Bibliometric Study on Mathematics Research

in the Netherlands

1993 - 2002

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February, 2007

Research Report to the Exact Science Division of NWO (NWO-EW)
Report CWTS

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Executive summary

This report covers a large-scale bibliometric study on the scientific output and impact of academic mathematics and statistics research in the Netherlands during 1993 - 2002. The study covers the complete scientific research output of Dutch researchers (only those affiliated with mathematical units of universities in the Netherlands or the NWO-institute CWI in either a permanent or a tenure track position on September 1st, 2003) active in these two fields, and its related areas. The main focus of the study is on aggregations of these researchers and their output: mathematical units of universities and the NWO-institute CWI, and research schools. The bibliometric study includes analyses of scientific publications covered by source journals of the Science Citation Index and associated Citation Indices (in brief: CI-publications), and a limited analysis of the other scientific publications ('non-CI publications'; non-scientific publications were not included).

While the first three sections of this report describe the general methodology and indicators applied in this study, the main findings are presented in sections 4 and 5. Section 6 contains background information on output and citation characteristics of mathematics research. Finally, Section 7 provides general comments and discussion.

The bibliometric indicators that are presented in the report all describe specific characteristics of the research analysed. However, among the bibliometric indicators presented in this study, the three normalized indicators of citation impact ***CPP/JCSm,*** ***CPP/FCSm***, and ***JCSm/FCSm*** are perhaps the strongest, as they provide information relative to the worldwide environment of the research. Here, ***CPP/JCSm*** expresses the appreciation of an output as the mean received number of citations per publication of mathematics and statistics research units in the Netherlands (CPP) compared to that of the articles in the journals in which the publications appeared (JCSm). These journals are classified into CI fields (e.g., *Mathematics; Statistics & probability*) and ***CPP/FCSm*** compares the mean received number of citations per publication to that of articles in the fields to which the journals belong (FCSm). Finally, ***JCSm/FCSm*** indicates the overall journal quality in which the output was published by comparing the mean CPP of a journal with that of the corresponding CI field.

The overall analysis of Dutch mathematics and statistics research covers 3,116 publications in journals processed for the Citation Indices. This output receives in total 10,677 citations, that is, including self-citations. The mean impact is 2.38 citations per publication, which results in ***CPP/JCSm*** and ***CPP/FCSm*** scores of 1.13

and 1.17, both significantly above worldwide average level. The Dutch output appeared in journals with an impact level that is competitive with the world average.

Universities or institutes with a relatively large output (>400 publications) are: TUE, TUD, UT and CWI. Of these four, TUE and CWI have high impact scores, and UT a relatively low impact. Five universities have an output ranging between 200 and 400 publications over ten years: VU, UvA, UU, UvT, and LEI. Here, UU and UvA have high impact scores. The other four universities have an output smaller than 200 publications in the period 1993 - 2002.

The study includes three mathematics research schools, and four other 'multidisciplinary' research schools that cover mathematics and one or more other disciplines (Beta, Burgerscentrum, CentER, and DISC; here, only publications of mathematics and statistics researchers are included). Not surprisingly, the largest output is found in the three mathematics schools: Stieltjes, MRI, and EIDMA, with the first two having a high citation impact. DISC has a high impact as well.

A remarkable result of the knowledge user analysis is that mathematics and statistics papers are more often cited by papers outside the domain of mathematics and statistics than by papers inside that domain. This illustrates the relevance of mathematical research in the Netherlands for researchers active in more applied fields of science and technology.

An important issue in the study concerns the applicability of a bibliometric study to non-CI publications appearing in media that are not covered by the Citation Indices (See Section 5). The citation impact of 'non-CI publications' of Dutch mathematics and statistics researchers can be derived from the Citation Indices. A limitation of the non-CI analyses is that the impact of non-CI publications could not be compared to international reference values. Findings show that about equal numbers of CI and non-CI publications were produced, although the ratio of CI and non-CI publications varied considerably among universities. In general, the mean CPP scores for non-CI publications were lower than those for CI publications included in the study. This might be the result of retrieving citations only from the journal literature processed for the Citation Indices, possibly a disadvantage for the non-CI publications. However, the present citation impact scores provide a considerable advantage to non-CI publications, as self-citations of co-authors have been included for non-CI publications, but were removed for CI publications. This notwithstanding, the findings show that:

1. Non-CI publications contribute considerably to the scientific output of Dutch mathematicians in terms of numbers;
2. The total volume of citations to non-CI publications is considerable, although the average number of citations per publication tends to be lower than that of CI publications. This is as expected, as the Citation Indices prefer to cover high impact media;
3. For two to three out of thirteen universities, the impact of non-CI publications is considerably higher than of their CI publications. However, these universities are cited above average in the CI analyses. For the other nine universities and the CWI institute, impact of CI publications is either higher than, or about equal to, that of their non-CI publications.

In general, the findings from the limited non-CI analysis seem to accord reasonably well with the results and conclusions obtained in the CI analysis. Combined, the analyses indicate that the impact of academic mathematics and statistics research in the Netherlands is well above world average during 1993 – 2002.

1. Introduction

The objective of the present study is to provide insight in important aspects of publication output and international impact of academic mathematics researchers of participating research schools (EIDMA, MRI, Stieltjes, as well as Beta, Burgerscentrum, CentER, and DISC), which were affiliated with mathematical units of universities in the Netherlands or the NWO-institute CWI in either a permanent or a tenure track position on September 1st, 2003.

The study was commissioned by the Exact Science Division of NWO (NWO-EW). It covers the period 1993 - 2002 for both publications and their citation impact. In our experience, a period of about eight to ten years is needed to assess research performance fully. This period allows most units to produce a number of publications sufficient for statistical analysis. The study is primarily, but not exclusively, based on a quantitative analysis of scientific articles published in journals and serials processed for the CD-ROM versions of the Science Citation Index and eight associated indices (in brief: **CI**): the **Science Citation Index** (SCI), the **Social Science Citation Index** (SSCI), and the **Arts & Humanities Citation Index** (A&HCI), recently extended with six specialty Citation Indices (Compumath, Chemistry, Materials Science, Biotechnology, Biochemistry & Biophysics, and Neuroscience).

Using bibliometric techniques, the present study assesses the publication output and citation impact of universities, research schools, and fields in the Dutch mathematics landscape. Furthermore, we analyse the effects on research performance of academic rank of the researchers as well as of the country or region where the researchers were trained. The impact, as measured by citations, is compared with worldwide reference values.

Both non-serial scientific literature and scientific publications in journals not covered by the CI (both designated as ‘non-CI publications’) are important for Dutch mathematics and statistics research. Therefore, a limited bibliometric study has also been directed at the assessment of the citation impact of these scientific non-CI publications.

In recent years, CWTS has made a number of major changes and improvements in its methodology:

- All impact indicators and worldwide reference values are now calculated *without* self-citations;

- An important innovation concerns the algorithm that relates citations to source publications in the database. This has been improved, resulting in more accurate citation counts. For example, authors with names that are misspelled in citations will usually benefit.

There are two main approaches to what research performance indicators should address.
(1) The '*past performance*' approach focuses on an assessment of the past performance of a group of scientists from a perspective of accountability of research funds allocated to the research unit during a certain period. Then, retiring scientists and those formerly working in the research unit should be included.
(2) The '*back-to-the-future*' approach addresses the performance of the scientists who are still active in a particular research unit, from the objective of obtaining a view on the research performance of those who have the task to shape the future of this research unit. Therefore, this approach has been called 'back-to-the-future'. Then, it seems appropriate to exclude scientists no longer working in the research unit.

Both approaches relate to the past performance of groups of scientists. However, the policy view underlying the second approach is more directed to the future, while the perspective adopted in the first approach is more focused on the past. In the present report, the second, so-called 'back-to-the-future' approach has been adopted.

We thank a Supervisory Commission consisting of Prof. dr. R. Tijdeman (UL) (chairperson), Prof. dr. J.G. Verwer (CWI), Prof. dr. C.A.J. Klaassen (UvA), Prof. dr J.H.M. Steenbrink (RU), Prof. dr. R. Gill (UL), and dr. A.P. Zandee (NWO-EW), for their assistance.

Structure of the report
The structure of this report is as follows. **Section 2** gives the main lines of **data collection**, while the bibliometric **indicators** applied in this study are described in **Section 3,** with an overview in Section 3.8. **Section 4** presents the **'overall' results** of the CI analysis for Mathematics research in the Netherlands, and for universities and research schools (main results in Sections 4.1 - 4.3; main additional analyses in Sections 4.6 - 4.9 and 4.11). Results for non-CI publications are presented in **Section 5**. **Section 6** contains background information on output and citation characteristics of mathematics research. Finally, **Section 7** provides general comments and discussion.

2. Data collection

2.1 Introduction

Bibliometrics is the quantitative study of written products of research. It is assumed that scientific subjects develop at an international research front (Price, 1963). Research results are communicated in publications that are submitted to evaluation by professional colleagues. In the references of their papers, scientists acknowledge relevant publications by others, as they build on previous work. Therefore, the number of times a publication is referred to gives a partial indication of the 'impact' of a publication, its reception and use by scientists at the research front.

In nearly all scientific fields, the scientific journal is by far the most important medium of communication. The Citation Indices claims to cover the most important 'leading' international journals and serials (such as Annual Reviews) with a well-functioning referee system. In addition, the overall citation rate of journals is considered, as well as their timeliness of publication, and adherence to international editorial conventions. Regularly, a limited number of new journals is added, while other journals are no longer covered. More 'peripheral' journals, often national in scope, are usually not covered by the Citation Indices. The CI contains about 10,000 journals (listed in the Journal Citation Reports of ISI; e.g., ISI, 2003).

The process of data-collection and the methodology applied in this study are comparable to those adopted in previous studies on, for instance, physics research (Rinia et al., 2001), biology (Nederhof et al., 1999), electrical and electronic engineering (Van Leeuwen et al., 2000), chemistry (Van Leeuwen et al., 2003), the humanities (Nederhof, 2006; Tijssen et al., 2006), medicine (Tijssen et al., 2002) and psychology (Nederhof, Van Leeuwen & Visser, 2000). Publications were derived from a large bibliometric database of scientific publications. This database contains all scientific articles published in serials processed during the period 1980 - 2003 by the Institute for Scientific Information (ISI; now part of Thomson Scientific.) for the CD-ROM versions of the Science Citation Index (SCI), the Social Science Citation Index (SSCI), the Arts & Humanities Citation Index (A&HCI), as well as six specialty Citation Indices (Compumath, Materials Science, Biotechnology, Biochemistry & Biophysics, Neuroscience, and Chemistry). The CWTS database includes citation data and indicators on all journals processed for the SCI, SSCI, A&HCI, and specialty Citation Indices worldwide or **CI** for short. A detailed description of the main principles behind this database is given in Moed, De Bruin & Van Leeuwen (1995) and Moed (2005).

Both statistical requirements and imperfections in the citation process (for a discussion see Nederhof, 1988) make it necessary to aggregate across individuals, publications, and citations. As scientific (sub)fields differ in publication and citation patterns (as visible in differences in for example length of reference lists, or age of cited literature), it is usually not meaningful to compare directly the raw impact of publications from one (sub)field with those of a different (sub)field. Therefore, in our studies raw impact scores are compared to the impact of similar publications within the same journal, or within the same (sub)field.

2.2 Data collection

The present study set out as a bibliometric study of the publication material originally gathered for the VSNU visitation study of mathematics (Qanu, 2004). However, the present study bears no one-to-one relation with the VSNU study, which focused mainly on research programs within universities (a level not addressed in the present study), and on a more limited period (1996 – 2001) than the present study (1993 – 2002). Nevertheless, both studies address the research performance of mathematical researchers affiliated with universities in the Netherlands and concern a similar population of both scientists (here updated to September 1, 2003) and publications, the latter extended to 1993 - 2002.

In this study, the field of mathematics is defined by the NWO-EW Supervisory Committee as the population of mathematics and statistics researchers at research schools in the Netherlands (EIDMA, MRI, Stieltjes, and Beta, Burgerscentrum, CentER, and DISC), which were affiliated with mathematical units of universities in the Netherlands or the NWO-institute CWI in either a permanent or a tenure track position on September 1st, 2003. Included are those who graduated in a different field (e.g., physics), but who are appointed at a chair or position in mathematics, e.g., in geometry. Excluded in this study are mathematicians working in a mathematical unit, but which were not members of a research school, for instance because they were conducting hardly any research or none at all. Furthermore, mathematicians affiliated with non-mathematical units are excluded, as are those working outside universities or CWI. Also excluded are those not having a permanent or tenure track position on September 1, 2003 (e.g., AIOs, postdocs, bursars). NWO-EW supplied us with the names of 300 researchers and their publications.

Although CWI was involved in the VSNU visitation (Qanu, 2004), it did not appear there as a separate institute, as in the present study. A Wageningen program linked to two non-mathematical units was part of the VSNU visitation study, but not of the present study. VSNU studies tend to focus on past performance, while the present study had a back-to-the-future approach (cf. Section 1).

The process of data-collection and the methodology in this study is based on a comparison and matching of the output files of Dutch mathematics researchers, with a large CWTS bibliometric data-system of scientific publications based on the Science Citation Index and associated Citation Indices (designated as CI, see Section 2.1). This CWTS CI data-system contains all articles classified by the Institute for Scientific Information (ISI) as *articles*, *letters*, *notes*, and *reviews* (only review articles, no book reviews) published during the period 1980 - 2003 in journals processed by ISI for the CD-Rom versions of the Science Citation Index (SCI) and associated Citation Indices (see Section 2.1). Thus, this CI data-system can also provide citation data on all *journals* processed for the CD-Rom versions of the SCI, SSCI, A&HCI, and the Specialty Citation Indices. However, we need to stress that although the individual researchers' output formed the basis of the data-collection process, no analyses were conducted on the level of the individual researchers.

Publications of the 300 Dutch mathematics researchers matching with those in CI source journals were included in the CI analysis. Non-matching papers from 1993 – 2002 were included in the non-CI analysis.

3. Methodology

3.1 Levels of aggregation

Indicators are computed at the following levels of aggregation of mathematical scientists:

a) the total collection of all articles, published by all scientists involved in the study (Dutch Mathematics);

b) the universities (Erasmus University of Rotterdam (EUR), Leiden (LEI), Groningen (RUG), Delft (TUD), Eindhoven (TUE), Maastricht (UM); Nijmegen (KUN), Twente (UT), Utrecht (UU), Amsterdam (UvA), Tilburg (UvT), the Free University of Amsterdam (VU)), and the Amsterdam based NWO-institute Centre for Mathematics and Informatics (CWI);

c) the research schools: three research schools deal with mathematics only: the Euler Institute for Discrete Mathematics and its Applications (EIDMA), the 'Mathematisch Research Instituut' (MRI), and Stieltjes, while four other research schools cover mathematics and one or more other disciplines: the Institute for Business Engineering and Technology Application (Beta), Burgerscentrum, the Centre for Economics Research (CentER), and the Dutch Institute of Systems and Control (DISC).

Double occurrences of papers are excluded within each unit of analysis. So one paper, labeled to two or more different research units, is counted only once on a higher level of aggregation. Similarly, a paper, co-authored by several scientists belonging to the same unit, is counted only once.

The bibliometric CI analysis relates to journal articles published during the period 1993 - 2002. Actually, these are 'database' years: papers are included for the year in which they were processed by the Citation Indices. Due to a time lag in processing articles some papers that were published late in 2002 are not included. Data on more recent articles were not available during the data collection period of this study. Apart from an overall analysis of the 1993 - 2002 impact data, we also conducted an analysis of the main indicators across five-year periods at the level of universities and research schools. The non-CI analysis relates to non-CI publications from the publication years 1993 - 2002.

3.2 Output and impact indicators

We calculate several indicators for the oeuvre of a research unit, as produced within the time-frame of the study. For a detailed description we refer to Moed, De Bruin and Van Leeuwen (1995). Our work is partly based upon previous work by Garfield (1979), Martin and Irvine (1983), Narin (1990), Van Raan (1997), and Schubert, Glaenzel and Braun (1989). One reason for computing indicators on the oeuvre of a research unit rather than on individual papers is that within an oeuvre, later articles or review articles may draw citations that otherwise would have gone to earlier articles. The oeuvre approach prevents that a transfer of citations within an oeuvre is treated as a statistical error in the assessment of single articles. The sequence in which the indicators are discussed below corresponds to the position these indicators occupy in the data tables (e.g., Table 1).

Indicators for the CI analyses

The *first* indicator is the total number of papers published by a group during the entire period (**P**). We considered only normal articles, letters, notes, and review articles (not book reviews). Meeting abstracts, corrections and editorials are *not* included. In a few cases we found papers published in a journal for which no citation data are available, or in a journal that is not assigned to any field of science[1]. Such papers are not considered in the calculation of the indicators. The *second* indicator comes in two forms and concerns the total number of citations received, excluding self-citations ***(C)*** or including self-citations (***C+sc)***. A self-citation to a paper is a citation given in a publication of which at least one of the authors (either first author or a co-author) is also an author of the cited paper (again either first author or a co-author). The *third* indicator is the average number of citations per publication, corrected for self-citations (***CPP***). The *fourth* indicator is the percentage of articles *not cited* during the time period considered, self-citations excluded (***Pnc***).

International reference values: JCSm and FCSm

Next, two international reference values are computed. A first value represents the mean (worldwide) citation rate of the journals in which the institute/group has published (***JCSm,*** the mean **J**ournal **C**itation **S**core), taking into account both the type of paper (e.g., normal article, review) and the specific years in which the institute/group's papers were published. For example, the number of citations received in 1999 - 2002 by a *letter* published by an institute/group in 1999 in journal X, is

1 Fields of sciences are determined by the ISI classification of journals in so-called Subject Categories. Field-specific impact scores are calculated on the basis of this classification scheme.

compared to the average number of citations received during the *same* period (1999 - 2002) by all *letters* published in the *same* journal (X) in the *same* year (1999). Generally, an institute/group publishes its papers in several journals rather than one. Therefore, we calculated a weighted average ***JCS*** indicated as ***JCSm***, with the weights determined by the number of papers published in each journal.

A unit U that has published two articles in journal X in 1995 (JCS = 3) and one letter in journal Y in 1996 (JCS = 0.3) obtains a JCSm of (3 + 3 + 0.3)/(1+ 1 +1) or 6.3/3 is 2.1.

