from Slovenia is rapidly increasing, especially in the subfields of clinical medicine. Comparison of the number of papers per million inhabitants puts Slovenia slightly above the EU average, but in terms of impact or the average number of citations received per article, Slovenia is in penultimate place among EU Member States.

Conclusions: The size of the human research potential in the fields of medicine in Slovenia is modest. The majority of researchers are also engaged in medical practice and education. Consequently, funds from public sources for research per researcher are low. Research fields of medicine primarily require an increase in human research resources, which can then provide a basis for a rise in funding and the impact of its research results becoming comparable to the EU and world averages.

Izvleček

Izhodišča: V študiji celovito prikazujemo financiranje raziskovalne dejavnosti iz javnih virov, kadrovske raziskovalne potenciale v Sloveniji in raziskovalne rezultate (objave v soavtorstvu slovenskih raziskovalcev v revijah, indeksiranih v bibliografskih bazah ISI). V okviru tega podrobneje analiziramo raziskovalna področja medici-

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ne in njihov delež v strukturi vseh znanstvenih področij v Sloveniji. Prikazi financiranja raziskovalne dejavnosti iz javnih virov in kadrovskih potencialov v Sloveniji kažejo relativno velike razlike med vedami in raziskovalnimi področji. Obseg kadrovskih potencialov in sredstva za znanstveno-raziskovalno delo ter njihova razdelitev so v veliki meri rezultat razvoja znanosti in znanstvene politike v Sloveniji v preteklih šestdesetih letih.

Metode: V študiji opredeljujemo raziskovalne potenciale kot število raziskovalnih skupin, število raziskovalcev in njihove razpoložljive zmogljivosti za raziskovalno delo, izražene v FTE (ekvivalent polnega delovnega časa). Kot raziskovalne rezultate obravnavamo znanstvene objave, objavljene v revijah, indeksiranih v bibliografskih bazah ISI, in citiranost teh objav. Kvantitativni kazalniki, ki smo jih uporabili za vrednotenje raziskovalnih rezultatov, so: kazalniki raziskovalne dejavnosti ter kazalniki znanstvene produktivnosti in vpliva. Med sektorji izvajanja raziskovalnega dela smo podrobneje analizirali državni sektor in visokošolski sektor, saj tu v pretežni meri poteka raziskovalno delo, čigar rezultati se kažejo v znanstvenih objavah, ki so osnovna tema naše študije.

Rezultati: Raziskovali oz. analizirali smo, ali obstajajo razlike v kadrovskih potencialih in financiranju iz javnih virov, ki se odražajo tudi pri znanstveni produkciji in odmevnosti znanstvenih rezultatov. Rezultati kažejo, da se je v zadnjem obdobju število objav povečalo predvsem na področjih klinične medicine, tako da je Slovenija v primerjavi z državami EU po številu objav na milijon prebivalcev približno v povprečju. Znatno slabše je glede odmevnosti oz. kakovosti objav, saj je Slovenija med vsemi državami EU na repu.

Zaključki: Obseg raziskovalnih kadrovskih potencialov na področju medicine v Sloveniji je skromen. Večina raziskovalcev je razpetih med strokovno oz. klinično delo, pedagoško dejavnost in raziskovalno delo. Zato je obseg sredstev iz javnih virov za raziskovalno delo na raziskovalca nizek. Brez bistvenega povečanja kadrovskih raziskovalnih zmogljivosti na področju medicine ni pričakovati večjega in trajnejšega izboljšanja stanja v kakovosti, t.j. odmevnosti objav v slovenskem soavtorstvu.

Introduction

It is a cliché that while modern societies can hardly function without science, science has become very expensive and highly specialized, hence requiring an evaluation system. There are two socially justifiable reasons for supporting science. The first is that scientists make discoveries that increase our knowledge, and the second is to teach students and produce a group of specialists in various fields who can adapt the newest scientific achievements to their society.

Research underlines much progress in our modern world and provides hope that we can solve some of the seemingly intractable problems facing humankind, from the environmental issues to our expanding population. For these reasons, governments and institutions around the world provide considerable financial support for scientific research. Naturally, they want to know their money is being invested wisely and to assess the quality of the research for which they pay in order to make informed decisions about future investments. Articles about the economic benefits of publicly funded basic research usually emphasize the extensive evidence that basic research does indeed lead to considerable economic benefits, both direct and indirect [1,2]. It is often difficult to distinguish between the economic and non-economic benefits; for example, if a new medical treatment improves health and reduces the days of work lost to a particular illness, are the benefits economic or social?

There is a long and tortuous route from articles in journals, particularly those concerned with basic research, to the improvement of patient care and the prevention of disease, the twin goals of biomedical research.[3]

Policy makers and others who are responsible for funding science need a tool to identify the best science. The demand from researchers for financial resources is rising, but the supply is limited and choices have to be made. The evaluation process helps in making the right ones. The system of rewards in science must assure the promotion of the best, improvement of the good, and the denial of public funds to the worst.

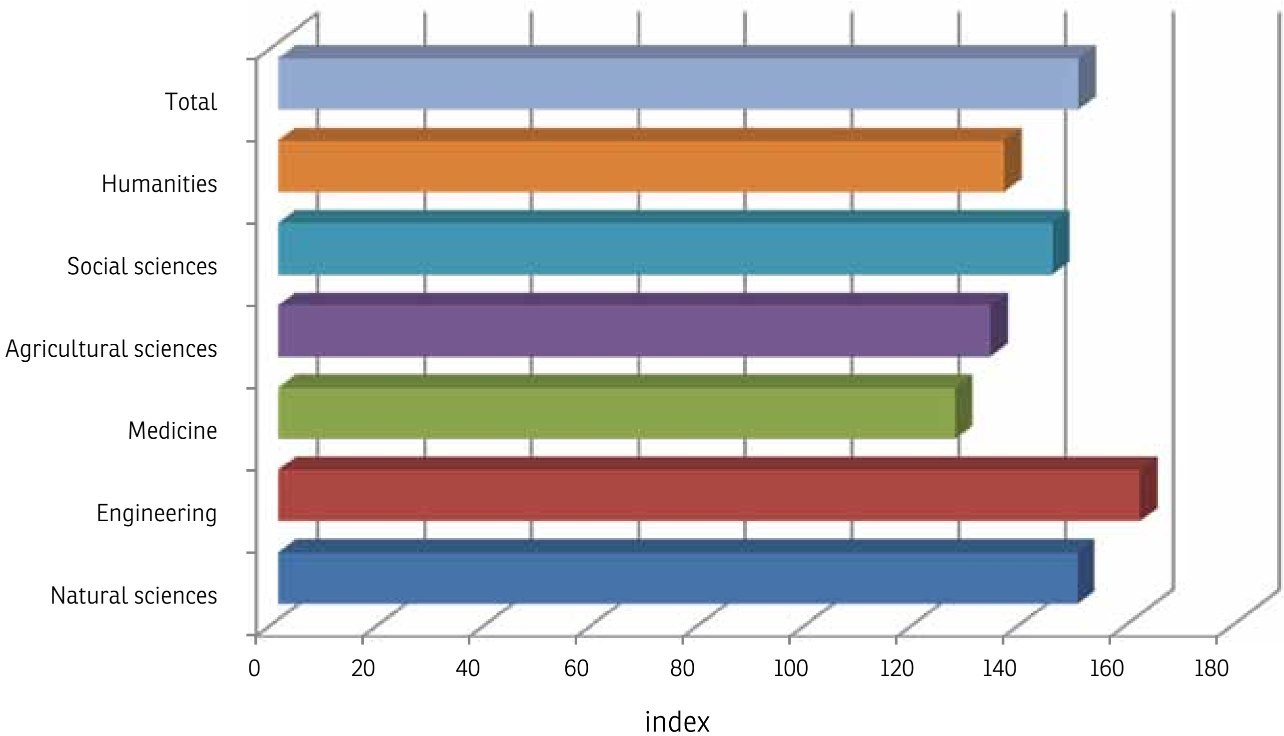


Figure 1: Growth trend in the number of research groups 1998–2008 by scientific disciplines