A second reference value presents the mean citation rate of the fields in which the institute/group is active (***FCSm,*** the mean **F**ield **C**itation **S**core). Our definition of sub-fields is based on a classification of scientific journals into about 250 *subject categories* developed by ISI (now Thomson Scientific) (e.g., ISI, 2003). For example, the CI field *Mathematics* covers journals with a broad, general approach to mathematics. It includes also journals focusing on specific areas of fundamental research in mathematics such as topology, algebra, functional analysis, combinatorial theory, differential geometry, and number theory. The CI field *Mathematics, Applied* deals with areas of mathematics that may be applied to other fields, including areas such as differential equations, numerical analysis, nonlinearity, control, software, systems analysis, computational mathematics and mathematical modelling. However, journals concerned with mathematics and with a primary focus on a specific non-mathematics discipline such as biology, economics, psychology, history etc. are included in the CI subfield *Mathematics, Interdisciplinary Applications* (ISI, 2003).

Although not perfect, it is at present the only classification that can be automated consistently in our data-system, and that fits the multidisciplinary character of the CI databases. In calculating ***FCSm***, we used the same procedure as for the calculation of ***JCSm***, with journals replaced by fields. In most cases, an institute/group is active in more than one field of science. In those cases, we calculate a weighted average value, the weights being determined by the total number of papers the institute/group has published in each field.

Suppose that journal X belongs to subfield Z, and that all 1995 articles in subfield Z are cited 1.5 times on average in 1995 - 2003, while journal Y belongs to subfield A where all 1996 letters are cited 0.6 times on average in 1996 - 2003. Then, the unit U mentioned before obtains an FCSm score of (1.5 + 1.5 + 0.6)/(1 + 1 + 1) or 1.2.

Main indicators

JCSm and ***FCSm*** are ‘intermediate’ statistics and are not printed in the data-tables. The two most important indicators compare the average number of citations to the oeuvre of a research unit (***CPP***) to the two international reference values, namely the corresponding journal and field mean citation scores (***JCSm*** and ***FCSm***, respectively), by calculating the ratio for both. Self-citations are excluded in the calculation of the ratios ***CPP/JCSm*** and ***CPP/FCSm***, the *fifth* and *sixth* indicators, to prevent that ratios are affected by divergent self-citation behavior.

The ***CPP/JCSm*** indicator matches the impact of papers closely to the publication pattern of research units. If the ratio CPP/JCSm is above 1.0, the mean impact of a research unit's papers exceeds the mean impact of all articles published in the journals in which the particular research unit has published its papers (the research unit's journal set). A limitation of this indicator is that low impact publications published in low impact journals may get a similar score as high impact publications published in high impact journals.

The ***CPP/FCSm*** indicator is free from this limitation, because it takes the impact level of a units’ journal set into account. Therefore, it seems the most suitable indicator of the international position of a research unit. If the ratio CPP/FCSm is above (below) 1.0, this means that the oeuvre of the research unit is cited more (less) frequently than an 'average' publication in the subfield(s) in which the research unit is active. ***FCSm*** constitutes a *world subfield average* in a specific (combination of) subfield(s). In this way, one may obtain an indication of the international position of a research unit, in terms of its impact compared to a 'world' average. This 'world' average is calculated for the total population of articles published in CI journals assigned to a particular subfield or journal category. As a rule, about 80 percent of these papers are authored by scientists from the United States, Canada, Western Europe, Australia and Japan. Therefore, this 'world' average is dominated by the Western world.

If a *seventh* important indicator, ***JCSm/FCSm***, is above (below) 1.0, the mean citation score of the journal set in which the research unit has published exceeds the mean citation score of all papers published in the subfield(s) to which the journals belong. In this case, one can conclude that the research unit publishes in journals with a relatively high (low) impact. It should be noted that the CPP/JCSm, CPP/FCSm and the JCSm/FCSm indicators are not independent. The value of each one of these follows directly from the values of the other two indicators.

Recent research has shown, that in comparisons across year blocks (e.g., when publications from 1995 - 1999 are compared with those of another year block), it is important to focus on these three main indicators only, as these normalised values are free from influences by distribution and document types effects (Nederhof & Visser, 2004).

The *eighth* indicator is the percentage of self-citations (***% Self-citations***), relative to the total number of citations received. The percentage of self-citations to an institute/group's oeuvre is influenced by a number of factors. Important factors are: research field; type of articles; age distribution of the articles published by an institute/group; size of the institute/group and number of articles published by the institute/group; and the extent to which the papers published by an institute/group are cognitively related.

Statistical test

We apply a statistical test to establish whether the average impact of a research unit's publication oeuvre ***(CPP)*** differs significantly from the average impact of all papers in the research unit's journal set ***(JCSm)*** or from the world subfield average ***(FCSm)*** in the subfield(s) in which the research unit is active (see the Appendix for an explanation of this statistical test). If a research unit has a citation per publication ratio (***CPP***) significantly above (below) the average field (***FCSm***) or journal citation score (***JCSm***), this is indicated in the tables by means of a '+' ('-') symbol directly after the numerical value of the indicators ***CPP/FCSm*** and ***CPP/JCSm.*** A '?' indicates that the test has insufficient information to interpret the result.

Due to the presence of error (Moed et al., 1995), only the first decimal of the ratios is usually reliable, given that it is based on a sufficient number of publications (N>50). Even for a quite large number of publications, a 5% difference or shift in the value of an indicator should not be regarded as a significant result.

3.3 Research profiles

The research profile of a research centre, institute or school is analyzed by classifying its papers according to scientific (sub-) fields. In the Citation Indices, publications are classified into (sub)fields by means of the journal in which they appear into Journal Subject Categories such as '*Mathematics'*, '*Statistics & Probability'*, *'Physics, Applied'*, and so on. These CI subject categories are attached as (sub)fields to each publication of a research unit. Subsequently, these publications are aggregated for each CI subfield, and output and impact indicators are computed separately for these aggregates. The purpose of this procedure is to show how frequently a centre has published papers in various subfields of science, what the impact of the centre is in its main subfield(s), and how the impact of the centre in its main subfields of science compares to its impact in (for the centre) more peripheral subfields of science.

If a paper appears in a journal that is classified in more than one subject category, the paper (and its citations) is distributed equally over the subject categories. Thus, a paper with 7 citations published in a journal categorized in three subject categories is counted as 0.333 publication with 2.333 citations in each of the three subject categories. Also, the impact reference values (JCSm and in particular FCSm) are divided by three. Note that the CPP of such a publication does not change, as both the numerator and the denominator are divided by three.

For publications in each subject category, the impact is compared to the mean field citation score (***FCSm***), as described above. At the subject category level, relatively low numbers of publications prevent frequent use of statistical tests. As an indication, if the ratio ***CPP/FCSm*** is lower than 0.8, the impact is said to be 'low' (graphically indicated by a 'white' bar), if the ratio is higher than 1.2, the impact is designated as 'high' (graphically indicated by a 'black' bar), while a ratio between 0.8 and 1.2 is called 'average' (subsequently indicated by a 'shaded' bar).

Fields indicated in the research profile with an '*' or '#' indicate respectively fields covered by the Social Sciences Citation Index (SSCI), and by the Arts & Humanities Citation Index (A&HCI), respectively.

3.4 Knowledge users of Dutch mathematics research papers

Who is using results of Dutch mathematics research, and where are these users located? To answer these questions, a 'knowledge user profile' is calculated for Dutch mathematics research. A knowledge user profile is a breakdown of the publications citing Dutch mathematics research papers into subfields of science (based on the CI subject categories, see Section 3.3). This 'knowledge user profile' is made in analogy to the cognitive orientation profiles discussed in Section 3.3. In the cognitive orientation profiles, the output of Dutch mathematics research is categorized in subject categories, whereas the knowledge user profiles focus on the subfields of the users citing the Dutch mathematics research output. This offers insight into knowledge diffusion as well as knowledge use, and the analysis may identify interdisciplinary 'bridges', potential for collaboration, and potential 'markets' for applied research.

3.5 Analysis of scientific collaboration

Indicators for scientific collaboration are based on an analysis of all addresses in papers published by a research unit. Each paper is classified in one of three categories. First, we identified all papers authored by scientists sharing the same address, i.e., from the same research unit or institute. These papers are classified as '***Single address'***, as they involve no collaboration or only 'local' collaboration (i.e., within the institute, group, etc. depending on the chosen level of aggregation within the analysis). The remaining papers are classified as '***national collaboration'*** when there are different addresses but from the same country, and as ***'international***' when the papers contain addresses from at least two *different countries*. For example, if a paper is the result of collaboration with both another Dutch institution and an institute outside the Netherlands, it is marked as '***international'***. Papers in each of the three categories are aggregated for each research unit and for each of these aggregated sets, impact and output indicators are computed.

The purpose of this analysis is to show (1) how frequently a research unit has co-published papers with other research units, and (2) how the impact of papers resulting from national or international collaboration compares to the impact of papers authored by scientists from one research unit only.

For publications in each collaboration category, the impact is compared to the field citation average (***FCSm***), as described in section 3.2.

3.6 Basic elements of bibliometric analysis

All above discussed indicators are important in a bibliometric analysis as they relate to different aspects of publication and citation characteristics. Generally, we consider ***CPP/FCSm*** as our 'crown' indicator. This indicator relates the measured impact of a research group or institute to a worldwide, field-specific reference value. Therefore, it is a powerful internationally standardised impact indicator. This indicator enables us to observe immediately whether the performance of a research institute/group or institute is significantly far below (indicator value < 0.5), below (indicator value 0.5 - 0.8), about (0.8 - 1.2), above (1.2 - 2.0), or far above (>2.0) the international (western world dominated) impact standard of the field.

We stress however that the meaning of the numerical value of the indicator is related to the aggregation level of the entity under study. The higher the aggregation level, the larger the volume in publications and the more difficult it is to have an average impact significantly above the international level. At the 'meso-level' (e.g., a large institute, or faculty, about 500 – 1,000 publications per year), a ***CPP/FCSm*** value above 1.2, means that the institute's impact as a whole is significantly above (western) world average. The institute can be considered as a scientifically strong organization, with a high probability to find very good to excellent groups. Therefore, it is important to split up large institutes into smaller groups. Only this allows a more precise assessment of research performance. Otherwise, excellent work will be 'hidden' within the bulk of a large institute or faculty.

Nevertheless, the CPP/JCSm remains an important alternative indicator of citation impact. It can be used if one wants to compare the citation impact with a reference value at a lower level of aggregation than CI (sub)fields. Then, the JCSm/FCSm indicator can be used to check if articles are published in low or high impact level journals within the CI subfield.

3.7 Analysis of non-CI publications

As we have received all scientific publications of Dutch mathematics researchers, the present study offers an analysis of the total scientific output of the field, representing not only the share of the output as could be retrieved from the Citation Indices (CI publications), but also the part of the scientific output that appeared in other media, such as non-covered journals, scientific books, book chapters, monographs, contributions to conference proceedings (non-CI publications)(see Section 2.2). Non-scientific publications were not included (e.g., those primarily directed at a non-scientific public). For the non-CI analysis, we searched for citations to non-CI publications in the source journals of the Citation Indices.

The non-CI analysis suffers from a number of shortcomings. The first issue is the search of citations to non-CI publications in CI journal publications. It should be taken into consideration that the CI might be less sensitive to the citation impact of non-CI publications than non-CI sources would be. However, in practice the reference lists of CI journals contain many references to non-CI material. Nevertheless, if CI journals do not adequately represent an important subfield of research, the citation impact of non-CI publications pertaining to that subfield might be seriously underestimated. Also, in some fields (e.g., in sociology), non-CI books and, mostly CI, journals address, to some extent, different publics, which might lead to differences in citation patterns, and thus to under-representation of citation impact of non-CI publications. In that sense, one can perhaps see the retrieved number of citations to non-CI publications in CI journals as the so-called ‘tip of the iceberg’.

From other studies, several characteristics of the citation impact of non-CI publications are known (e.g., Nederhof, 2006; Visser et al., 2003). In general, publications in languages other than English tend to be cited less frequently. However, various types of non-CI publications are likely to have a different average impact, even if they employ the English language. In general, books and monographs published by international publishers tend to be cited considerably more often on average, especially on the long run, than CI journal publications, which in turn are usually cited (considerably) more often than publications in non-CI serials, contributions to edited volumes, contributions to conference proceedings, reports, and other unpublished material.

A perhaps more serious problem is that worldwide reference values similar to JCSm and FCSm are not easily computed for non-CI publications (cf. Visser et al. (2003) for a partial approach). As explained above, the journal literature as covered in the Citation Indices is classified through the Journal Subject Categories found in the Citation Indices. Since we are lacking this information for the non-covered output, we cannot calculate FCSm values for the non-CI sources.
The only reference that can be used here is the impact received by the publications that appeared in journals processed for the Citation Indices, as the closest approximation of a similar set of publications. It will be clear that the value of such a comparison is limited, but nevertheless it might be helpful in exploring the limitations attached to CI analysis (see below).

An important difference with the standard CI analysis is that self-citations to non-CI publications can only be determined for the first author of the non-CI publication (the full names of co-authors are not always available). It is not possible to determine easily whether or not co-authors cite a non-CI publication, as the reference strings in citations contain only the name of the first author.

Nevertheless, similar to the CI analyses (see Section 3.2), we can compute the number of non-CI publications (**P**), and the number of citations to these publications without (**C**) and with first-author self-citations (**C+sc**). Also, we can compute the number of citations per publications (**CPP**), excluding first-author self-citations, and the percentage of first-author self-citations (**%sc**). As self-citations of co-authors are not counted in non-CI analyses, %sc will tend to be considerably lower than the comparable figure in CI analyses. As a result, C and CPP will be overestimated compared to CI analyses that exclude all self-citations.

Combined CI and non-CI analyses

For research units, we can compare the shares of CI and non-CI publications. In addition, we can compare CPP scores of CI publications and non-CI publications. This might provide insight in publication preferences of units, and might also be helpful in determining limitations and/or showing the strength of the more sophisticated CI analyses (cf. Visser et al., 2003).

3.8 Overview of bibliometric indicators for CI articles

P Number of articles (normal articles, letters, notes and reviews (not book reviews)) published in journals processed for the CD-ROM version of the ISI Citation Indices (CI).

C Number of citations recorded in CI journals to all articles involved. Self-citations are excluded.

C+sc Number of citations recorded in CI journals to all articles involved. Self-citations are included.

CPP Average number of citations per publication, or citation per publication ratio. Self-citations are excluded.

Pnc Percentage of articles not cited during the time period considered.

JCSm Average citation rate of all articles published in the journals in which an institute/group has published (excluding self-citations) (not printed in the data-tables).

FCSm Average citation rate of all articles in the fields in which the institute/group is active. Also indicated as the world citation average in those fields. Fields are defined by means of ISI journal subject categories (excluding self-citations) (not printed in the data-tables).

CPP/FCSm Impact of an institute/group's articles, compared to the world citation average in the (sub)fields in which the institute/group is active. A '+' ('-') symbol behind the numerical value indicates that the field-normalized impact of the institute/groups' articles is significantly above (below) world average.

CPP/JCSm Impact of an institute/group's articles, compared to the average citation rate of the articles in the institute/group's journals. A '+' ('-') symbol behind the numerical value indicates that the journal-normalized impact of the institute/group's articles is significantly above (below) the average citation rate of the journals concerned.

JCSm/FCSm Impact of the journals in which an institute/group has published, compared to the world citation average in the fields covered by these journals.

% self-citations Percentage of self-citations. A self-citation is defined as a citation in which the citing and the cited paper have at least one author in common (first author or co-author).

4. Results of the CI analyses

4.1 General bibliometric results on Dutch mathematics research

In **Table 1**, the bibliometric analysis of the output and impact of the combined Dutch mathematics research is presented. The first line of each Table presents the overall results for the bibliometric indicators for the period 1993 - 2002. This means that for publications from each of the publication years (1993 - 2002), citations are counted up to and including 2003. For example, a seven-year citation window is used for papers published in 1996, and a three-year citation window for papers published in 2000.

Next to an overall analysis of the 1993 - 2002 impact data, we also conducted a trend analysis of the main indicators calculated for 'overlapping' five-year periods at each level of aggregation. A similar method has been applied to the five-year periods between 1993 - 1997 and 1998 – 2002 (six blocks in total). To facilitate comparison between periods, citations were counted for the same number of years. If we take the 1994 - 1998 five-year period as an example, this means that, for publications from 1994 citations are counted during 1994 - 1998 (but *not* during 1999 - 2002), for publications from 1995 citations are counted in 1995 - 1998, for 1996 publications citations from 1996 – 1998, for 1997 publications citations from 1997 – 1998, and for 1998 publications, only citations from 1998 are taken into account.

The total CI output over the period 1993 - 2002 is 3,116 papers (***P***), which get cited 10,677 times in total (***C+sc***), of which 7,416 times externally (***C***). The mean impact (***CPP***) is 2.4 citations per published paper. This mean impact is significantly higher than both the journal average impact score (***CPP/JCSm*** = 1.13), and the average field impact score (***CPP/FCSm*** = 1.17). About 49% of the papers are not cited externally during 1993 – 2002 (***Pnc***). The Dutch mathematicians publish in journals with a citation impact level that is 4% higher than the world average (***JCSm/FCSm*** = 1.04). Finally, the final column of Table 1 shows that the percentage of ***self-citations*** (31%) is not disproportionally high.

The trend analysis uses moving five-year publication blocks. It shows an increasing number of publications, while the impact increases as well, up until the last period, where we find a decrease in the number of received citations. This causes the mean impact to drop, and consequently, also the normalized impact scores ***CPP/JCSm*** and ***CPP/FCSm***. These decrease to a level that does not significantly differ from the world average. The Dutch mathematicians continue to publish in journals with an

Table 1: Bibliometric statistics of Dutch mathematics research, 1993 - 2002

Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	% Self-Citations
1993 - 2002	**3,116**	**7,416**	**10,677**	**2.38**	**49%**	**1.13**	**+**	**1.17**	**+**	**1.04**	**31%**
1993 - 1997	1,370	1,101	1,827	0.80	70%	1.16	+	1.12		1.00	40%
1994 - 1998	1,458	1,324	2,154	0.91	68%	1.18	+	1.17	+	1.02	39%
1995 - 1999	1,546	1,640	2,561	1.06	66%	1.24	+	1.28	+	1.05	36%
1996 - 2000	1,610	1,906	2,934	1.18	66%	1.26	+	1.31	+	1.06	35%
1997 - 2001	1,675	2,052	3,209	1.23	64%	1.32	+	1.39	+	1.06	36%
1998 - 2002	1,746	1,658	2,861	0.95	65%	1.02		1.04		1.05	42%

impact level that is competitive with the world average. In this type of trend analysis, the absolute number of publications and citations is evidently lower than in a longer term timeframe. The number of publications and citations observed in this type of analysis does not correspond to the numbers found in the overall, ten-year period of analysis. ***Pnc*** is lower than in the ten-year analysis, as over an extended period more articles get cited eventually. Self-citations tend to occur more often in the first few years after publication (cf. Sections 3.6 and 6). These phenomena relate to a more 'mature' nature of the research in the ten-year period.

4.2 General bibliometric results on the level of Dutch universities

Table 2 contains the results for the universities and the CWI-institute. The Erasmus University Rotterdam (EUR) mathematicians published 99 papers in the period 1993 - 2002 in CI journals, which get cited 270 times, or 167 times, excluding self-citations, on average 1.7 times. The impact of EUR is at world average level when compared with the journal average (***CPP/JCSm*** = 0.99), and also not significantly different from the world field average level (***CPP/FCSm*** = 0.83). The output is published in average impact journals.

The trend analysis indicates a stable output, in combination with stable impact scores. Except for the period 1994-1998, where we observe a high impact (***CPP/FCSm*** = 1.23), we find relatively low impact scores for the later year-blocks in the analysis, in particular for 1995 – 1999 and 1996 – 2000, where impact is significantly below the world field average. However, impact improves somewhat in the two most recent five-year periods. The percentage of self-citations tends to be rather high (41% - 60%).

The output of the Nijmegen University (KUN) mathematicians in CI journals contains 143 publications. These get cited 463 and 335 times, with and without self-citations respectively. Papers are cited on average 2.3 times. For KUN, both the journal and field normalized impact scores are competitive with the world average level (with ***CPP/JCSm*** = 1.01 and ***CPP/FCSm*** = 1.10).

The trend analysis shows a decreasing output after 1995 - 1999. This is combined with variable levels of impact. The normalized impact scores improve from average to high following the significantly below average normalised scores in the initial five-year period, except for the period 1998 - 2002. Finally, the output is published in journals with an impact at or above the world average level.

The output of the Leiden University (LEI) mathematicians includes 219 ISI covered journal publications. These papers get cited 468 times externally, leading to an average of 2.1 citations per publication. The comparison with the journal-normalised impact score indicates a position at world average level (***CPP/JCSm*** = 1.01). However, LEI papers are published in high impact journals, as can be concluded from the ***JCSm/FCSm*** value of 1.23. As a result, LEI impact is 24% above world field average level (***CPP/FCSm*** = 1.24).
The trend analysis indicates both a slightly increasing output and an increasing impact. Both the journal and the field normalized impact scores are increasing, and for the latter indicator the impact is significantly above average in the period 1997-2001. Finally, LEI output is published in high impact journals.

The Groningen University (RUG) output (***P*** = 111) gets cited 191 times or 309 times, respectively without and with self-citations. The average impact per publication is 1.7. The impact compared to the journal average is 1.03, while the impact compared to field impact is 1.12. The output is published in journals with an impact 9% above world average.
The trend analysis indicates a somewhat increasing output, while the impact shows a fluctuating pattern: lower average impact scores in 1993 - 1997, 1994 - 1998 and 1998 - 2002, while we observe higher impact scores in the other periods. The journal-normalised impact score indicates a decreasing impact of RUG mathematics research. However, RUG papers were published in journals with an increasing impact level, resulting in field- normalised impact scores that are above average (1994 – 1998 - 1997 – 2001), or competitive with the world average (in 1998 - 2002). The percentage of self-citations is high in the last two periods of the analysis (1997 - 2001 and 1998 - 2002).

Delft University of Technology (TUD) has the second largest output in CI journals, namely 492 papers. These get cited 1,567 times in total, and 1,022 times externally. This leads to an average impact score of 2.1 citations per publication. The TUD mathematics research has slightly, but not significantly, above world average level impact scores, when compared with both the journal package (***CPP/JCSm*** = 1.10) and field (***CPP/FCSm*** = 1.15).
The trend analysis shows an increasing output. The impact scores related to this output are decreasing, for both ***CPP/JCSm*** and ***CPP/FCSm***. TUD papers are published in journals with an impact that is competitive with the world average.

The output of the Eindhoven University of Technology (TUE) is the largest of the Netherlands, with 641 publications in CI journals between 1993 and 2002. These papers get cited 2,268 times in total, and 1,601 times externally. This leads to an average impact score of 1.1 citations per publication. The mean impact is 12% above the journal-normalised average and significantly above the fields average score of this output, as evident from the ***CPP/JCSm*** score of 1.12 and the ***CPP/FCSm*** score of 1.22. The percentage of papers not cited is 50%.
The trend analysis indicates an increasing output, combined with an increasing impact. The comparison of the mean impact with journal and field average scores shows a fluctuating situation: high and low scores are found in the trend analysis. The mean impact compared to the field impact shows slightly higher scores for TUE than the journal-normalised scores. The output of TUE is published in journals with a somewhat higher impact in the field, particularly in later years. On the one hand, the percentage of self-citations is increasing, whereas on the other hand the percentage of papers not cited is decreasing.

The University of Maastricht (UM) mathematicians have an output of 53 CI publications over the period 1993 - 2002. The mean impact of this output is 1.1. Compared to the journal and field average scores, this mean impact is significantly below average: ***CPP/JCSm*** is 0.55 while ***CPP/FCSm*** is 0.45.
The trend analysis indicates some increase in output, while the impact remains roughly on the same level. The normalized impact scores are frequently significantly below average, both for the journal and the field normalized scores. The percentages of papers not cited and of self-citations are relatively high. After 1995 – 1999, the papers tend to be published in journals with a below average impact level.

The output of the University Twente (UT), one of the three universities of technology in the Netherlands, amounts to 488 CI papers. These papers are cited 1,164 times, respectively 799 times, that is, including and excluding self-citations. The comparison of the mean impact score excluding self-citations is 0.86 for the ***CPP/JCSm*** and 0.81, a somewhat, but significantly below average impact score, for the ***CPP/FCSm***. The papers appeared in average impact journals.
The trend analysis shows an increasing output, while the impact (C) increases strongly. This results in higher mean impact scores over the periods in the analysis. However, the normalized impact scores show a slight improvement for the ***CPP/JCSm*** values, and only for the ***CPP/FCSm*** values we observe a strong increase. This is combined with publishing in journals with a slightly increasing impact that approaches the world average.

The University Utrecht (UU) published 233 CI papers in the period 1993 - 2002, which get cited 1.027 times in total, and 789 times externally. This results in a mean impact of 3.4 citations per publication that compares very well with the journal average, namely a significantly above average ***CPP/JCSm*** score of 1.72, and even better with the field average score, as evident from a significantly above average ***CPP/FCSm*** score of 1.92. Finally, the output is published in above average impact level journals.
The trend analysis shows an increasing number of papers over the period 1993 - 2002. This growing output receives more impact, especially in the period 1996 - 2000, which is underlined by the significantly above average normalised impact scores in that period. In general, the normalized impact scores are high, in some cases even twice as high as world average level.

The University of Amsterdam (UvA) published 283 CI papers, which get cited 1,717 times in total, and 1,308 times externally. This results in an average impact of 4.6. The comparison with both the journal and the field averages indicates high and significantly above average impact scores. The output is published in average impact journals.
The trend analysis shows a more or less stable output, in combination with increasing impact scores. However, the impact diminishes sharply in the last period of the trend analysis. This results in a sharp drop in both the journal and the field normalized impact scores from significantly above average to a level that is competitive with the world average.

The University of Tilburg (UvT) published 219 CI papers during 1993 - 2002. These papers were cited 627 respectively 405 times, resulting in an average impact score of 1.85 citations per publication (excluding self-citations). The comparison with the journal and field average values shows scores for UvT at a level competitive with the world average.
The trend analysis shows an increasing output, in combination with a more or less stable impact per paper. The normalized impact scores fluctuate near world average level, without ever being equal to one (world average level). There is some decrease in the impact level of the journals in which the papers were published.

The Free University of Amsterdam (VU) published 333 CI papers, which get cited 1,031 times in total, and 680 times externally. The mean impact of 2.0 compares well with the journal average (***CPP/JCSm*** = 1.14) and field average level (***CPP/FCSm*** =

1.07), although not at a statistically significant level. The papers are published in average impact level journals.

The trend analysis shows an increasing output, combined with an increasing impact. We observe a decrease in the number of papers not cited. For the normalized impact scores, we find that both ***CPP/JCSm*** and ***CPP/FCSm*** show a strongly increasing trend, finishing in an impact that is significantly above the world field average in 1998 – 2002. This development is paralleled by an increase in the impact level of the journals in which the papers were published.

Finally, the Amsterdam based NWO-institute CWI (the Centre for Mathematics and Informatics research) is indicated as a separate institute/university in this study. It has to be taken into consideration that only the CWI mathematics departments are included in this study. This centre published 449 CI papers in the period 1993 - 2002. These 449 papers are cited 1,370 times externally, leading to an average impact of 3.05 citations per publication. Compared with the journal average, we find a score that is competitive with world average level (***CPP/JCSm*** = 1.05), while the comparison with the fields shows a high impact score, significantly above average (***CPP/FCSm*** = 1.31). The papers appeared in high impact journals, as can be concluded from the score of 1.24 for ***JCSm/FCSm***.

The trend analysis shows a slightly increasing output, combined with an increasing impact. We find fluctuating scores for ***CPP/JCSm***, but generally increasing scores for ***CPP/FCSm***. The researchers of CWI published in high impact journals throughout the period 1993 - 2002.

Table 2: Bibliometric statistics of the Dutch universities and institutes, 1993 - 2002

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
EUR									
1993 - 2002	**99**	**167**	**270**	**1.69**	**51%**	**0.99**	**0.83**	**0.83**	**38%**
1993 - 1997	50	30	54	0.60	74%	1.18	0.95	0.81	44%
1994 - 1998	53	39	66	0.74	72%	1.28	1.23	0.96	41%
1995 - 1999	53	19	48	0.36	81%	0.75	0.56 -	0.75	60%
1996 - 2000	57	25	61	0.44	75%	0.66	0.54 -	0.82	59%
1997 - 2001	50	31	64	0.62	74%	0.88	0.74	0.84	52%
1998 - 2002	49	30	59	0.61	69%	0.77	0.71	0.92	49%
KUN									
1993 - 2002	**143**	**335**	**463**	**2.34**	**45%**	**1.01**	**1.10**	**1.09**	**28%**
1993 - 1997	77	24	53	0.31	79%	0.61 -	0.59 -	0.97	55%
1994 - 1998	88	62	115	0.70	69%	0.95	1.07	1.13	46%
1995 - 1999	90	96	156	1.07	64%	1.02	1.20	1.17	38%
1996 - 2000	81	97	146	1.20	69%	1.04	1.21	1.16	34%
1997 - 2001	76	117	165	1.54	66%	1.41	1.52	1.08	29%
1998 - 2002	66	53	82	0.80	59%	0.83	0.86	1.04	35%

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self- Citations
LEI									
1993 - 2002	**219**	**468**	**687**	**2.14**	**47%**	**1.01**	**1.24**	**1.23**	**32%**
1993 - 1997	102	66	125	0.65	72%	0.86	0.88	1.03	47%
1994 - 1998	100	60	117	0.60	66%	0.70 -	0.96	1.38	49%
1995 - 1999	98	76	128	0.78	63%	0.84	1.17	1.39	41%
1996 - 2000	104	109	174	1.05	58%	1.04	1.50	1.45	37%
1997 - 2001	106	126	192	1.19	59%	1.20	1.80 +	1.50	34%
1998 - 2002	117	114	190	0.97	66%	1.22	1.56	1.28	40%
RUG									
1993 - 2002	**111**	**191**	**309**	**1.72**	**46%**	**1.03**	**1.12**	**1.09**	**38%**
1993 - 1997	49	27	39	0.55	69%	1.14	1.08	0.95	31%
1994 - 1998	51	35	56	0.69	69%	1.27	1.48	1.17	38%
1995 - 1999	53	51	78	0.96	62%	1.31	1.46	1.12	35%
1996 - 2000	58	53	92	0.91	57%	1.14	1.22	1.07	42%
1997 - 2001	58	53	100	0.91	62%	1.35	1.45	1.07	47%
1998 - 2002	62	42	106	0.68	66%	0.90	1.01	1.12	60%

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
TUD									
1993 - 2002	**492**	**1,022**	**1,567**	**2.08**	**51%**	**1.10**	**1.15**	**1.05**	**35%**
1993 - 1997	211	206	318	0.98	63%	1.48 +	1.49 +	1.01	35%
1994 - 1998	227	189	324	0.83	66%	1.16	1.22	1.05	42%
1995 - 1999	234	184	339	0.79	66%	1.04	1.07	1.02	46%
1996 - 2000	243	201	363	0.83	67%	1.00	1.06	1.07	45%
1997 - 2001	259	240	401	0.93	63%	1.15	1.17	1.02	40%
1998 - 2002	281	179	361	0.64	69%	0.86	0.83	0.97	50%
TUE									
1993 - 2002	**641**	**1,601**	**2,268**	**2.50**	**50%**	**1.12**	**1.22 +**	**1.09**	**29%**
1993 - 1997	275	248	367	0.90	73%	1.23	1.26	1.02	32%
1994 - 1998	297	233	377	0.78	70%	1.03	1.04	1.00	38%
1995 - 1999	322	298	467	0.93	68%	1.11	1.22	1.10	36%
1996 - 2000	342	345	553	1.01	69%	1.06	1.22	1.15	38%
1997 - 2001	361	400	668	1.11	66%	1.11	1.23	1.11	40%
1998 - 2002	366	406	700	1.11	62%	0.92	1.05	1.14	42%

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
UM									
1993 - 2002	**53**	**58**	**101**	**1.09**	**60%**	**0.55 -**	**0.45 -**	**0.81**	**43%**
1993 - 1997	21	8	20	0.38	71%	0.46 -	0.39 -	0.86	60%
1994 - 1998	23	6	23	0.26	83%	0.28 -	0.29 -	1.06	74%
1995 - 1999	24	6	22	0.25	83%	0.27 -	0.27 -	1.03	73%
1996 - 2000	28	15	31	0.54	75%	0.68	0.47 -	0.70	52%
1997 - 2001	27	8	21	0.30	81%	0.44 -	0.29 -	0.66	62%
1998 - 2002	32	11	19	0.34	84%	0.58	0.35 -	0.61	42%
UT									
1993 - 2002	**488**	**799**	**1,164**	**1.64**	**57%**	**0.86**	**0.81 -**	**0.94**	**31%**
1993 - 1997	207	101	175	0.49	74%	0.80	0.68 -	0.85	42%
1994 - 1998	218	141	229	0.65	71%	0.90	0.79	0.88	38%
1995 - 1999	236	145	241	0.61	69%	0.80	0.71 -	0.89	40%
1996 - 2000	235	172	285	0.73	73%	0.85	0.79	0.93	40%
1997 - 2001	260	169	302	0.65	75%	0.84	0.78	0.93	44%
1998 - 2002	281	226	382	0.80	73%	0.95	0.92	0.96	41%

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	% Self- Citations
UU											
1993 - 2002	**233**	**789**	**1,027**	**3.39**	**46%**	**1.72**	**+**	**1.92**	**+**	**1.11**	**23%**
1993 - 1997	90	88	125	0.98	62%	1.52		1.68	+	1.10	30%
1994 - 1998	101	133	188	1.32	59%	1.83	+	1.95	+	1.06	29%
1995 - 1999	117	208	287	1.78	57%	2.11	+	2.47	+	1.17	28%
1996 - 2000	131	269	366	2.05	56%	2.06	+	2.41	+	1.17	27%
1997 - 2001	134	171	270	1.28	60%	1.33		1.50		1.13	37%
1998 - 2002	143	212	319	1.48	59%	1.54	+	1.62	+	1.05	34%
UvA											
1993 - 2002	**283**	**1,308**	**1,717**	**4.62**	**39%**	**1.72**	**+**	**1.65**	**+**	**0.96**	**24%**
1993 - 1997	145	235	383	1.62	60%	1.88	+	1.81	+	0.96	39%
1994 - 1998	137	336	465	2.45	59%	2.58	+	2.17	+	0.84	28%
1995 - 1999	141	451	597	3.20	49%	2.68	+	2.42	+	0.90	24%
1996 - 2000	139	482	608	3.47	51%	2.59	+	2.32	+	0.89	21%
1997 - 2001	148	560	691	3.78	51%	2.59	+	2.61	+	1.01	19%
1998 - 2002	138	181	254	1.31	57%	1.12		1.01		0.90	29%

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	% Self-Citations
UvT											
1993 - 2002	**219**	**405**	**627**	**1.85**	**56%**	**0.84**		**0.93**		**1.11**	**35%**
1993 - 1997	81	53	101	0.65	68%	0.71		0.87		1.22	48%
1994 - 1998	86	41	92	0.48	77%	0.65	-	0.66		1.01	55%
1995 - 1999	106	67	137	0.63	73%	0.79		0.84		1.07	51%
1996 - 2000	114	99	161	0.87	65%	0.97		0.96		0.99	39%
1997 - 2001	121	98	164	0.81	69%	0.90		0.89		0.99	40%
1998 - 2002	138	100	187	0.72	73%	0.85		0.83		0.97	47%
VU											
1993 - 2002	**333**	**680**	**1,031**	**2.04**	**46%**	**1.14**		**1.07**		**0.94**	**34%**
1993 - 1997	136	85	154	0.63	71%	0.93		0.77		0.82	45%
1994 - 1998	150	89	162	0.59	71%	0.91		0.71	-	0.77	45%
1995 - 1999	158	79	141	0.50	75%	0.79		0.71	-	0.90	44%
1996 - 2000	177	135	226	0.76	70%	1.10		1.00		0.91	40%
1997 - 2001	191	177	315	0.93	60%	1.27		1.33		1.04	44%
1998 - 2002	197	221	386	1.12	59%	1.25		1.39	+	1.11	43%

University Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm		JCSm/ FCSm	% Self- Citations
CWI										
1993 - 2002	**449**	**1,370**	**2,006**	**3.05**	**41%**	**1.05**	**1.31**	**+**	**1.24**	**32%**
1993 - 1997	209	174	342	0.83	66%	0.93	1.02		1.09	49%
1994 - 1998	220	268	440	1.22	59%	1.20	1.33		1.11	39%
1995 - 1999	219	320	485	1.46	56%	1.17	1.44	+	1.23	35%
1996 - 2000	223	312	481	1.40	58%	1.06	1.30		1.22	34%
1997 - 2001	229	344	544	1.50	60%	1.12	1.58	+	1.41	37%
1998 - 2002	240	323	538	1.35	58%	0.96	1.30		1.36	40%

4.3 General results on Dutch mathematics research schools

Next, we discuss the results for the research schools. The research school EIDMA published 564 CI papers, which get cited 1,531 times in total. 1,094 Citations were received from external papers. This school has a mean impact of 1.94 citations per publication, which results in 10% - 13% above average impact scores (not statistically significant) when compared with, respectively, the journal and field average impact scores.