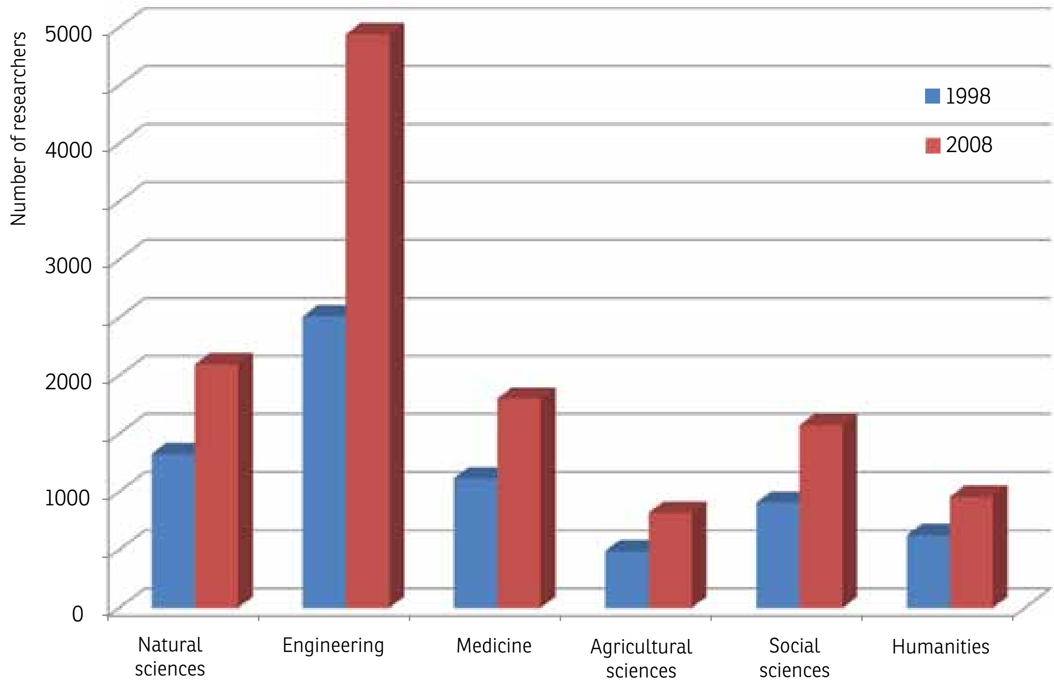
To make an objective distinction between good and poor science, some means of evaluation are required. Traditionally, evaluation was done by scientists themselves through peer review, the only method used until the 1970's. However, peer review has a number of shortcomings and disadvantages due to its qualitative nature and subjective measures. Some of them are well known, such as conflict of interests, old-boys networks, and similar weaknesses. In the last twenty years, this system has been not so much challenged as improved by various quantitative methods.[4] The building of a proper peer review system is a very difficult process in which the motivation and competence of peer reviewers is extremely important, as illustrated by the evaluation of the Slovenian Research Agency (ARRS) peer review system of recent years.[5]

The purpose of using quantitative methods is basically to improve the peer review system by collecting, processing, and making available as much objective data and information about past performance of certain research, recent developments, and predictions for prospective research as possible.[6,7]

Indicators based on scientific pubications data and the publications of research work are particularly useful quantitative methods. These are called bibliometric indicators and are used for the bibliometric assessment of research quality. Bibliometric assessment is based on one important assumption: the work to be evaluated must be published in open and available forms that are the prime channel and basis for the system of scientific communication and information sharing. Publication in international journals is a major driving force of scientific development. The funding of science, to the extent that it leads to publication, helps to promulgate relevant knowledge, and publication is consequently an essential aspect of publicly funded science. Publication expands the opportunities for different users of scientific results to access the knowledge and skills base in the scientific community created by public investment in research.

An important part of our study is devoted to the relationship between research funding and research output. Countries differ considerably in terms of the efficiency of turning financial input into measurable output and both funding schemes and disciplinary portfolios differ among countries. The cost per paper or the ratio between financial inputs and publication outputs can nevertheless be estimated.[8] Of course, an

Figure 2: Number of researchers (head count) by scientific disciplines



output-based evaluation is only one aspect and a change from an output-based to an outcomes-based perspective is seen by some as a critical step in examining the role that scientific research can play in the society. [9] However, measuring outcomes against input is very complex and the results are often necessarily presented in hypothetical terms.

Basis and methods

This study analyses funding of research from public resources, research potential, and research results (papers authored or co-authored by researchers from Slovenia). Fields of medical research are analysed more thoroughly and comparatively with other research fields. The analysis has a twenty-year scope, with more data from the last ten years. Funding and its structure, the division of funds among different science fields, are seen as the result of science policy. Our hypothesis is that differences between research potential and funding among different research fields are reflected in the number of papers and their impact.

The sources of our data were varied. We defined research potential as the number of research groups and number of researchers (head count) as expressed in their capacity to research in FTE (full time equivalent). For this data, we used the following sources: the Slovenian Current Research Information System (SICRIS), records kept by the ministry responsible for science and later ARRS for the needs of financing research activities from the budget, and the Statistical Office of the Republic of Slovenia (SURS). The data used for the analysis of public resources science funding came from two sources, Eurostat and ARRS. Countries differ in terms of funding schemes and sectors performing R&D. For example, state-funded R&D in some countries is concentrated in the universities and therefore funded as part of Higher Education Expenditure on R&D (HERD), while in other countries such as Slovenia, national research institutes are also an important, possibly even the major contributor to scientific publishing. In such cases, Government Intramural Expenditure on R&D (GOVERD) is larger than HERD. Where possible, we used both HERD and GOVERD as indicators of financial input.

For research results, we used data from the Web of Science (WoS) bibliographical databases and the domestic Slovenian database, the national Co-operative Online Bibliographic System and Services (COBISS), which is linked to the WoS databases. For international comparisons we used the In-

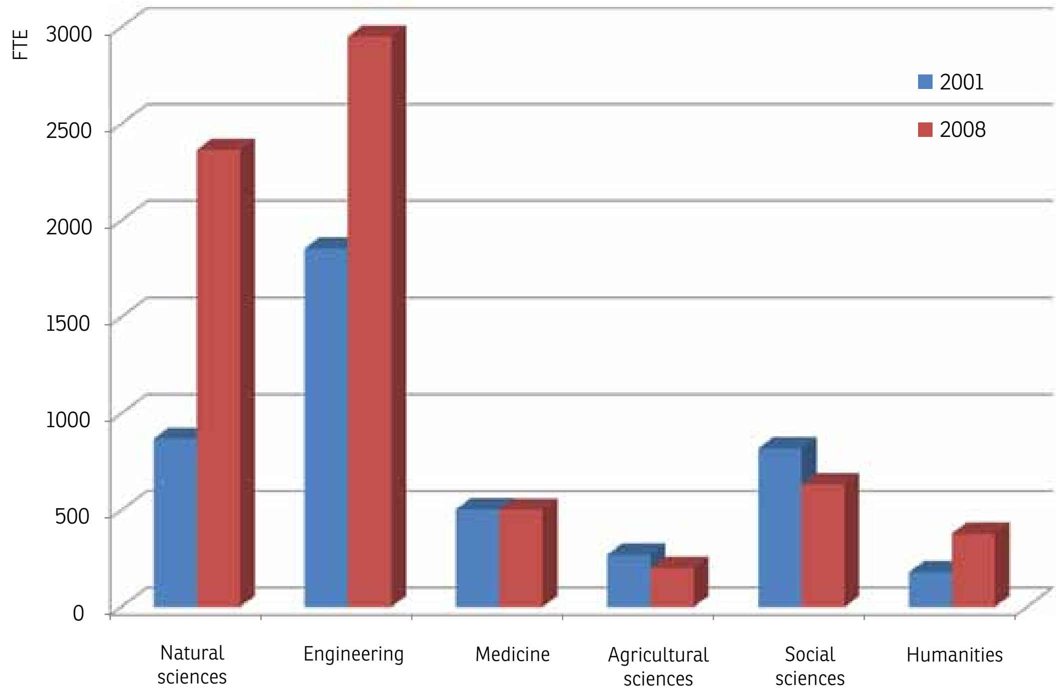


Figure 3: Number of researchers (FTE) by scientific disciplines

Cites research evaluation tool of Thomson Reuters.

Data of research results defined as bibliometric data included the number of papers published in ISI – indexed journals and their impact, that is, the number of received citations. Quantitative indicators used for the evaluation of research results were divided into two groups. The first group of indicators of scientific activities included the number of research groups, the number of researchers in one research field, and the FTE of researchers co-funded from public resources. To this group we also added The Relative Specialisation Index (RSI). The RSI indicates whether a country has a relatively higher or lower share in world publications in a particular field of science than its overall share in world total publications.[10] The second group of indicators included indicators of scientific productivity and impact: the number of papers per single researcher and FTE, the average number of papers per FTE in different research fields, the total number of citations, the number of citations per paper, the number of uncited papers, the number of papers with international co-authorship, and the relative impact factor. The relative impact factor is a standardised international bibliographic indicator measuring the relationship or ratio between the number of citations and the number of papers relative to the global average value for an individual research field. In different scientific fields the average number of citations per publication (within a certain time period) is much higher than in other scientific fields. This is due to differences among fields in the average number of cited references per publication, the average age of cited references, and the degree to which references from other fields are cited. This provides a basis for comparing different scientific fields to a world average. The basis for calculating the relative impact factor are papers and citations in journals indexed in the Web of Science bibliographic databases. In bibliometric practice, it is statistically relevant and normal to consider overlapping five-year periods in analysing bibliometric trends. The calculations made on the basis of this indicator show unequivocally the research results of a specific research group, research institution, or specific country in a specific research field: substantially below average (relative impact factor of 0.5 or less), below average (0.5–0.8), average (0.8–1.2), above average (1.2–1.5), and substantially above average (more than 1.5) with regard to the world average.[11] In measuring the scientific impact, the aggregate level of analysed entities should be taken into consideration: the higher the aggregate level, the

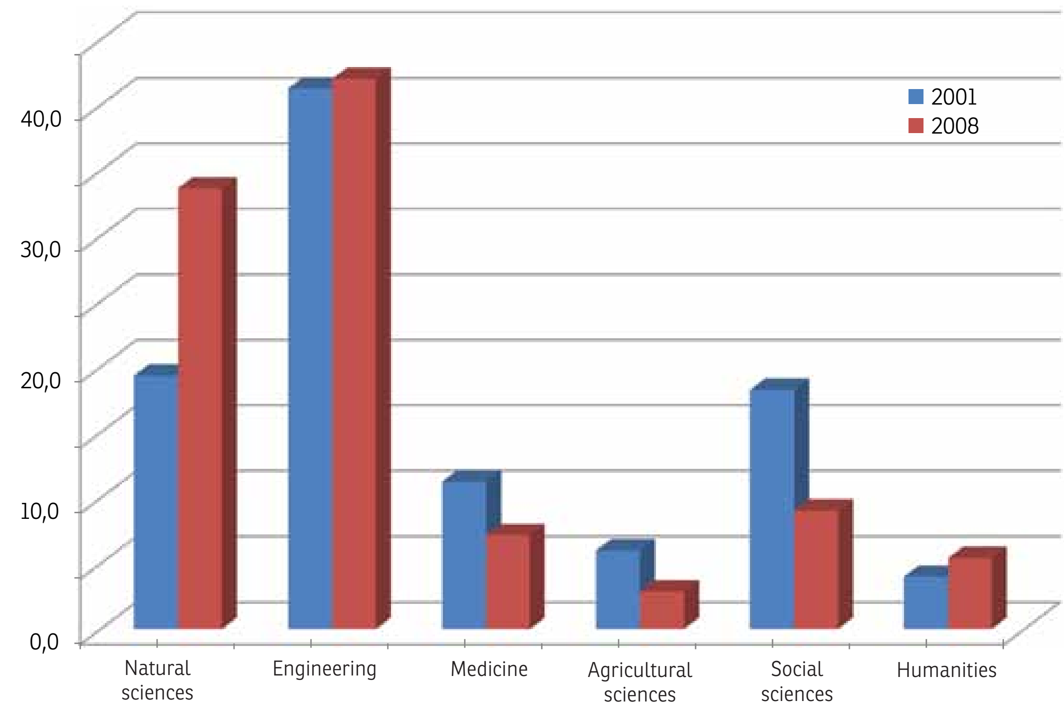


Figure 4: Structure of researchers (FTE) by scientific disciplines

greater the volume of publications and the more difficult it is to keep the impact substantially above the international average.

Findings

1. Research potential

One of the indicators that show the development and growth of research activity is the increasing number of research groups. We compared the number of research groups in 1998 and ten years later in 2008 (Figure 1).

In 1998, 753 research groups were active in Slovenia: 121 research groups in the fields of natural sciences, 346 research groups in the fields of engineering, 75 research groups in the fields of medical sciences, 60 research groups in the fields of agricultural sciences and biotechnology, 98 research groups in the fields of social sciences, and 53 research groups in the fields of humanities. Ten years later in 2008, 1128 research groups were active in Slovenia, a 50 % increase: 181 research groups in the fields of natural sciences, 558 research groups in the fields of engineering, 95 research groups in the fields of medical sciences, 80 research groups in the fields of agricultural sciences and biotechnology, 142 research groups in the fields of social sciences, and 72 research groups in the fields of humanities.

Medical sciences showed the lowest rate of increase among all scientific fields, barely 27 %. Twenty-seven research groups were from universities, 61 from hospitals and research institutions and 7 from industry. In 2008, these included 19 groups in microbiology and immunology, 5 groups in stomatology, 22 groups in neurobiology, 3 groups in oncology, 8 groups in human reproduction, 16 groups in heart and circulation, 5 groups in metabolic and hormonal disorders, 16 groups in public health, and one research group in psychiatry.

The number of registered researchers was 6,971 in 1998. Ten years later, this number almost doubled to 12,182 registered researchers (Figure 2).

The overall percentage of PhD holders was also higher in 2008, increasing from 30 % to almost 40 %. The percentage of PhD holders among researchers in the medical sciences was slightly lower at 37.5 %, the percentage being lower only in engineering.

Even more important for comparison than the number of researchers is the number of FTE researchers (Figure 3). In the fields of medicine, the majority of researchers are "part time" since they can only work on research projects in addition to their regular