The trend analysis shows a slowly increasing output, which receives roughly the same amount of citations. This causes the normalized impact scores to decline somewhat, from a high impact position to a level competitive with the world average. The percentage of papers not cited externally within a five-year citations window is high: roughly 70%. EIDMA publishes in journals with a slightly increasing impact.

The research school MRI published 618 CI papers that get cited 2,064 times in total, and 1,474 times externally. The mean impact is 2.4 citations per publication, which compares well with the journal-normalized impact score and is significantly above the field-normalised impact score. The percentage of self-citations is relatively low (29%).

The trend analysis shows that the number of CI publications is increasing slowly, with faster increasing numbers of citations. This results in higher mean impact scores per publication. The normalized impact scores increase during the period 1993 - 2002, to a level that is significantly above average in 1996 - 2000. In the last period of the trend analysis, the normalized impact scores decrease to a level that is competitive with the world average.

The research school Stieltjes is the largest in terms of the CI journal publications. The 1,573 CI papers get cited 5,469 times in total, and 3,703 times externally. This results in a mean impact score of 2.35, which compares well, at a statistically significant level, with both the journal and the field impact scores.

The trend analysis of the school indicates an increasing output, combined with increasing impact scores, both as regards the mean impact per publication of the school, and the normalized impact scores ***CPP/JCSm*** and ***CPP/FCSm***. However, we also observe, as in the case of the research school MRI, a decrease in impact in the last period of the trend analysis: the mean impact drops 0.4 citations per paper, resulting in decreases in ***CPP/JCSm*** from 1.42 to 0.99 and in the ***CPP/FCSm*** from 1.58 to 1.09, still levels competitive with the world average.

The research school Beta published 58 CI papers in the period 1993 - 2002, which received 108 citations, of which 71 were external ones. The mean impact score is 1.2, compared with the normalized journal and field scores this is below average, although not at a statistically significant level.
The trend analysis shows an increasing output, with fluctuating impact scores. In the period of high mean impact (1995 – 1999 and 1996 – 2000), the comparison with the journal package results in high ***CPP/JCSm*** values, and high field impact scores. In the two most recent five-year periods, impact is significantly below the field-normalised impact score. The output was published in journals with below average impact.

The four other research schools cover mathematics and one or more other disciplines: *here only the results for Dutch mathematical researchers have been included.*

The research school Burgerscentrum published 151 CI papers in the period 1993 - 2002. These publications received 569 citations, 377 were external citations. The comparison of the resulting mean impact of 2.5 citations per publication shows impact scores that compete with the world average.
The trend analysis shows a slightly increasing output, combined with decreasing impact scores. The comparison with journal and field mean impact scores indicates a decreasing impact of this school. Furthermore, the percentage of papers not cited is increasing, as is the percentage of self-citations.

The research school CentER published 105 CI papers, which get cited 382 and 245 times, respectively including and excluding self-citations. The resulting mean impact of 2.3 compares very well with both the journal mean impact (***CPP/JCSm*** = 1.15) and the field mean impact (***CPP/FCSm*** = 1.36), although not at a statistically significant level. The output is published in journals with an impact that is 18% above world average level.
The trend analysis shows an increasing output, with an increasing number of citations. The mean impact increases, and we observe for both ***CPP/JCSm*** and ***CPP/FCSm*** scores (well) above world average level, although not at a statistically significant level.

Finally, the research school DISC published 360 CI papers, which received 1,433 citations in total, of which 1015 are received externally. The mean impact (***CPP*** = 2.82) of DISC is high when compared with the journal average score (***CPP/JCSm*** = 1.21) and even higher when compared with the field mean score (***CPP/FCSm*** = 1.29). The papers appeared in journals of world average level.

The trend analysis shows an output that increases in particular in the last two periods of the analysis (1997 - 2001 and 1998 - 2002). The impact is increasing in the last three periods of the analysis, indicating especially high impact papers in the period 1997 - 2001.

Table 3a: Bibliometric statistics of the Dutch mathematics research schools, 1993 - 2002

Research School Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
EIDMA									
1993 - 2002	**564**	**1,094**	**1,531**	**1.94**	**54%**	**1.10**	**1.13**	**1.03**	**29%**
1993 - 1997	259	196	311	0.76	72%	1.29	1.29	1.00	37%
1994 - 1998	276	178	307	0.64	72%	1.10	1.03	0.98	42%
1995 - 1999	297	210	346	0.71	70%	1.11	1.09	0.99	39%
1996 - 2000	292	224	355	0.77	71%	1.03	1.10	1.06	37%
1997 - 2001	298	223	372	0.75	72%	0.97	1.04	1.04	40%
1998 - 2002	305	259	413	0.85	67%	0.97	1.12	1.10	37%
MRI									
1993 - 2002	**618**	**1,474**	**2,064**	**2.39**	**50%**	**1.17**	**1.19 +**	**1.02**	**29%**
1993 - 1997	275	161	274	0.59	71%	0.99	0.98	0.99	41%
1994 - 1998	310	266	431	0.86	67%	1.18	1.22	1.04	38%
1995 - 1999	333	383	585	1.15	65%	1.28	1.37 +	1.07	35%
1996 - 2000	335	449	662	1.34	64%	1.32 +	1.39 +	1.06	32%
1997 - 2001	341	371	600	1.09	65%	1.21	1.15	0.99	38%
1998 - 2002	343	343	569	1.00	64%	1.09	0.99	0.97	40%

Research School Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
Stieltjes									
1993 - 2002	**1,573**	**3,703**	**5,469**	**2.35**	**49%**	**1.12 +**	**1.16 +**	**1.04**	**32%**
1993 - 1997	679	572	998	0.84	70%	1.13	1.09	0.96	43%
1994 - 1998	718	693	1,145	0.97	69%	1.25 +	1.20	1.00	39%
1995 - 1999	751	837	1,316	1.11	67%	1.30 +	1.35 +	1.05	36%
1996 - 2000	815	1,052	1,578	1.29	65%	1.34 +	1.41 +	1.07	33%
1997 - 2001	851	1,193	1,801	1.40	62%	1.42 +	1.58 +	1.11	34%
1998 - 2002	894	854	1,489	0.96	64%	0.99	1.09	1.10	43%

Table 3b: Bibliometric statistics of the Dutch mathematics related research schools, 1993 - 2002

Research School Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
Beta									
1993 - 2002	**58**	**71**	**108**	**1.22**	**64%**	**0.80**	**0.65**	**0.81**	**34%**
1993 - 1997	19	8	13	0.42	74%	0.61	0.53	0.87	38%
1994 - 1998	19	21	14	0.74	68%	1.24	1.09	0.85	33%
1995 - 1999	20	31	22	1.10	80%	1.76	1.20	0.72	29%
1996 - 2000	31	44	33	1.06	81%	1.63	1.24	0.78	25%
1997 - 2001	35	18	8	0.23	83%	0.47 -	0.33 -	0.73	56%
1998 - 2002	39	27	12	0.31	85%	0.58	0.42 -	0.78	56%
Burgerscentrum									
1993 - 2002	**151**	**377**	**569**	**2.50**	**51%**	**0.97**	**0.96**	**0.99**	**34%**
1993 - 1997	67	69	99	1.03	66%	1.11	1.07	0.97	30%
1994 - 1998	69	121	80	1.16	64%	1.06	1.07	1.03	34%
1995 - 1999	74	149	86	1.16	54%	0.90	0.87	0.99	42%
1996 - 2000	71	123	76	1.07	68%	0.85	0.81	0.99	38%
1997 - 2001	79	137	78	0.99	67%	1.16	0.97	0.91	43%
1998 - 2002	84	130	60	0.71	71%	0.86	0.64 -	0.86	54%

Research School Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self-Citations
CentER									
1993 - 2002	**105**	**245**	**382**	**2.33**	**52%**	**1.15**	**1.36**	**1.18**	**36%**
1993 - 1997	36	28	54	0.78	58%	1.09	1.19	1.09	48%
1994 - 1998	38	31	59	0.82	66%	1.21	1.31	1.10	47%
1995 - 1999	52	50	99	0.96	63%	1.19	1.45	1.21	49%
1996 - 2000	54	67	109	1.24	59%	1.35	1.70	1.24	39%
1997 - 2001	66	72	120	1.09	62%	1.16	1.35	1.17	40%
1998 - 2002	69	74	134	1.07	67%	1.18	1.29	1.10	45%
DISC									
1993 - 2002	**360**	**1,015**	**1,433**	**2.82**	**48%**	**1.21**	**1.29 +**	**1.07**	**29%**
1993 - 1997	166	164	241	0.99	64%	1.30	1.30	1.00	32%
1994 - 1998	163	144	218	0.88	62%	1.01	1.02	1.05	34%
1995 - 1999	167	157	244	0.94	63%	1.10	1.09	1.05	36%
1996 - 2000	171	188	325	1.10	68%	1.23	1.27	1.10	42%
1997 - 2001	188	276	447	1.47	64%	1.80 +	1.64 +	1.01	38%
1998 - 2002	194	198	367	1.02	64%	1.31	1.08	0.95	46%

4.4 General results on training location of Dutch mathematics researchers

Table 4 contains the results of the analysis concerning of the location of formal education and training of the mathematics researchers in the Netherlands included in this study, in particular its effect on research performance. While viewing and interpreting these data, it has to be taken into account that, while we can classify the researchers from the Netherlands into different groups, due to co-authors, many papers cannot be classified definitely and exclusively to one specific class or category.

Table 4 starts with the output of those researchers that received their formal training in the Netherlands. Not surprisingly, this is the largest set of papers. The 2,518 CI papers get cited 8,895 times of which 6,200 are external citations. The mean impact is 2.5 citations per publication, which compares well with both the journal and field average impact scores: ***CPP/JCSm*** = 1.19 and ***CPP/FCSm*** = 1.21, both significantly above average.

The trend analysis shows an increase in output, and again, as in the previous section for the two large research schools MRI and Stieltjes, a decrease in impact in the period 1998 - 2002. This causes the mean impact per publication to decline from 1.3 to 0.9 citations per paper, while the ***CPP/JCSm*** and ***CPP/FCSm*** scores show related decreases: the journal-normalised impact score from 1.38 to 1.03 and the field-normalised impact score from 1.43 to 1.04, levels that are competitive with the world average.

The next largest set is the set of publications is related to scientists that received their training in Western Europe, namely 382 CI publications. These papers are cited 1,293 times, and 897 times externally. The mean impact is 2.35 citations per publication. Compared with the journal and field impact we find world average level impact scores for this group of researchers. However, the trend analysis indicates that the impact of the papers of researchers trained in Western Europe is increasing over time, especially the ***CPP/FCSm*** values, while the output is published in relatively high impact journals.

The other sets of publications, from researchers that received their training both in the Netherlands ***and*** elsewhere, or entirely outside Western Europe, are either small (trained in the Netherlands and in Western Europe) or have an impact significantly below the world field average (training exclusively / also outside Western Europe).

Table 4: Bibliometric statistics on the formal location of training of Dutch mathematics researchers, 1993 - 2002

Formal location of training Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	% Self-Citations
In the Netherlands											
1993 - 2002	**2,518**	**6,200**	**8,895**	**2.46**	**49%**	**1.19**	**+**	**1.21**	**+**	**1.01**	**30%**
1993 - 1997	1,119	955	1,564	0.85	69%	1.24	+	1.18	+	0.95	39%
1994 - 1998	1,192	1,119	1,808	0.94	68%	1.24	+	1.20	+	0.96	38%
1995 - 1999	1,252	1,399	2,149	1.12	66%	1.32	+	1.32	+	1.00	35%
1996 - 2000	1,305	1,643	2,474	1.26	65%	1.36	+	1.37	+	1.01	34%
1997 - 2001	1,342	1,693	2,623	1.26	64%	1.38	+	1.43	+	1.04	35%
1998 - 2002	1,399	1,290	2,272	0.92	65%	1.03		1.04		1.01	43%
In the Netherlands/in Western Europe											
1993 - 2002	**54**	**103**	**160**	**1.91**	**61%**	**0.96**		**1.14**		**1.18**	**36%**
1993 - 1997	23	20	27	0.87	74%	1.14		1.70		1.50	26%
1994 - 1998	28	26	42	0.93	68%	1.62		1.71		1.06	38%
1995 - 1999	30	24	46	0.80	73%	1.16		1.10		0.95	48%
1996 - 2000	29	8	27	0.28	86%	0.41	-	0.34	-	0.83	70%
1997 - 2001	30	13	30	0.43	80%	0.62		0.57		0.91	57%
1998 - 2002	31	10	26	0.32	81%	0.46	-	0.43	-	0.94	62%

Formal location of training Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self- Citations
In the Netherlands/outside Western Europe									
1993 - 2002	**108**	**144**	**274**	**1.33**	**52%**	**0.79**	**0.76 -**	**0.97**	**47%**
1993 - 1997	43	21	37	0.49	70%	0.65	0.70	1.08	43%
1994 - 1998	46	23	46	0.50	70%	0.61 -	0.74	1.21	50%
1995 - 1999	44	23	56	0.52	61%	0.78	0.73	0.93	59%
1996 - 2000	51	26	58	0.51	63%	0.96	0.79	0.82	55%
1997 - 2001	61	42	98	0.69	64%	1.32	1.04	0.78	57%
1998 - 2002	65	57	124	0.88	62%	1.10	0.88	0.80	54%
In Western Europe									
1993 - 2002	**382**	**897**	**1,293**	**2.35**	**49%**	**0.95**	**1.14**	**1.20**	**31%**
1993 - 1997	160	93	189	0.58	73%	0.85	0.85	1.00	51%
1994 - 1998	172	150	269	0.87	67%	0.94	1.09	1.16	44%
1995 - 1999	193	189	320	0.98	63%	0.89	1.23	1.38	41%
1996 - 2000	195	192	325	0.98	67%	0.84	1.11	1.32	41%
1997 - 2001	213	270	412	1.27	65%	1.06	1.29	1.21	34%
1998 - 2002	222	271	412	1.22	63%	0.94	1.15	1.22	34%

Formal location of training Period	P	C	C+sc	CPP	Pnc	CPP/ JCSm	CPP/ FCSm	JCSm/ FCSm	% Self- Citations

Outside Western Europe

1993 - 2002	**125**	**172**	**266**	**1.38**	**50%**	**0.74 -**	**0.76 -**	**1.04**	**35%**
1993 - 1997	53	25	37	0.47	64%	0.71	0.73	1.03	32%
1994 - 1998	50	23	34	0.46	72%	0.87	0.77	0.89	32%
1995 - 1999	58	29	47	0.50	79%	0.83	0.86	1.04	38%
1996 - 2000	66	50	81	0.76	70%	0.93	1.01	1.09	38%
1997 - 2001	72	58	102	0.81	71%	0.98	1.01	1.03	43%
1998 - 2002	72	59	104	0.82	64%	0.99	0.92	0.93	43%

4.5 General results on academic ranks of Dutch mathematics researchers

Table 5 contains the results of the analysis concerning the effect of the academic ranks of researchers in the field of mathematics in the Netherlands on research performance. Authors and co-authors of CI articles were classified as professor; UHD/UD/scientific researcher; postdoc; 'retired professor'; 'retired', or 'other'. Again, as in the previous section, it has to be taken into account that, while we can classify the researchers from the Netherlands into different groups, due to co-authors, many papers cannot be classified definitely and exclusively as belonging to one specific class or category. Thus, the same paper may be listed under several headings, as co-authors belong to different categories.

The largest set of publications is related to the academic rank of professor. This set contains 1,702 CI publications, which get cited 6,938 times, of which 4,989 times external. The mean impact is 2.9 citations per paper, the comparison with the journal average impact score is 1.23 while the comparison with the field average impact is 1.31; both impact scores are significantly above average.

The second largest set of publications contains 1,473 CI papers and is related to the academic ranks UHD, UD, or scientific researcher. Some of these researchers may not have publishing careers that date back to the start year of this study, 1993, resulting in publications of a more recent date. The first two ranks are teaching ranks within the Dutch science system. The impact of this output is somewhat lower than the professor-rank related output: the normalized impact scores show impact scores competitive with the world average. Just as professors, they tend to publish in journals with an impact level that is competitive with the world average.

The remaining sets of publications pertain to co-authors of the 300 mathematics researchers and include post-docs, retired personnel, and a group 'other'; these are relatively small in terms of both the numbers of CI publications involved as well as the number of citations involved. However, the output of the category 'other' has a relatively high impact when compared with the field average impact, although not at a level that is statistically significant. The few postdoc publications are published in low impact journals, and are cited below the field-normalized average.

Table 5: Bibliometric statistics on the academic rank of Dutch mathematics researchers, 1993 - 2002

Academic Rank	P	C	C+sc	CPP	Pnc	CPP/ JCSm		CPP/ FCSm		JCSm/ FCSm	% Self- Citations
Professor	1,702	4,989	6,938	2.93	47%	1.23	+	1.31	+	1.06	28%
UHD, UD, Scientific researcher	1,473	2,740	4,203	1.86	53%	1.03		1.05		1.03	35%
Postdoc	8	20	29	2.50	13%	1.33		0.53	-	0.40	31%
Retired Professor	47	92	133	1.96	40%	1.17		1.17		1.00	31%
Retired	70	171	255	2.44	41%	1.13		1.04		0.92	33%
Other	84	150	243	1.79	49%	1.13		1.29		1.14	38%

4.6 Research profiles on mathematics research in Dutch universities

In Figures 1a - 1m, we present the research profiles of the universities where mathematics researchers are located in the Netherlands. Here, CI publications are labelled according to CI subject category attached to the journal in which they appear (see Sections 3.2 and 3.3).

Figure 1a contains the profile for the Rotterdam Erasmus University (EUR). Here, the CI subfield *Statistics & probability* is the largest field, accounting for more than 30% of the total EUR CI output. In this field, we find an average impact score (***CPP/FCSm*** = 0.93). The next two fields are *Mathematics, applied* and *Mathematics*, each covering roughly 27% of the EUR output. The impact is high for the latter field (***CPP/FCSm*** = 1.89), while the impact score for the former field is below average (***CPP/FCSM*** = 0.30).

In **Figure 1b**, we present the research profile for the Nijmegen University (KUN) mathematics researchers. Here, the largest CI subfield is *Mathematics*, followed by *Mathematics, applied*. Both cover about 30% of the output of KUN. The impact in the first field is low (***CPP/FCSm*** = 0.77), while the impact in the second field is high (***CPP/FCSm*** = 1.52). Combined, the next two fields cover about 20% of the output of the KUN mathematicians. In *Computer Science, theory*, we find a very high impact (***CPP/FCSm*** = 2.98), while in *Statistics & probability* the impact score is below average.

In **Figure 1c**, we find the research profile of the Leiden University (LEI) based mathematicians. In this profile, three fields account for about 80% of the total output. The largest field is *Mathematics*, followed by *Mathematics, applied*, and *Statistics & probability*. In all three fields, we find high ***CPP/FCSm*** impact scores, of respectively 1.35, 1.35, and 2.11. The remaining part of the profile contains much smaller fields, with varying impact scores.

The mathematics research based in the Groningen University (RUG) is profiled in **Figure 1d**. Here, we find one very large field, *Mathematics*, covering 50% of the output, with an average impact (***CPP/FCSm*** = 1.10). Combined, the next two fields cover 30% of the output, namely *Mathematics, applied* and *Automation & control systems*. In the former field, we observe a high impact (***CPP/FCSm*** = 1.47), while the latter field displays an average impact score (***CPP/FCSm*** = 0.90).

The profile of the Delft University of Technology (TUD) is presented in **Figure 1e**. Here, we find the strongest focus on *Mathematics* (28% of the output) and *Mathematics, applied* (26% of the output). The impact in *Mathematics* is high, with a ***CPP/FCSm*** of 1.29, while the impact in *Mathematics, applied* is of average level (***CPP/FCSm*** = 1.07). The remaining fields in the profile are related to computer sciences and technical sciences, with varying impact scores. A high impact score is found for *Electrical & electronics engineering* (***CPP/FCSm*** = 2.33).

The research profile for the Eindhoven University of Technology (TUE) is presented in **Figure 1f.** Here we find the same fields (*Mathematics* and *Mathematics, applied)* as in the previous profile on top, with average impact scores. The remaining part of the profile contains technical sciences as well as computer science fields, with a very high impact for *Electrical & electronics engineering* (***CPP/FCSm*** = 3.39), and a high impact for *Computer sciences, information systems* (***CPP/FCSm*** = 2.08).

Figure 1g contains the research profile for the University Maastricht (UM) mathematicians. In this profile, we find five fields, all with relatively low impact scores of which *Operations research & management* is the largest, with over 25% of the output.

The research profile of the University Twente (UT) is presented in **Figure 1h**, in which two fields play a dominant role. Both *Operations research & management* and *Mathematics, applied* contribute for 20% to the profile of UT. In the first field, we find an average impact score (***CPP/FCSm*** = 0.83), while we find for the second field an impact score just below world average level (***CPP/FCSm*** = 0.76). High impact scores are observed for several computer science and technical sciences fields.

The research profile of the University Utrecht (UU) is displayed in **Figure 1i**. The first two fields, *Mathematics* and *Mathematics, applied*, account for over 65% of the profile. Both fields have high impact, but especially in the latter field, we find a very high impact, (***CPP/FCSm*** = 3.06). A number of smaller fields are characterized by varying impact scores. In *Computer science, theory*, we find a high impact score as well (***CPP/FCSm*** = 2.02).

Figure 1j contains the research profile for the University of Amsterdam (UvA) based mathematicians. Here, we also find *Mathematics* and *Mathematics, applied* in the top of the profile. Both fields contribute together for nearly 60% to the total output of the UvA, and both fields display high impact scores. In two other physics research related fields, we find very high impact scores (*Physics, particles & fields* (***CPP/FCSm*** = 3.65), and *Physics, nuclear* (***CPP/FCSm*** = 6.85). Finally, we observe a high impact score for the social sciences field *Economics* (***CPP/FCSm*** = 2.70).

In **Figure 1k**, we find the profile for the University of Tilburg (UvT). The profile displays a mixture of social sciences fields and science fields. In the top of the profile, five fields each accounting for10% or more of the output are found, with high and low impact scores. For the two mathematics fields (*Mathematics* and *Mathematics, applied*) a high impact is observed.

The profile of the Free University of Amsterdam (VU), displayed in **Figure 1l**, contains only fields with either high or low impact scores. The first three fields account for 80% of the output of the VU. Both *Mathematics* and *Statistics & probability* have high impact scores (of 1.49 and 1.65 respectively), while *Mathematics, applied* has a relatively low impact score (***CPP/FCSm*** = 0.76). *Physics, mathematical* has also a high impact score (***CPP/FCSm*** = 1.41).

The research profile of CWI is displayed in **Figure 1m**. In this profile we find a large number of fields (N = 16), of which only one has a low impact score, and four other have average impact scores. The remaining eleven fields all have high impact scores. The largest field, *Mathematics, applied*, contributes 35% to the total output of CWI, with an impact of 1.52. Fields where we find high impact scores include: *Operations research & management* (***CPP/FCSm*** = 2.53), *Computer science, software & graphics* (***CPP/FCSm*** = 2.01) and *Engineering, chemical* (***CPP/FCSm*** = 2.14).