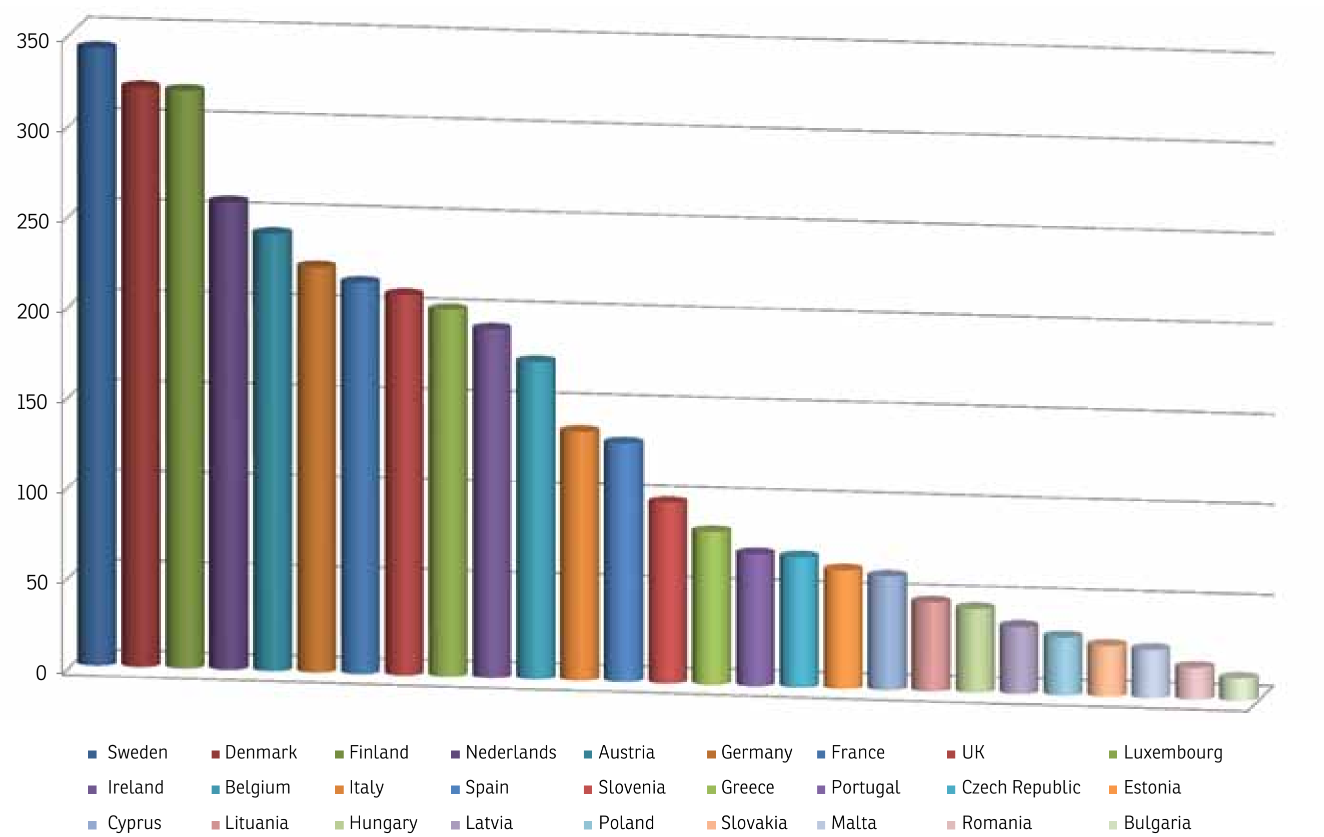


Figure 5: Funds for research performed in government and higher education sectors in EUR per capita (2007)

work. They are either practitioners or university professors, and very often both. Since certain limitations to additional employment were introduced into law between 2001 and 2008, the number of FTE in the field of medicine was the same in 2008 as it was seven years before. In some other disciplines the numbers of FTE were even lower than seven years before.

The research potential (FTE) in the fields of medicine fell from 11 % to 7 % of the total of research potential in Slovenia (Figure 4).

2. Structure of research funding

Investment in research institutions in the government sector and higher education sector was analysed more thoroughly since this was the research on which we concentrated our interests. The scientific publications are mostly the results of government investment. In Slovenia, research institutions in the government sector and higher education sector together receive 79 % of the funding for their research work from government funds (medicine 86 %).[12]

Data for 2007 on investments for research work at institutions in the higher education sector according to scientific fields and financial sources are available from Eurostat. For instance, 85 % of the research work at higher education institutions in Spain is funded from government and higher education resources (in the field of medical sciences only, 87 %). At Austrian higher education institutions, however, 88 % of the research work is funded from mainly government resources and only partly from higher education resources (the same proportion in the field of medical sciences only).

In 2007, investment in research at institutions in the government sector was 367.3 million euros in Austria, 2,348.8 million euros in Spain, and 122.5 million euros in Slovenia. In the same year, investment in institutions in the higher education sector for research work was 1,637.3 million euros in Austria, 3,518.6 million euros in Spain, and 77.9 million euros in Slovenia.[13] In the fields of natural sciences, investment in research at research institutions from the government sector was 483.5 million euros in Austria, 1,113.1 million euros in Spain, and 72.3 million euros in Slovenia, while in the field of medical sciences the investment in research

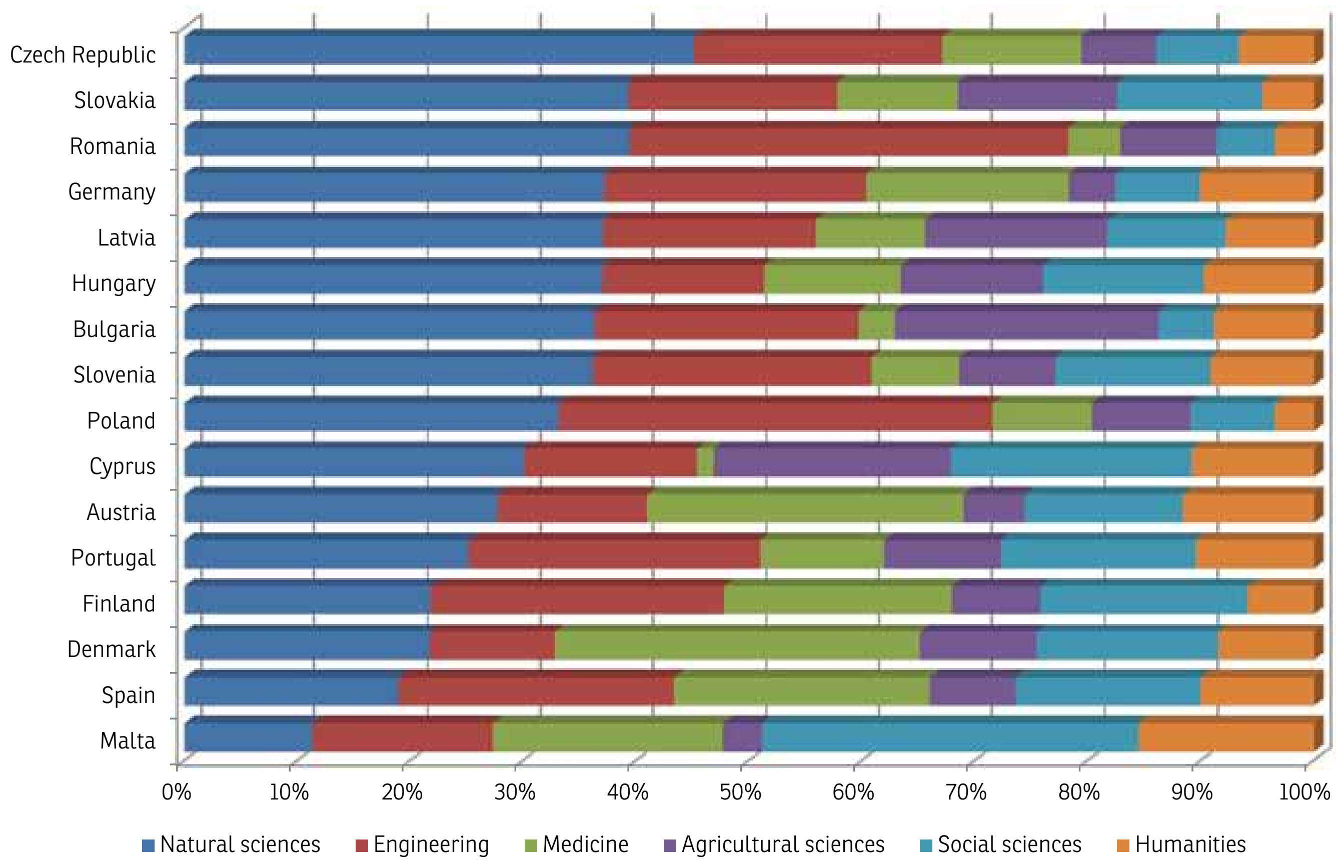


Figure 6: Funds for research performed in government and higher education sectors by science fields (2007)

at institutions in the government sector was 596.9 million euros in Austria, 1,322.5 million euros in Spain, and 15.6 million euros in Slovenia.

In Slovenia, investment in government sector research and the higher education sector is 100 euros per capita. Among EU Member States Sweden has the highest investment with 342 euros per capita followed by Finland with 321 euros (Figure 5).

Finland, for example, has the following structure by science fields: natural sciences 22.4 %, engineering 26.5 %, medicine 20.6 %, agriculture 8 %, social sciences 18.7 %, and humanities 6 %. Slovenia has a somewhat different structure: natural sciences 36 %, engineering 25 %, medicine 8 %, agriculture 9 %, social sciences 14 %, and humanities 9 % (Figure 6).

For the analysis of public funding of research in Slovenia, we also used data from ARRS, which is by far the largest public source of funding for scientific research in Slovenia. In 2009, 4,560 researchers participated in various programmes and projects (basic, applicative, and postdoctoral) financed by ARRS. Of these, 684 were active in one of the medical science research fields: 118 researchers (23.9 FTE) in microbiology and immunology, 26 researchers (3.28 FTE) in stomatology, 149 researchers (33.34 FTE) in neurobiology, 113 researchers (18.7 FTE) in oncology, 87 researchers (10.51 FTE) in human reproduction, 95 researchers (13.41 FTE) in heart and circulation, 30 researchers (3,77 FTE) in metabolic in hormonal disorder, 46 researchers (7,36 FTE) in public health and 19 researchers (3.00 FTE) in psychiatry.

At the same time there were 211 researchers (104.35 FTE) financed in the field of physics and 210 researchers (86.18 FTE) in the field of chemistry.

3. Scientific papers as a result of scientific research

The quantitative indicators for the measurement and evaluation of science, its production and impact, and therefore also of the quality and excellence in science chosen as bibliometric indicators are the following: number of papers, number of citations, and

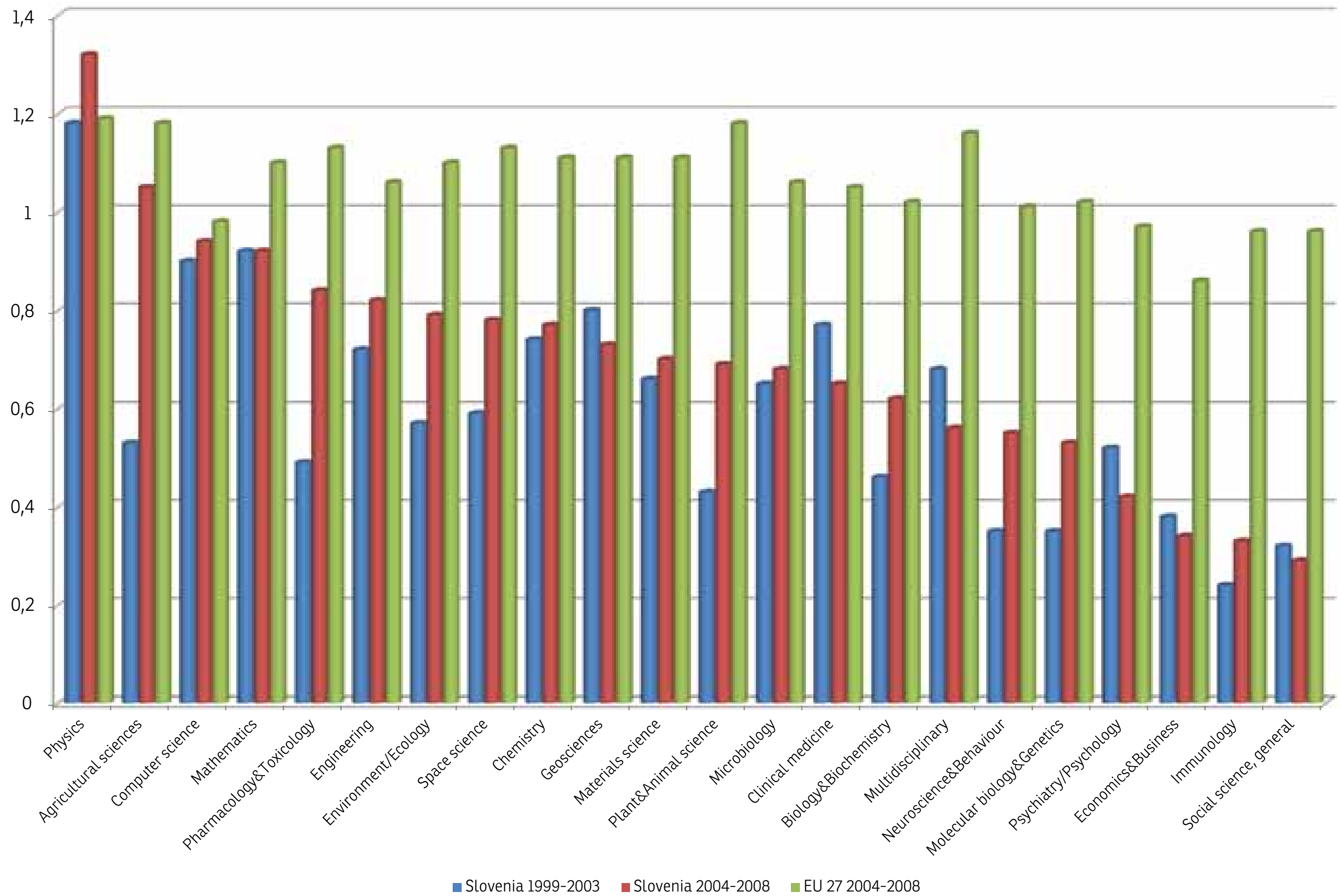


Figure 7: Relative impact factor

number of highly cited papers published in journals indexed in the SCI, SSCI, and AHCI citation databases that form Thomson's Web of Science. We compared the Slovenian results with the results of other EU Member States and the EU average relative to number of inhabitants. By number of papers, Slovenia was 30 % over the EU average in the period 2004–2008. Relative to the number of citations and number of highly-cited papers in the period 1998–2008, papers by Slovenian researchers reached 73 % and 60 % of the EU average. The number of papers indicator put Slovenia in the seventh place, the other two indicators a bit lower, in the 13th place.

The comparison of number of papers and number of their citations from two periods, 1999–2003 and 2004–2008, shows growth in both, compared to the EU average. Increase in publications has exceeded the EU average by 20 %, and the number of citations even slightly more than by 20 %.

In 2002, Slovenia had 809 papers per million inhabitants while the average for EU Member States was 629. In 2005, Slovenia had 1,104 papers per million inhabitants while the average for EU Member States was 887; in 2008, the numbers were 1,637 vs. 1,037. In 2002 Slovenia was in the 9th place, in 2005 in the 8th and in 2008 in the5th place.[14]

As previously noted (see Basis and Methods section), the relative impact factor is a standardised international bibliographic indicator measuring the relationship between the number of citations and the number of papers relative to the global average value for an individual research field. Figure 7 compares Slovenia in different research fields between 1999–2003 and 2004–2008 periods with the EU average.