Figure 1a

Research profile
Output and impact per field
1993 - 2002

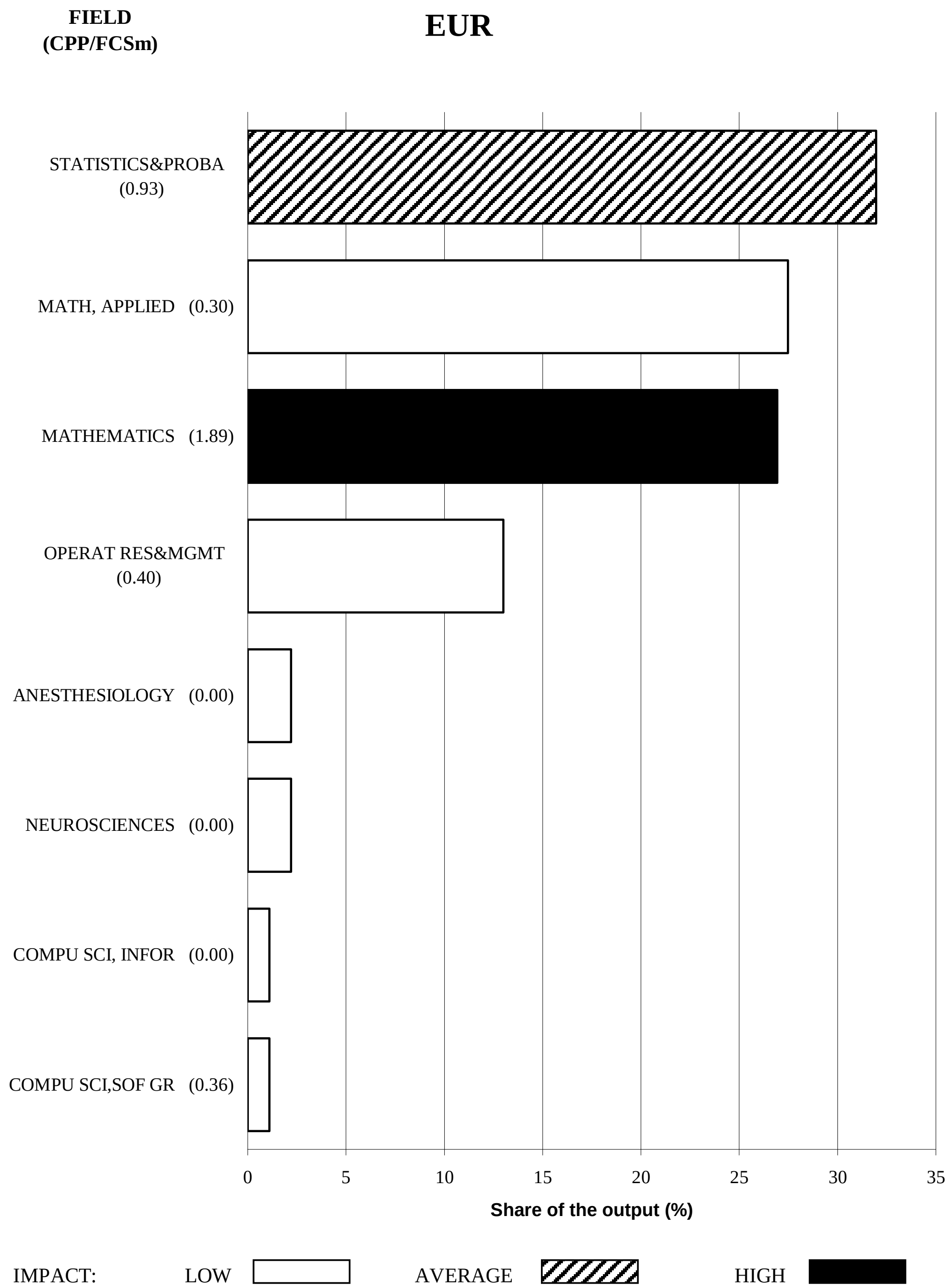


Figure 1b

Research profile
Output and impact per field
1993 - 2002

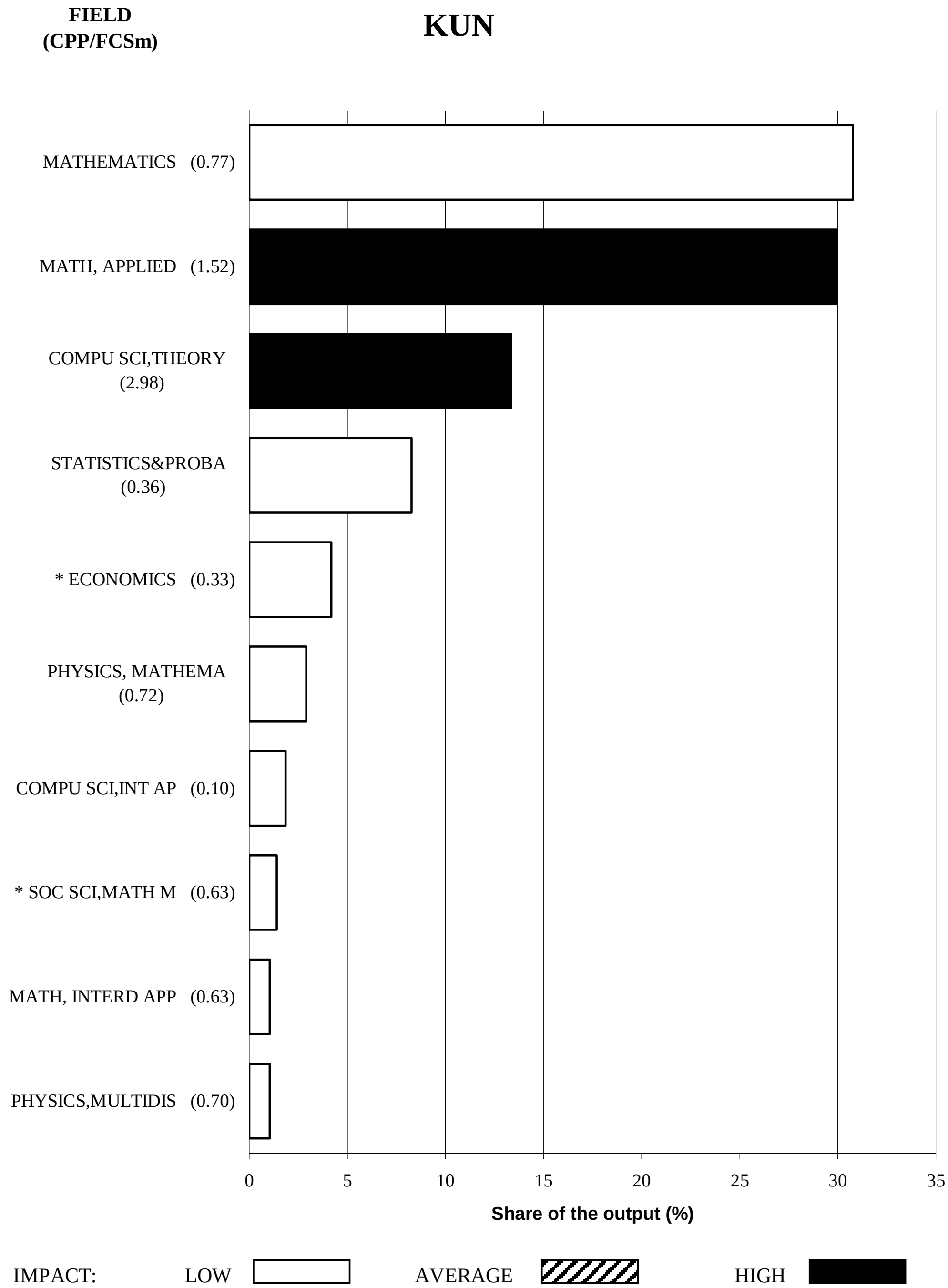


Figure 1c

Research profile
Output and impact per field
1993 - 2002

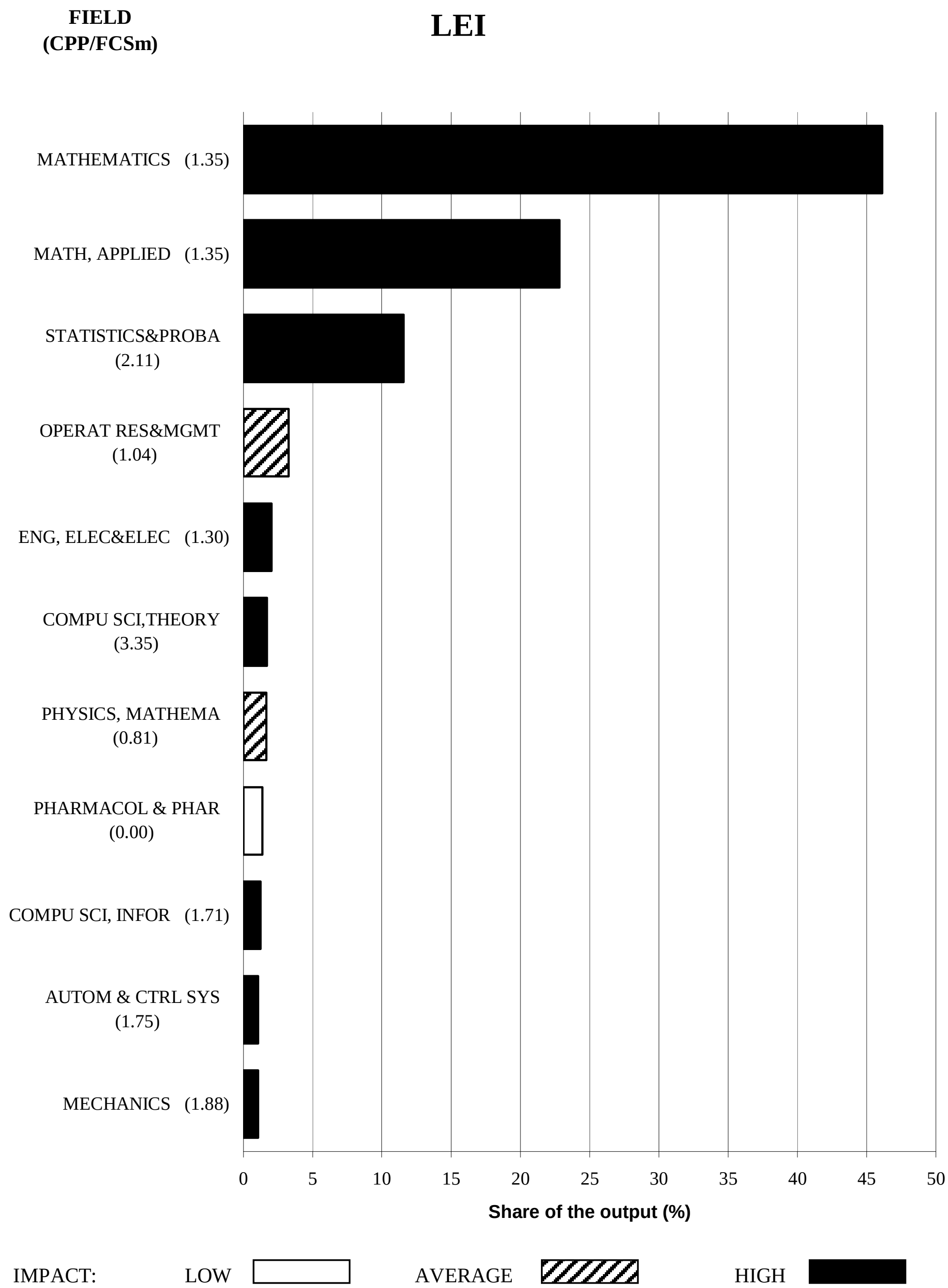


Figure 1d

Research profile
Output and impact per field
1993 - 2002

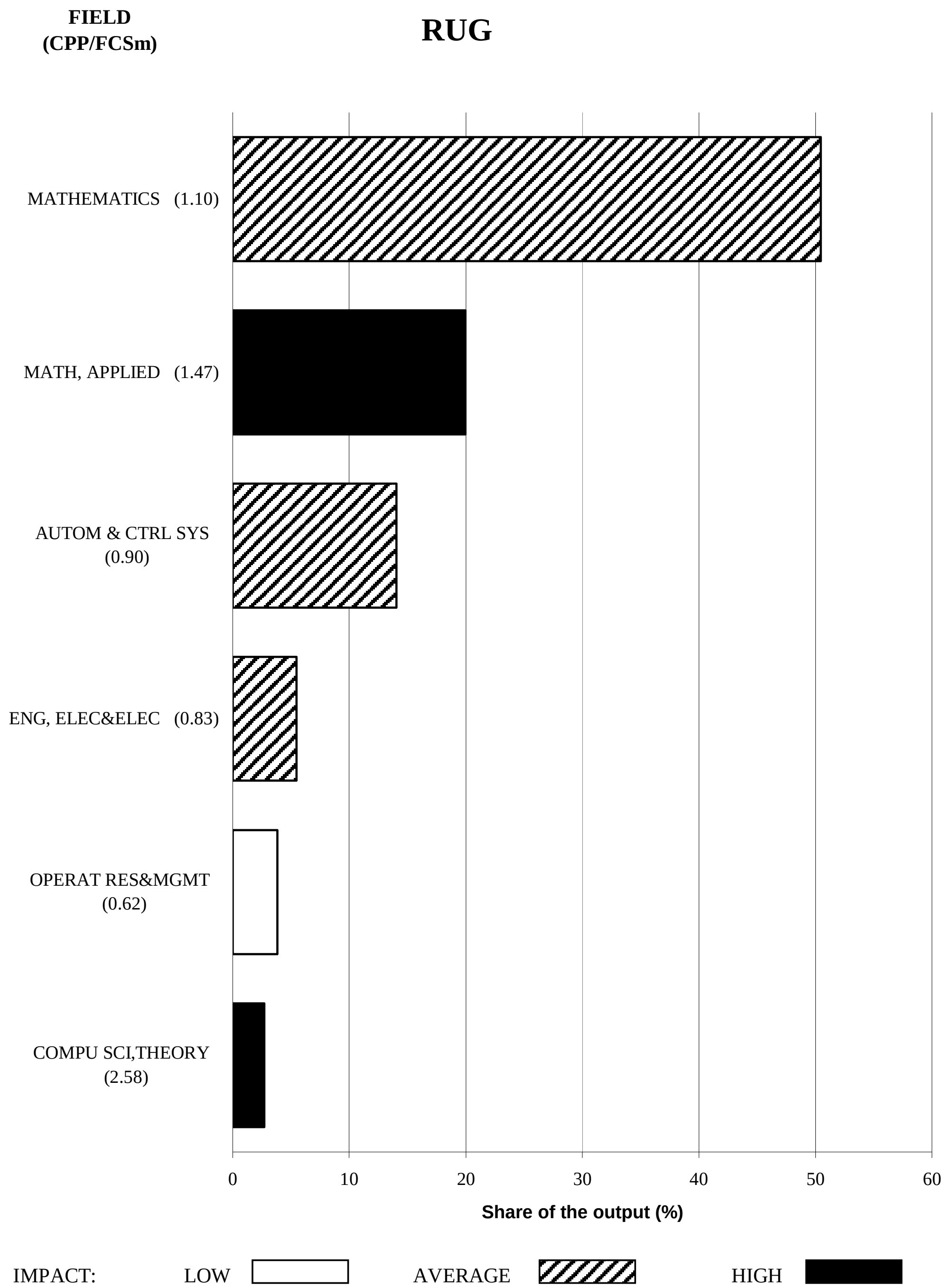


Figure 1e

Research profile
Output and impact per field
1993 - 2002

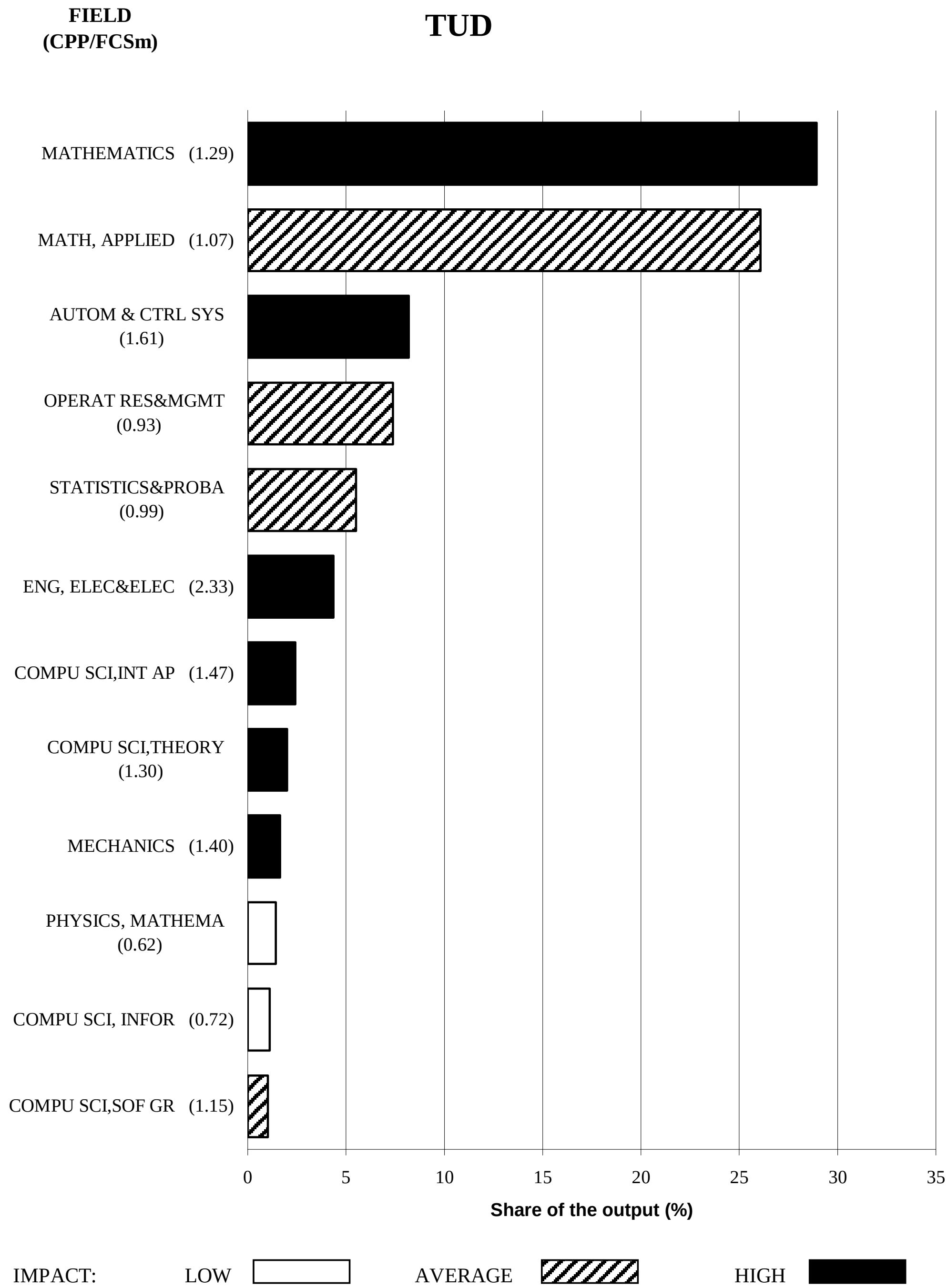


Figure 1f

Research profile
Output and impact per field
1993 - 2002

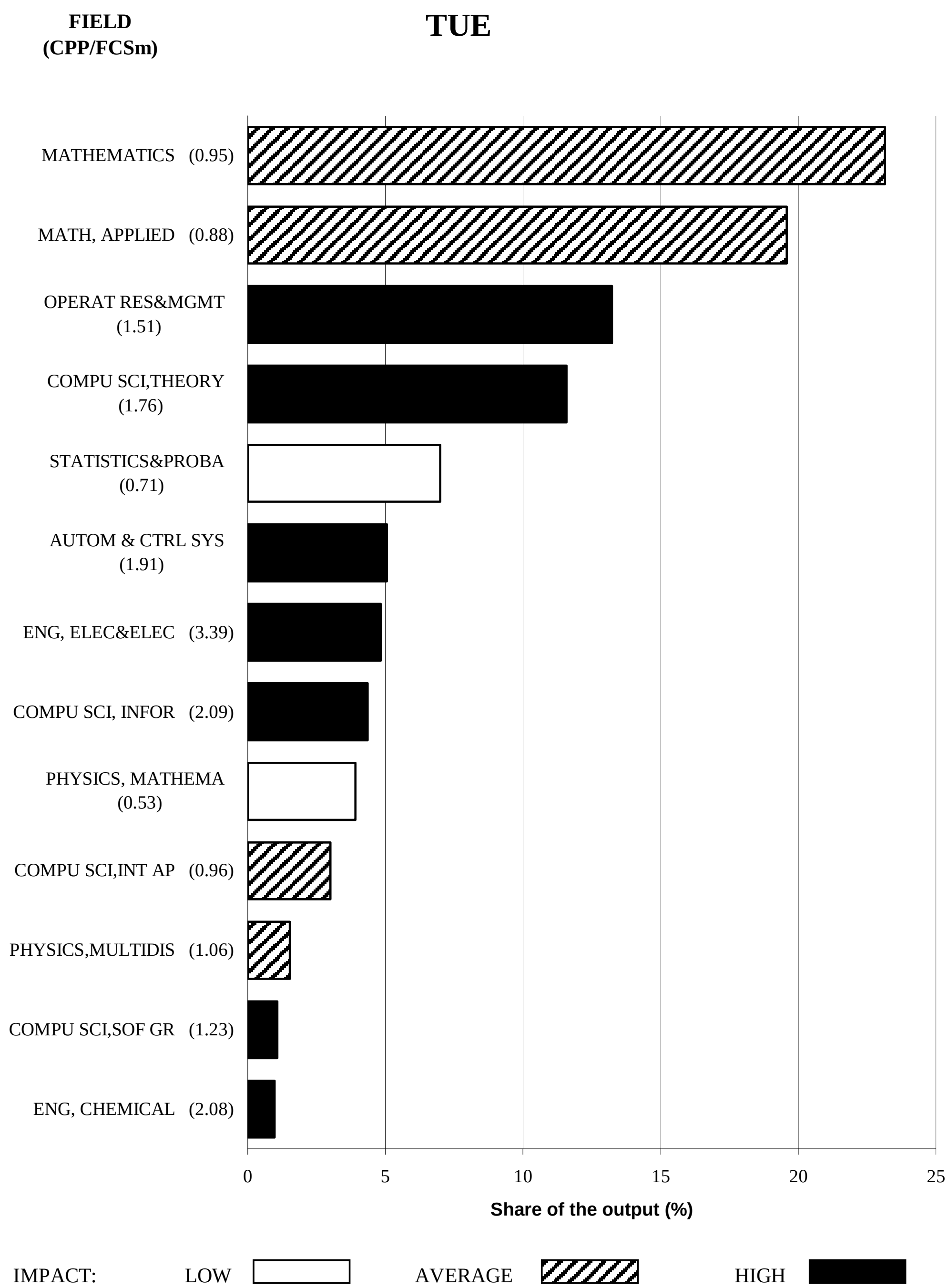


Figure 1g

Research profile
Output and impact per field
1993 - 2002

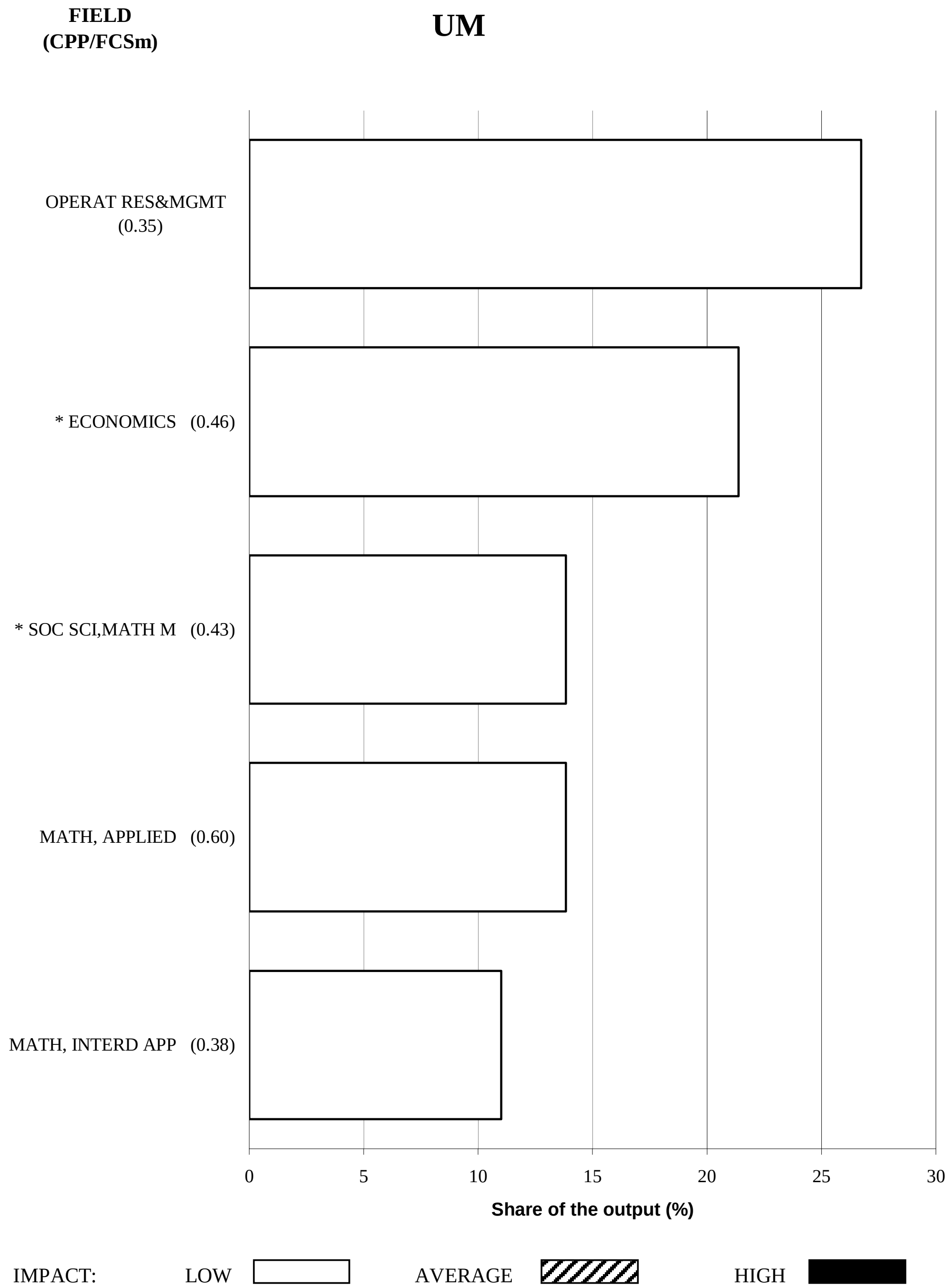


Figure 1h

Research profile
Output and impact per field
1993 - 2002

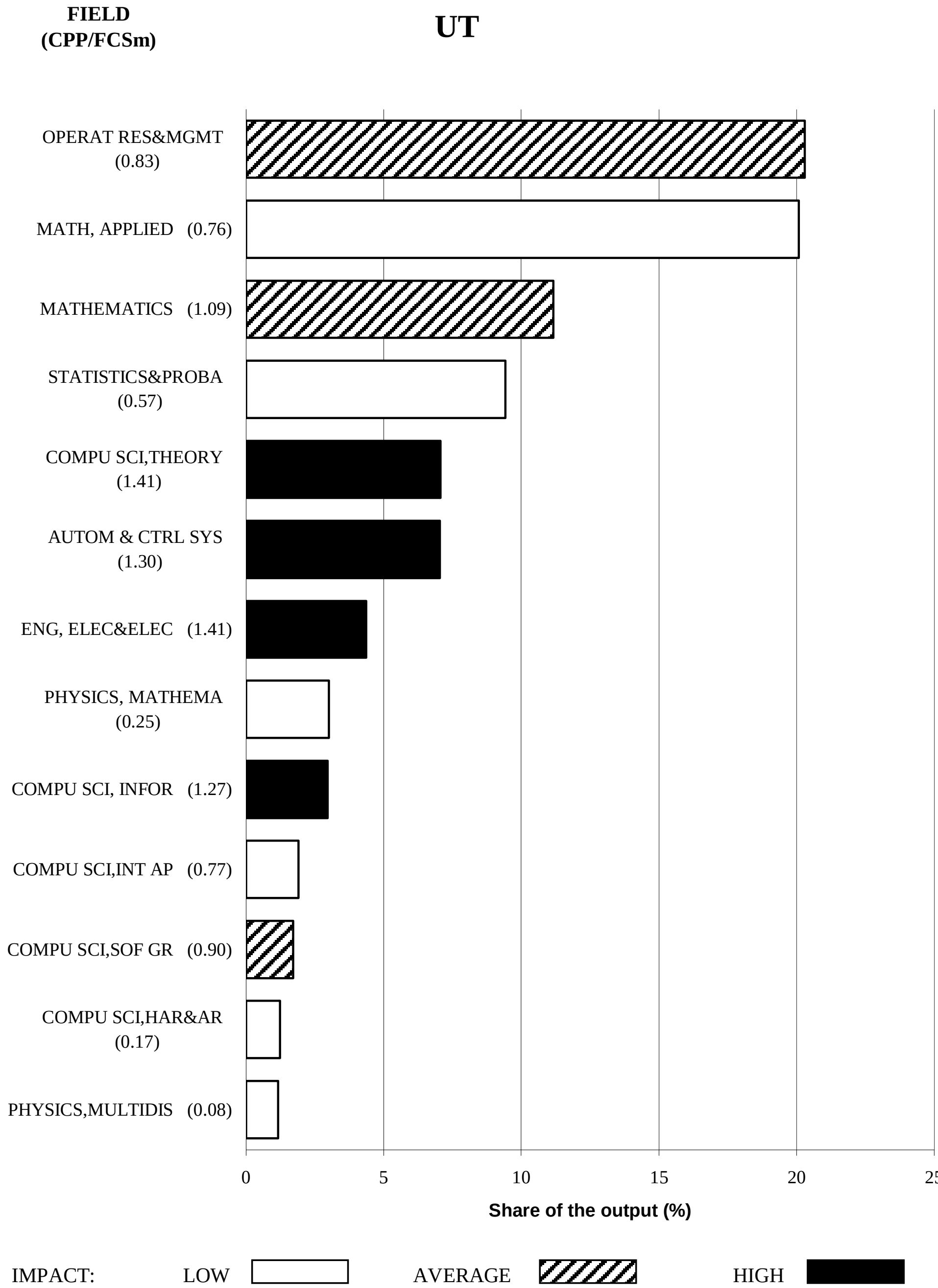


Figure 1i

Research profile
Output and impact per field
1993 - 2002

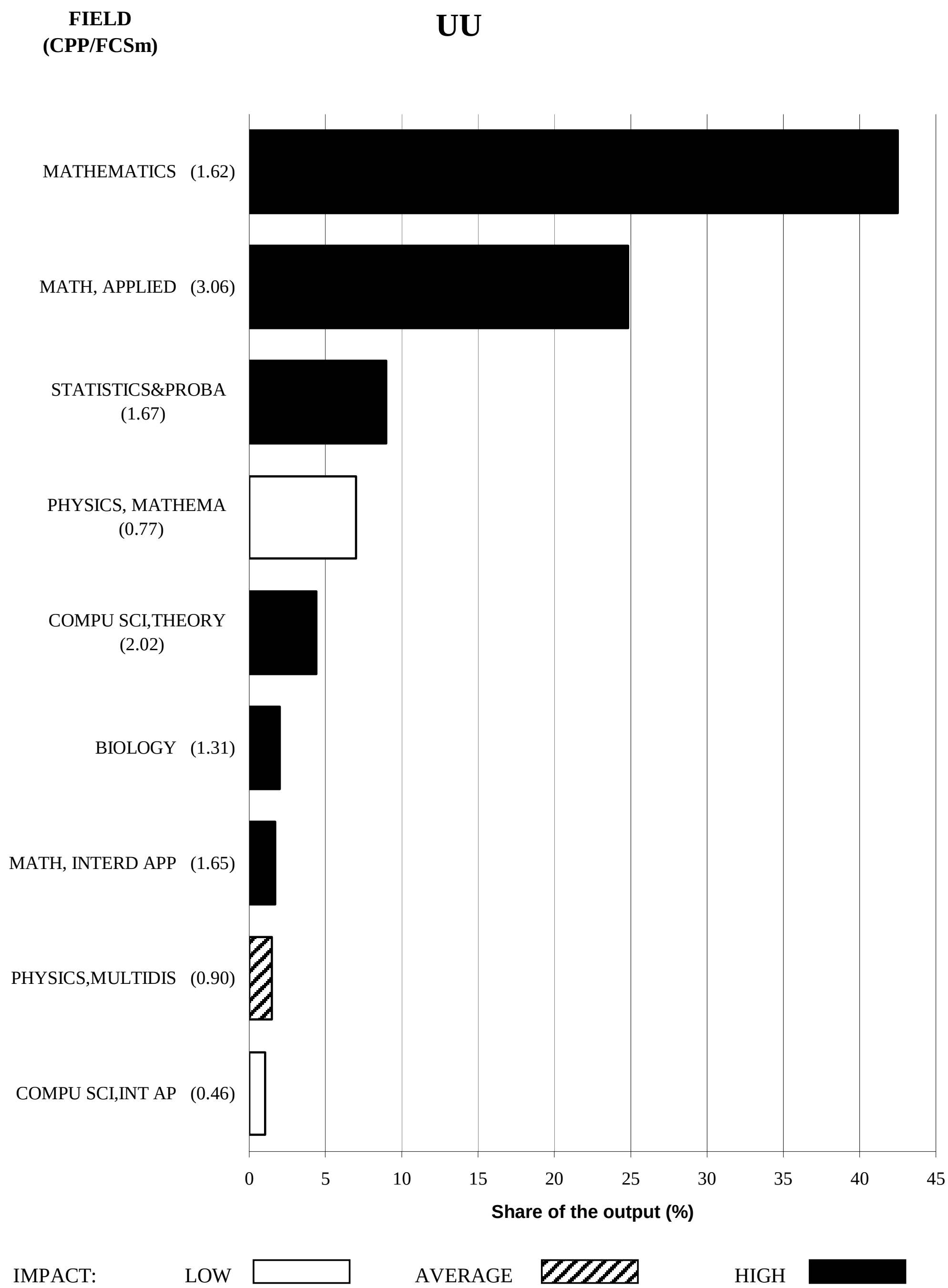


Figure 1j

Research profile
Output and impact per field
1993 - 2002