The relation between funding and research results can be presented in various ways. Papers published in scientific journals are certainly not the only indicator but it is a very important one. Figure 8 shows the number of papers with Slovenian co-authorship published in journals indexed in WoS bibliographic databases and the number of citations these papers received in the period 2004–2008 in different research fields, and

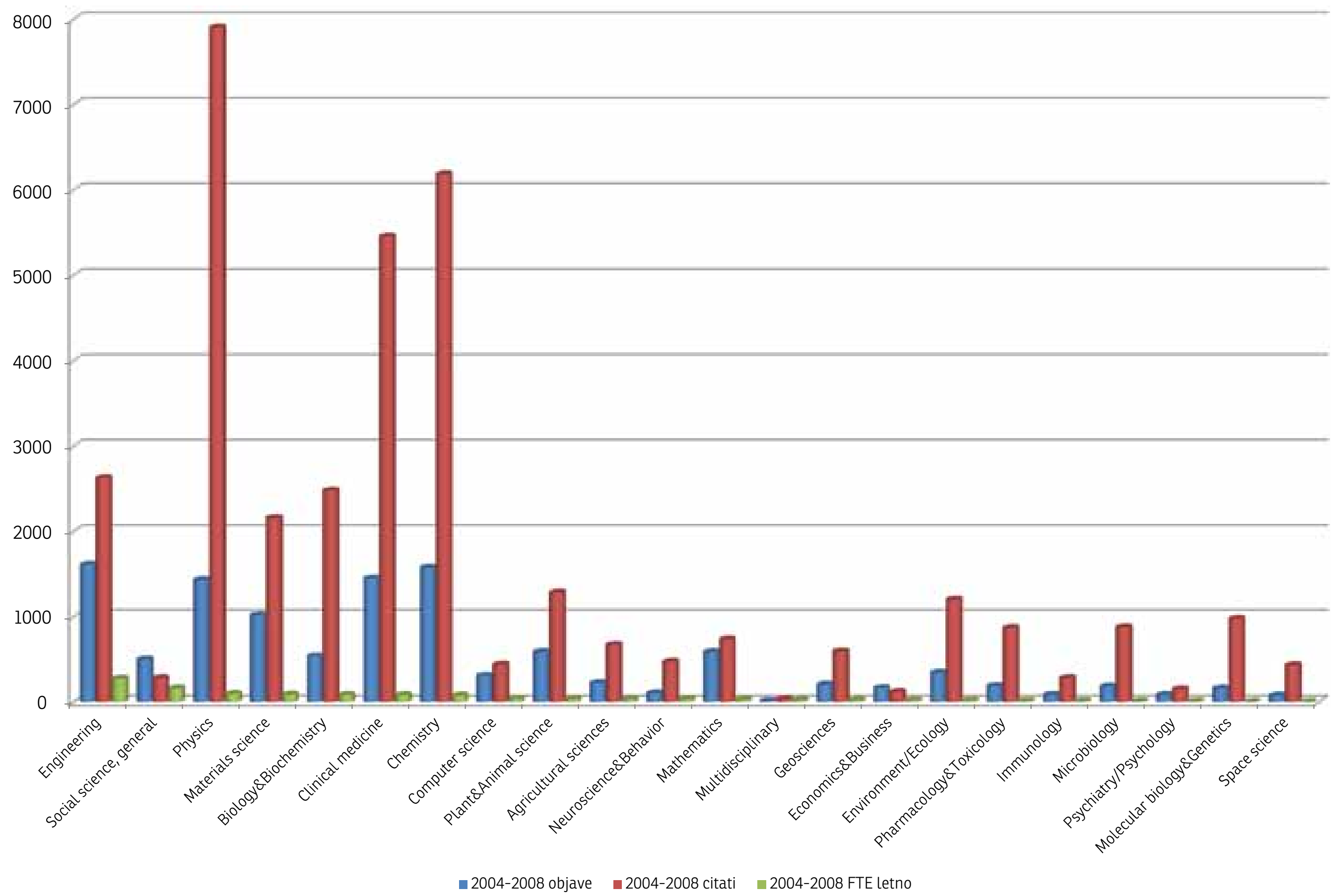


Figure 8: Papers and citations (2004–2008) and annual funds from ARRS

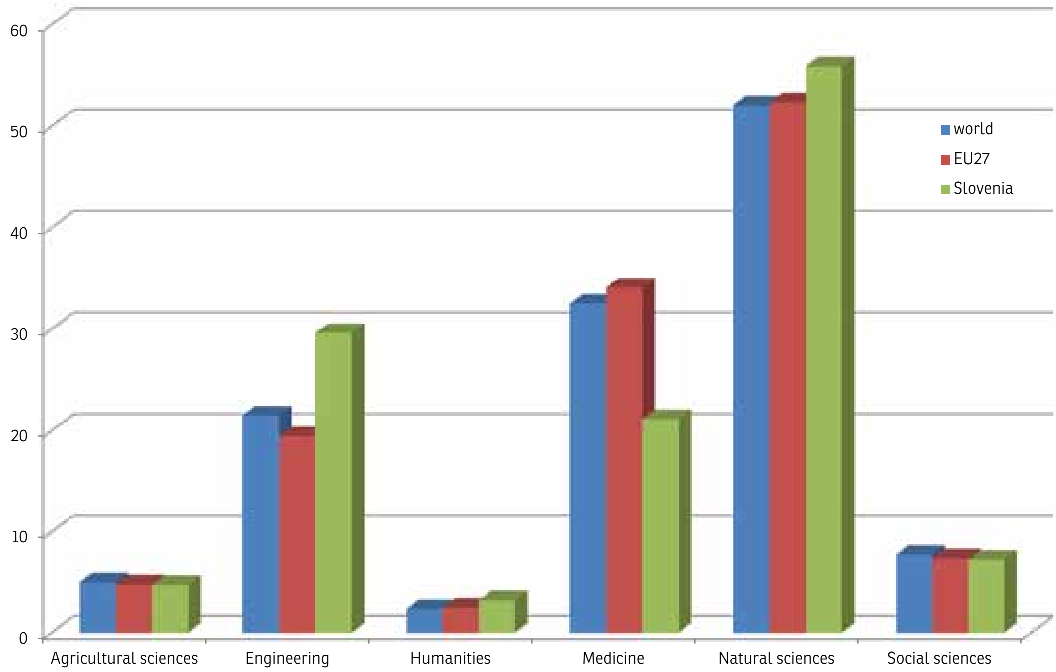
on the right axis funds provided annually from public sources expressed in FTE (1 FTE is 63,000 euros).

To gain a genuine insight into the quality of scientific production, a large number of papers is required. If the number of papers is rather small, the relative impact factor could improve quickly, especially in the case of international co-authorship; this, however, does not represent the actual research potential of a specific research field.

Considering data on research funding in government and higher education sectors research institutions, we constructed the »investment per publication« indicator. The data for 2007 show that investment per publication in the fields of natural and mathematical sciences was 98,800 euros in Austria, 54,140 euros in Spain and 49,439 euros in Slovenia. There were greater differences in the field of medical sciences where the investment per publications was 168,377 euros in Austria, 137,774 euros in Spain and 35,754 euros in Slovenia. An additional indicator is the impact of papers, defined as the number of citations papers receive. Considering the three-year citation window, for all fields of natural sciences together, the average number of citations per paper is 7.0 in the case of Austrian co-authorship, which is above the world average (relative impact factor of 1.30), 6.1 citations in the case of Spanish co-authorship (relative impact factor of 1.13), and 4.7 citations in the case of Slovenian co-authorship (relative impact factor of 0.87). For all fields of medical sciences together, the average number of citations per paper is 7.7 in the case of Austrian co-authorship, which is above the world average (relative impact factor of 1.22), 6.9 citations in the case of Spanish co-authorship (relative impact factor of 1.10), and 5.0 citations in the case of Slovenian co-authorship (relative impact factor of 0.79).

We also compared three research fields (clinical medicine, physics, chemistry) in Slovenia. The investment of ARRS in research programmes and projects in the period 2004–2008 and the number of papers in journals indexed in ISI biblio-

Figure 9: Share of total scientific papers (period 2005–2009)



graphic databases in the same period were analysed. The results show that investment per publication was 12,479 euros in the field of clinical medicine, 18,936 euros in the field of physics, and 13,991 euros in the field of chemistry. Furthermore, we investigated the relationship between the three research fields according to the »investment needed for a citation« indicator. In this case, the differences between the research fields proved to be much smaller: the investment per citation was 3,416 euros in the field of clinical medicine, 3,480 euros in the field of physics, and 3,560 euros in the field of chemistry. Considering the impact of papers relative to the average of the EU-27 Member States, the relative impact factor for publications with Slovenian co-authorship in the field of clinical medicine is below the average (0.64; EU-27 1.05), while the proportion of uncited publications is 39.45 % (EU-27 32.28 %); the relative impact factor for publications

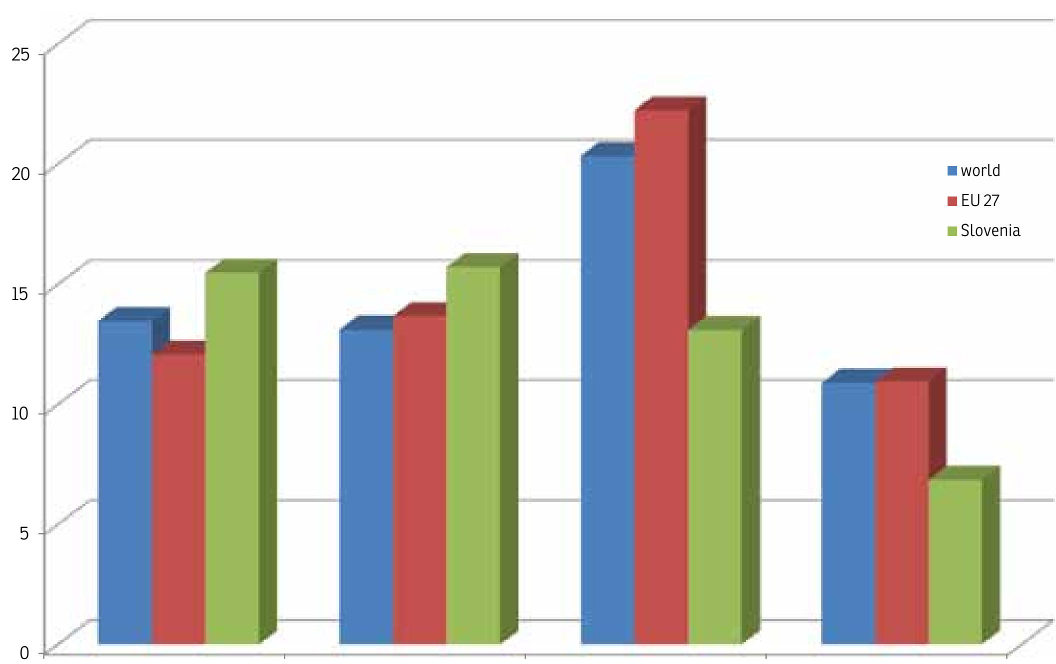


Figure 10: Share of total scientific papers (period 2005–2009) by four selected scientific fields

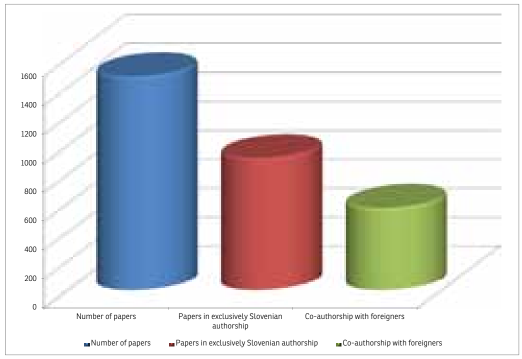


Figure 11: Papers with co-authorship of Slovenian researchers in the subfields of clinical medicine (period 2004–2008)

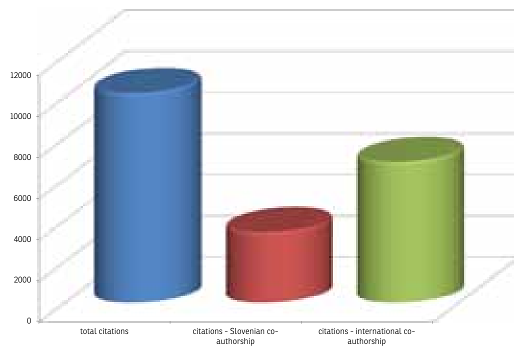


Figure 12: Impact of papers with co-authorship of Slovenian researchers in the subfields of clinical medicine (period 2004–2008)

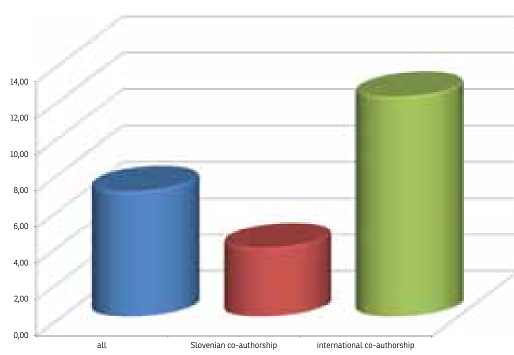


Figure 13: Number of citations per paper with co-authorship of Slovenian researchers in the subfields of clinical medicine (period 2004–2008)

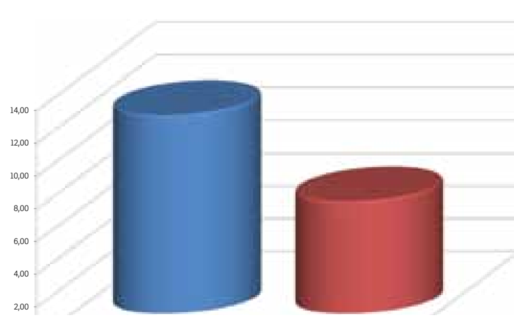


Figure 14: Number of citations per paper with co-authorship of Slovenian researchers with foreigners in the subfields of clinical medicine (period 2004–2008)

with Slovenian co-authorship in the field of physics is above the average (1.31; EU-27 1.19), while the proportion of uncited publications is 30.52 % (EU-27 32.61 %); and the relative impact factor for publications with Slovenian co-authorship in the field of chemistry is near the average (0.78; EU-27 1.11), while the proportion of uncited publications is 32.97 % (EU-27 28.15 %).

A comparison of the structure of world total scientific papers, EU papers, and papers with co-authorship of Slovenian researchers shows the greatest deviances of the Slovenian structure against world and EU structures in the fields of engineering sciences (Slovenian share nearly 10 % larger) and medical sciences (Slovenian share more than 10 % lower; Figure 9).

We also compared the shares of four scientific fields (basic medicine, clinical medicine, physics and chemistry) in world total papers, EU papers, and papers with Slovenian co-authorship. The shares of Slovenian clinical medicine and basic medicine papers lag considerably behind the shares at the world and EU levels (Figure 10).

3.1. Scientific papers with co-authorship of Slovenian researchers in the subfields of clinical medicine (2004–2008 period)

In this part of our study we analysed in detail papers in the research subfields of clinical medicine with Slovenian co-authorship in journals indexed in SCI bibliographic database, considering papers from the period 2004–2008. The citation window was from 2004 to October 2010, i.e. almost 7 years.

The total number of papers in the observed research subfields was 1,471. The highest number of papers with Slovenian co-authorship appeared in journals indexed in the WoS subject categories of oncology, general and internal medicine, clinical neurology, endocrinology and metabolism, and cardiac and cardiovascular systems.

We divided the papers into three parts: papers written with exclusively Slovenian authorship, papers with international co-authorship, and within the papers with international co-authorship those whose primary author was Slovenian(Figure 11).