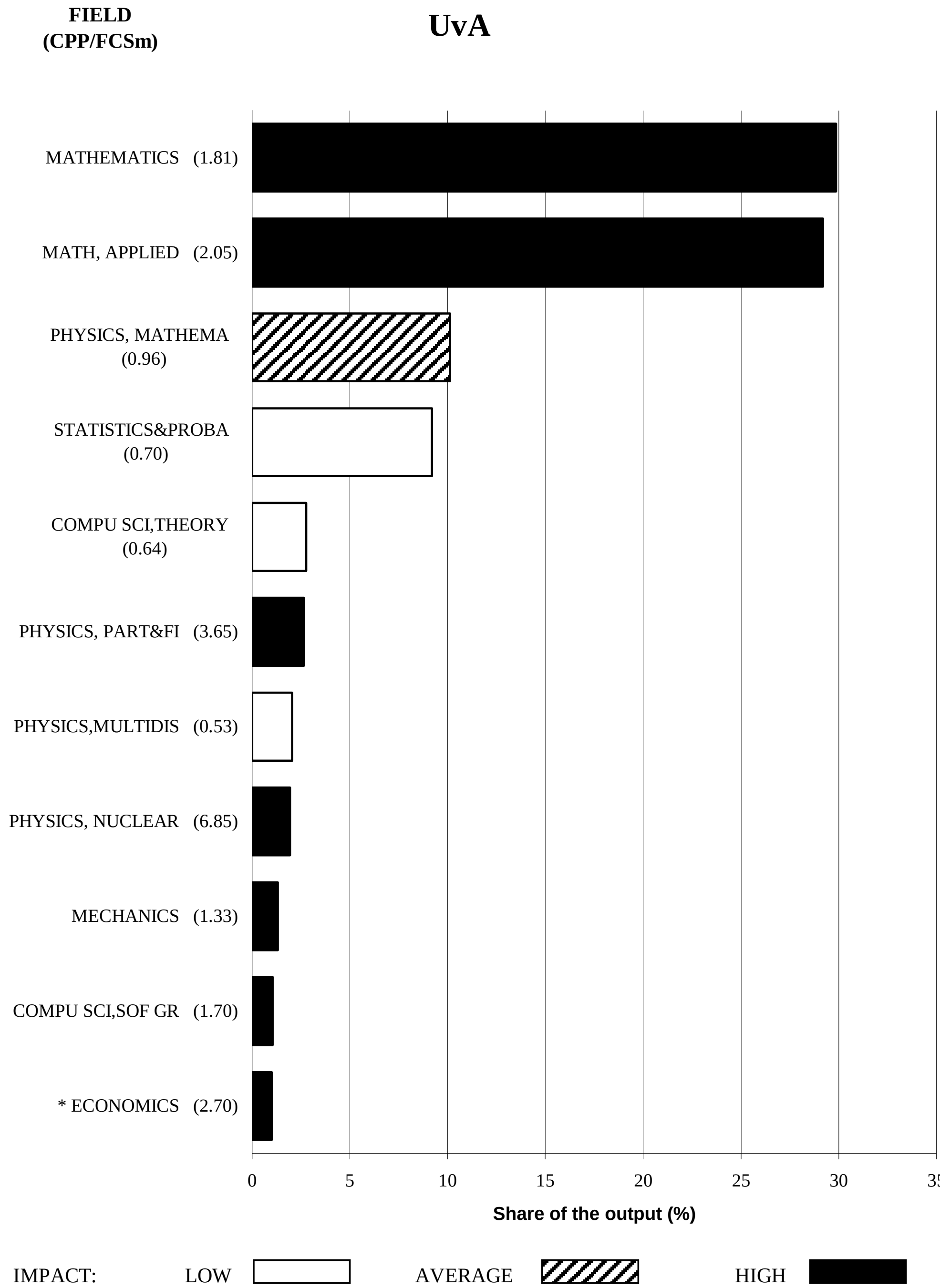


Figure 1k

Research profile
Output and impact per field
1993 - 2002

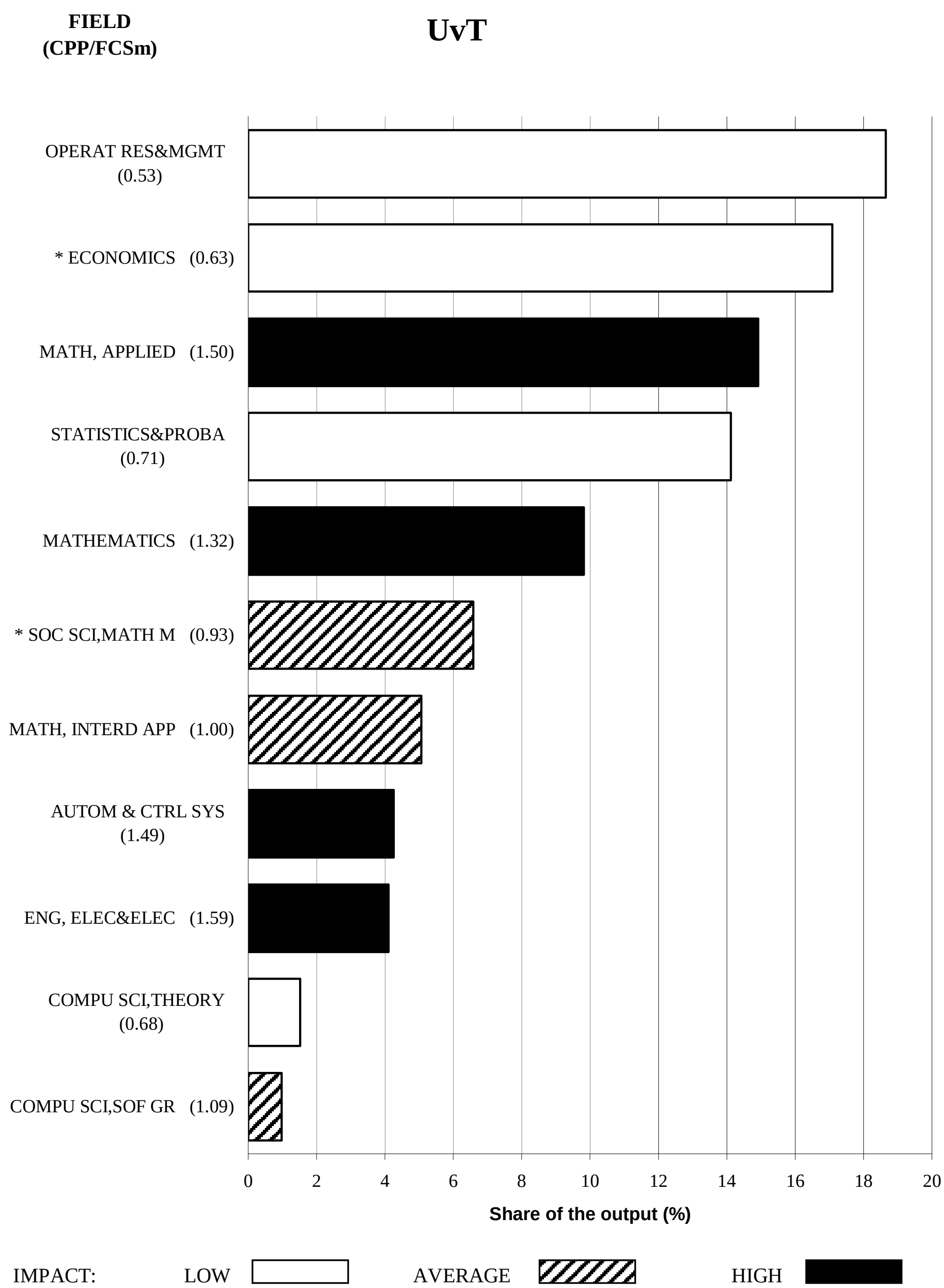


Figure 1l

Research profile
Output and impact per field
1993 - 2002

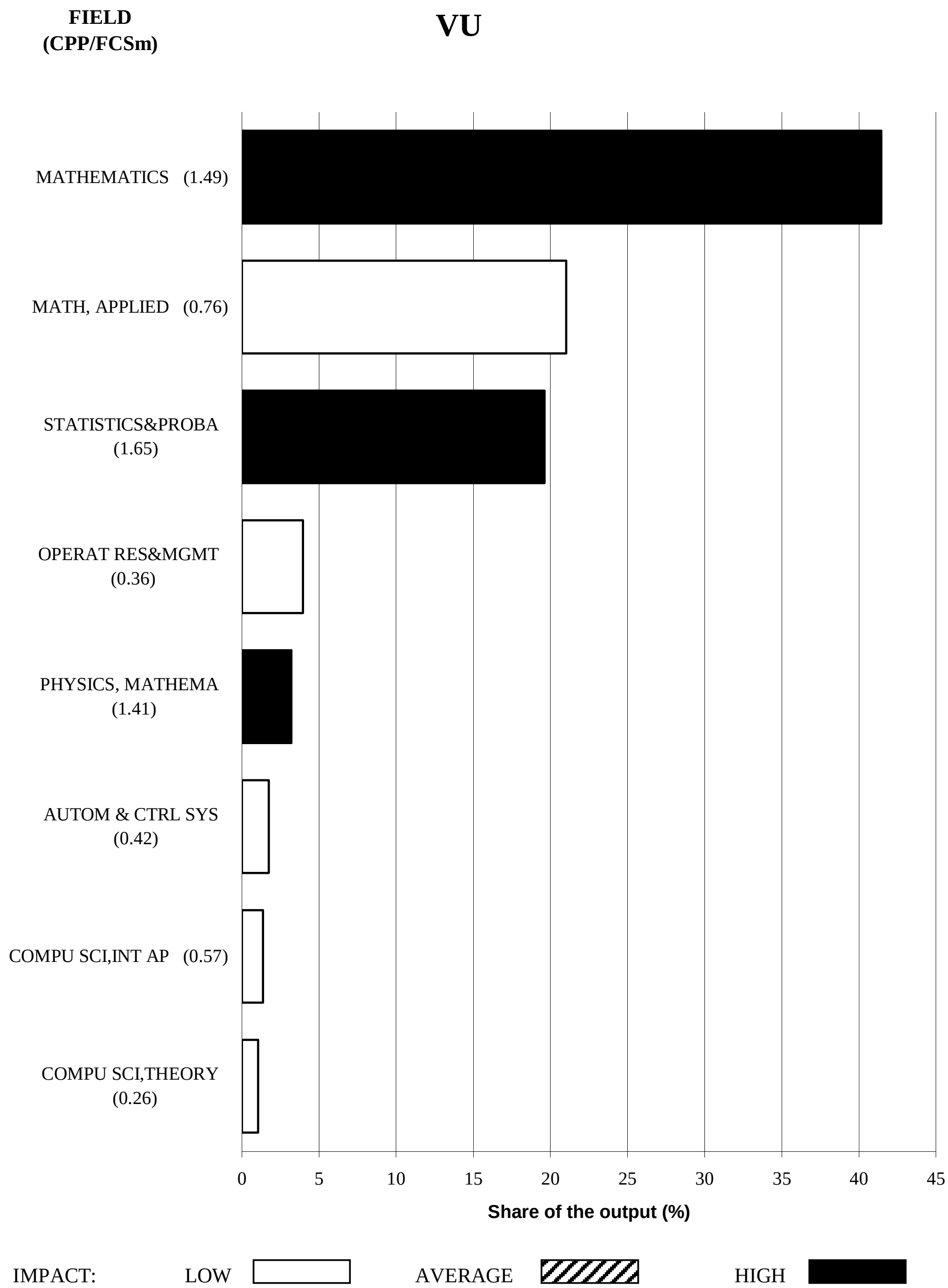
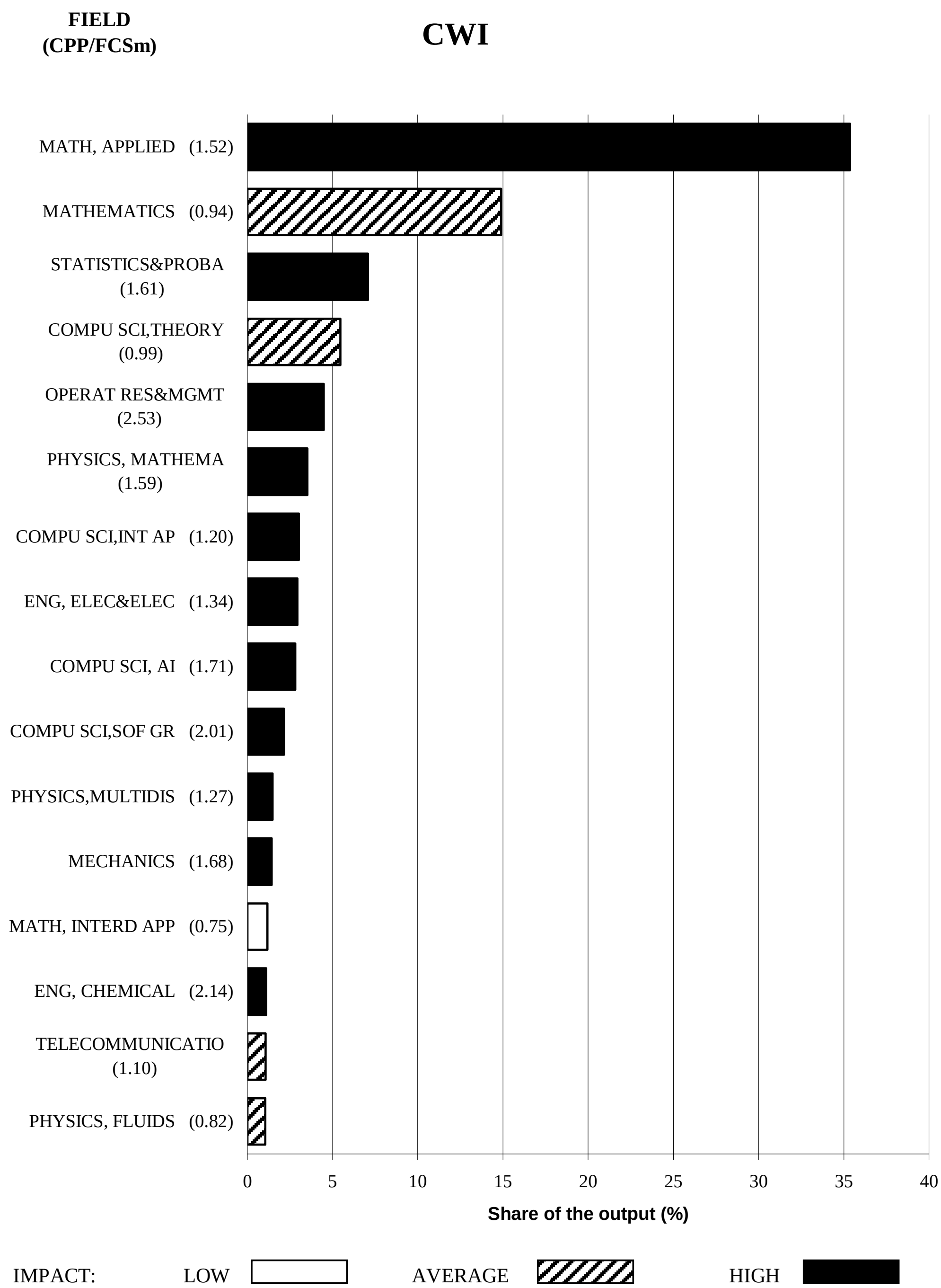


Figure 1m

Research profile
Output and impact per field
1993 - 2002



4.7 Research profiles on mathematics research in Dutch research schools

In Figures 2a - 2g we present the research profiles of the research schools in which mathematics researchers in the Netherlands are organized.

In **Figure 2a**, we find the profile of EIDMA, covering in the two uppermost fields (*Mathematics* and *Mathematics, applied*) roughly 55% of its output. In these fields, the school has average impact scores. In the next two fields, we observe high impact scores: for *Operations research & management*, we find a ***CPP/FCSm*** score of 1.38, and for *Computer science, theory*, a ***CPP/FCSm*** value of 1.75. In most of the small output fields we find high impact scores.