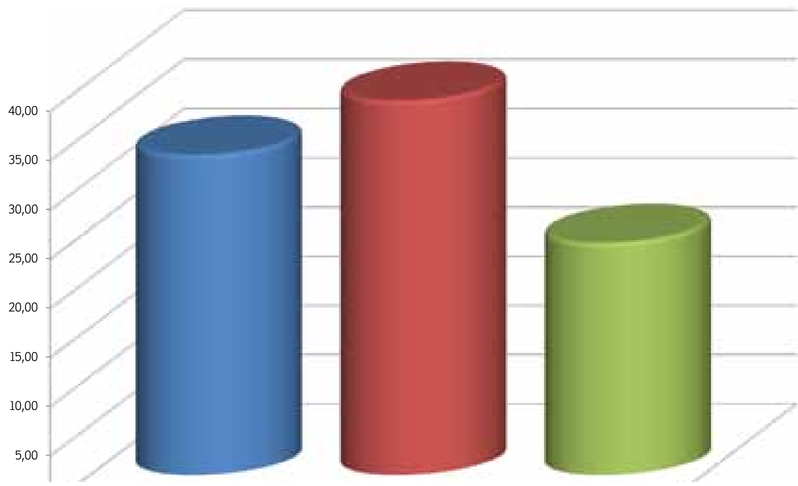


Figure 15: Share of uncited papers with co-authorship of Slovenian researchers in the subfields of clinical medicine (2004–2008 period)

We took a relatively long period, almost seven years, as the citation window. A consequence of this, of course, is a higher mean number of citations per paper than is the case with the commonly used five-year citation window. The total number of citations per papers published in the period 2004–2008 within the 2004–October 2010 citation window is close to 10,200 (Figure 12).

As already evident from the above two figures, there is a relatively large difference between the number of citations of papers with international co-authorship and papers with exclusively Slovenian authorship. Papers with international co-authorship are three times more frequently cited than those with exclusively Slovenian authorship (Figure 13). The number of citations of papers with international co-authorship with a Slovenian as the primary author are somewhere in the middle between those with international co-authorship and those with exclusively Slovenian authorship.

Table 1: RSI, Slovenia, 2005–2009

Research field	RSI
Chemistry	0.07
Physics	0.09
Basic medicine	-0.22
Clinical medicine	-0.22
Biology	-0.09
Mathematics	0.26
Geology	-0.19
Engineering	0.17

The share of papers in structure of all papers with Slovenian co-authorship in the subfields of clinical medicine with international co-authorship is 38 %; within these papers 36 % of papers have a Slovenian primary author.

The number of citations per paper with international co-authorship nearly doubled compared to papers with international co-authorship but with a Slovenian as primary author (Figure 14).

The share of uncited papers is also an interesting bibliometric indicator. The share of uncited papers written in co-athorship with foreigners is 23 % and those writen with exclusively Slovenian authorship 38 % (Figure 15).

3.2. Relative Specialisation Index

The RSI was conceived to reveal the tendencies for concentration or neglect in a particular country with regard to eight major fields of science. No country, including the richest ones, can afford to devote the same proportion of research efforts to all science fields.[15] Special attention can be given to certain fields only at the expense of some others. This is usually also reflected in a country's publication output. The RSI indicates whether a country has a relatively higher or lower share in world publications in a particular field of science than its overall share in world total publications. It is important to note that RSI reflects an internal balance among the fields in the given country, that is, positive RSI values must always be balanced by negative ones. The RSI is closely related to the Activity Index which is defined as follows: AI= the world share of a given country in publications in a given field divided by the overall world share of the given country in publications or, equivalently AI= the share of a given field in the publications of a given country divided by the share of the given field in the world total of publications. The RSI is then defined as RSI=AI-1 divided by AI+1. From this definition, it follows that RSI can take values in the range -1 to 1. Values lower than zero indicate lower than average activity and values higher than zero indicate higher than average activity.

For the analysis, the following eight fields of science were included in accordance with the methodology taken from the European Report on Science and Technology Indicators 1997, in which the RSI was defined.

Our results can be compared with the results of research by T. Braun from his 1997 study, which compared the publication activity of eastern Central European countries (Austria, Bulgaria, Finland, Hungary, Poland, Romania, Czech Republic, Slovakia, Lithuania, Latvia, Estonia, Croatia, Slovenia).[15]

There have been some significant changes: the number of papers in clinical medicine rose considerably, while physics and chemistry lost some ground in terms of the number of papers.

W. Glänzel distinguishes in general four basic paradigmatic patterns in publication profiles:[16]

- the »western model«, that is, the characteristic pattern of the developed Western countries with clinical medicine and biomedical research as dominating fields;
- the characteristic pattern of the former socialist countries, present economies in transition, and China with excessive activity in chemistry and physics;
- the »bio-environmental model", that is, the pattern most typical for developing and more »natural« countries (e.g., Australia, or South Africa) with biology and earth and space sciences in the main focus;
- the »Japanese model«, now also typical for other developed Asian economies with engineering and chemistry being predominant.

Table 2: RSI, Slovenia, 1997 (T. Braun)

Research field	RSI
Chemistry	0.22
Physics	0.20
Basic medicine	-0.20
Clinical medicine	-0.38
Biology	-0.08
Mathematics	0.27
Geology	-0.40
Engineering	0.10

Discussion

Physics and chemistry are two scientific fields with well-established human resources (researchers) and relatively high level of funding from public resources, but with different status in international comparisons. The relative impact factor is higher than the world average in the case of physics (1.32) but lower than the world average in the case of chemistry(0.77). In contrast, medical sciences as scientific discipline has very modest human resources, only 7 % of all researchers in Slovenia, and a corresponding low share in funding at 7.7 %. This is very low compared to both old and new EU Member States: Denmark 32.3 %, Austria 28 %, Spain 22.6 %, Finland 20.5 %, Germany 17.9 %, Czech Republic 12.2 %, Hungary 12.2 %. The relative impact factor of research published in the field of medical science is also low. It is interesting that despite these limitations in human and financial resources, the number of papers published in authorship or co-authorship of authors from Slovenia is growing. There were one third more publications in the period 2005–2009 compared to the period 2003–2007, mostly in the fields of clinical medicine. In the field of basic medicine, the comparison of number of publications per million inhabitants puts Slovenia in the 12th place for the period 2005–2009, and with 455 papers above the EU average of 436. In the field of clinical medicine, in the same period Slovenia is in the 14th place, and with 874 papers almost at the EU average, which is 879. These figures make the issue of impact or, indirectly, of quality even more significant since according to the relative impact factor Slovenian medical research is in the penultimate place among EU Member States at 0.65, and well below the EU average of 1.06.[17]

The impact of papers that researchers from Slovenia published in subfields of clinical medicine with international co-authorship are receiving in average three times more citations than papers with exclusively Slovenian authorship. The share of uncited papers is also higher among papers written solely by researchers from Slovenia than those with international co-authorship (38 % and 23 % respectively). Another study done recently yielded similar results showing that international co-authorship is a significant advantage for Slovenian researchers in the fields of medical science but gives no significant advantage in terms of impact and number of citations in other research fields, especially the most developed ones, such as physics.[18]

Conclusion

A comparison of government sector funding in two natural science research fields (physics and chemistry) with medical research fields reveals the following relationships:

In Slovenia, medical science research fields received 117.27 FTE, Physics 104.35 FTE and Chemistry 86.18 FTE. However, since researchers in the fields of medicine are rarely full-time researchers and are often engaged in medical practice and education work, there are differences in the extent of funding per individual researcher, which in the fields of medicine amount to 0.17 FTE, physics 0.49 FTE, and chemistry 0.41 FTE. Research fields of medicine primarily need an enlargement of research potential (number of researchers), which can provide a basis for a rise in funding and subsequently in the impact of its research results, which might then be comparable to some other more developed research fields in Slovenia. A more detailed analysis of different fields of medicine may be useful. In a similar study, an analysis of bibliometric indicators, funding from national institutes of health, and faculty size, the author suggests just that.[19] For instance, the general publication and citation statistics for pediatricians may be quite different from those for neurologists. Medical science fields might be much more varied than natural sciences.

We cannot speculate or predict that quantity will sooner or later produce a rise in quality and impact. However, it would be realistic to say that without increases in human and financial resources this change will not occur. The relative specialization index shows that the research fields of basic and clinical medicine in Slovenia have modest research potential. Slovenian research policy is slowly changing the old pattern inherited from its socialist period, but the Western pattern emphasizing clinical medicine and biomedical research has yet to be developed.

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