In **Figure 2b**, the research profile for MRI is shown. The two upper fields in the profile are *Mathematics* and *Mathematics, applied*, together contributing for 60% of the output of the school. In both fields, we find high impact scores (***CPP/FCSm* =** 1.28 and 1.68, respectively). In most other fields in the profile, the school has low impact scores. The other field in the profile with a high impact is *Computer science, theory* (***CPP/FCSm*** = 2.38).

In **Figure 2c**, the research profile of Stieltjes is presented. The most important field in this profile is *Mathematics*, with over 30% of the output, and a high impact score (***CPP/FCSm*** =1.47). The only other field with a high impact is *Engineering, electrical & electronics* (***CPP/FCSm*** = 1.47). Furthermore, the profile contains just three fields with a low impact score, all other fields having average impact scores.

The discussion of the results for the research schools with a smaller output will focus on the larger subfields in the research profile. We find the research profile for the research school Beta in **Figure 2d**. The two most important fields are *Operations research & management* and *Statistics & probability*. Both fields combined contribute over 60% of the total output of Beta. In both fields, we find relatively low impact scores. Most other fields are characterized by an average or low impact. However, we observe a high impact in *Engineering, industrial* (***CPP/FCSm*** = 1.94, and 6% of the output).

The research profile of Burgerscentrum is displayed in **Figure 2e**. In this profile, we observe a strong focus on *Mathematics, applied*, covering 30% of the output of the centre. In this field, the school has a 12% above average impact (***CPP/FCSm*** = 1.12).

The next three fields contribute each over 5% of the total output of the centre. Here, *Computer science, interdisciplinary applications* with an average impact (***CPP/FCSm*** = 1.09), and two subfields with a high impact: *Mechanics* (***CPP/FCSm*** = 1.22), and *Computer science, theory* (***CPP/FCSm*** = 1.23). Another field in which the centre has a high impact is *Engineering, chemical* (***CPP/FCSm*** = 1.87).

The research profile of CentER is shown in **Figure 2f**. Here, nearly 40% of the output is covered by two fields, namely *Mathematics* and *Mathematics, applied*. In the first field, the school has a high impact score (***CPP/FCSm*** = 1.48). The impact in the second field is also high (***CPP/FCSm*** = 1.54). In *Economics*, we find a low impact score for this school, while we find an average impact score for *Statistics & probability*. For two technical sciences fields, each covering 8% - 9% of the output, we find high impact scores (***CPP/FCSm*** = 1.58 and 1.60).

The research profile of the research school DISC is displayed in **Figure 2g**. Here we find *Automation & control systems* as the most important field, covering over 30% of the output of the school. In this field, the school has a high impact (***CPP/FCSm*** = 1.48). Next, we find *Mathematics, applied*, a field in which the school published over 20% of its output, with an average impact. In the next two fields, *Engineering, electrical & electronics* and *Operations research & management*, we find respectively 17% and 8% of the school's output, while the school has a high impact in the former field (***CPP/FCSm*** = 2.42).

Figure 2a

Research profile
Output and impact per field
1994 - 2003

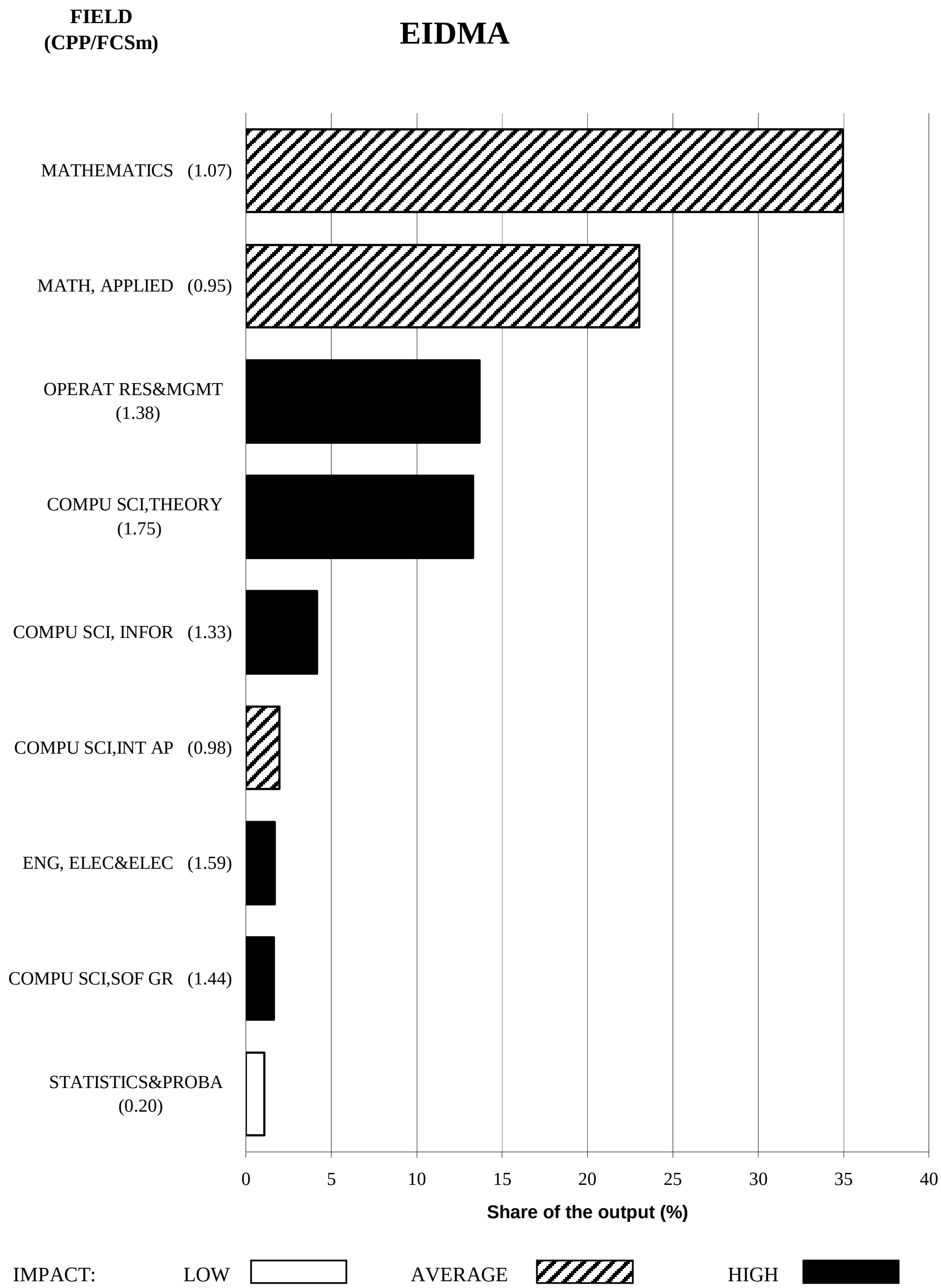


Figure 2b

Research profile
Output and impact per field
1994 - 2003

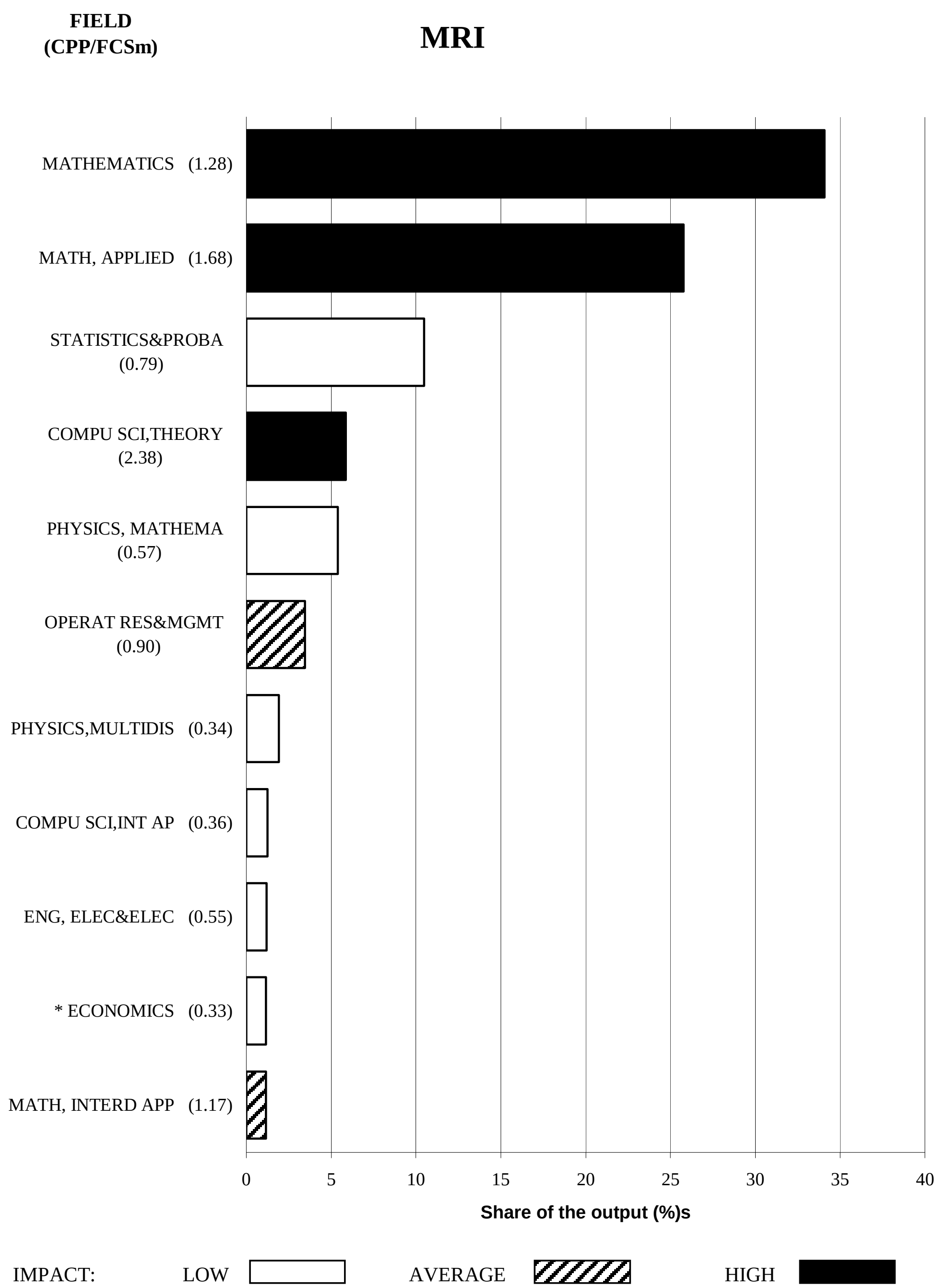


Figure 2c

Research profile
Output and impact per field
1994 - 2003

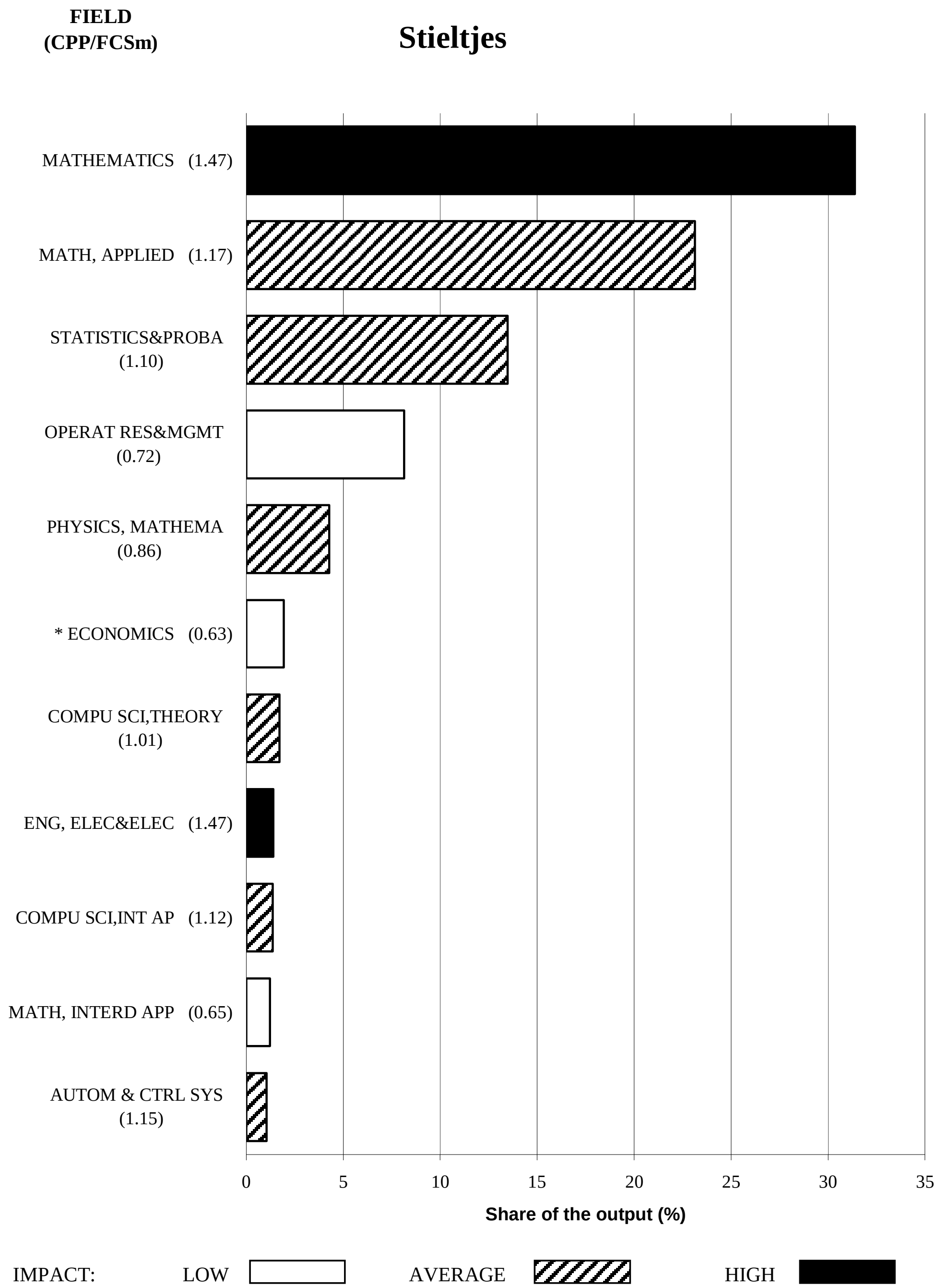


Figure 2d

Research profile
Output and impact per field
1994 - 2003

FIELD
(CPP/FCSm)

Beta

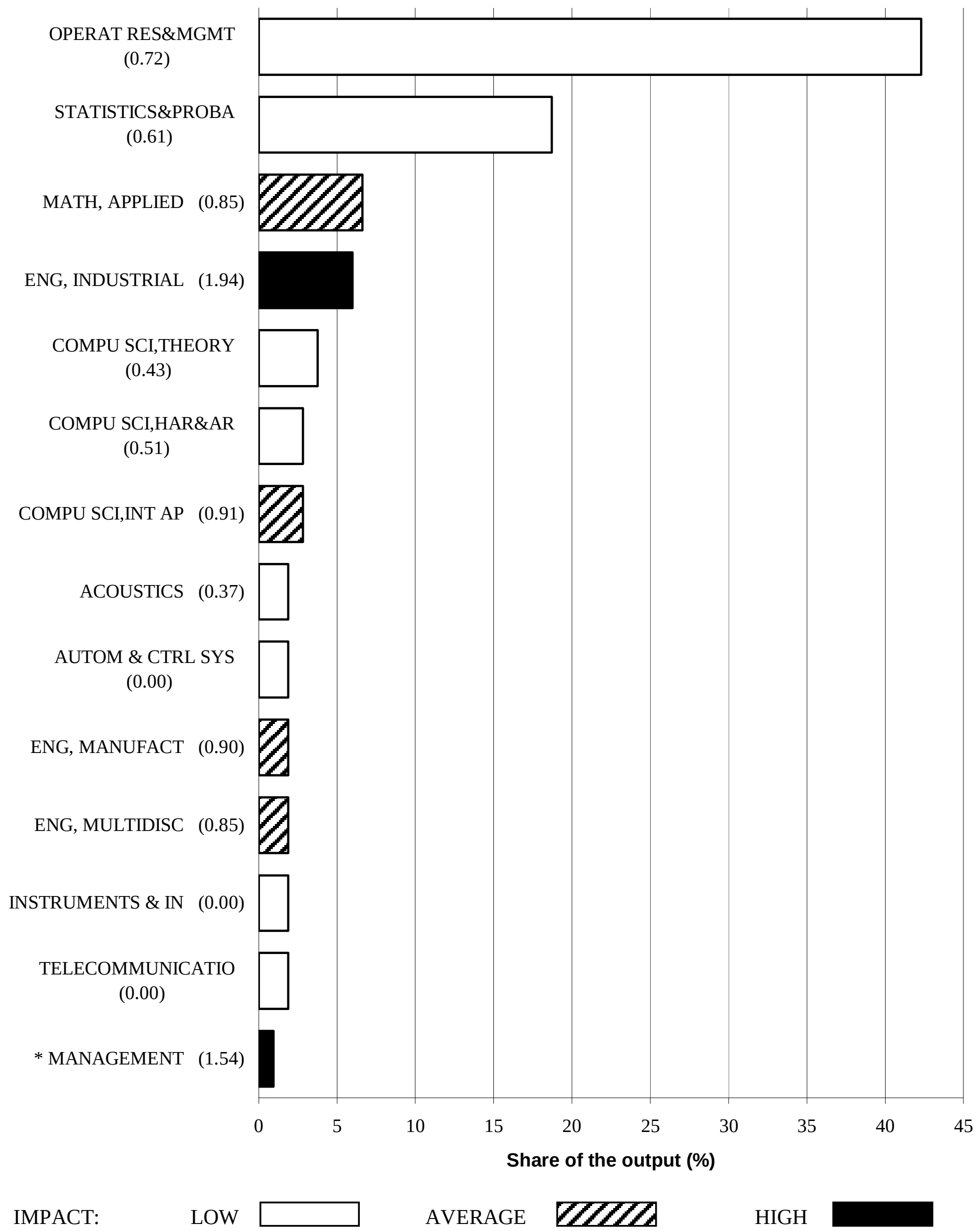


Figure 2e

Research profile
Output and impact per field
1994 - 2003

Burgerscentrum

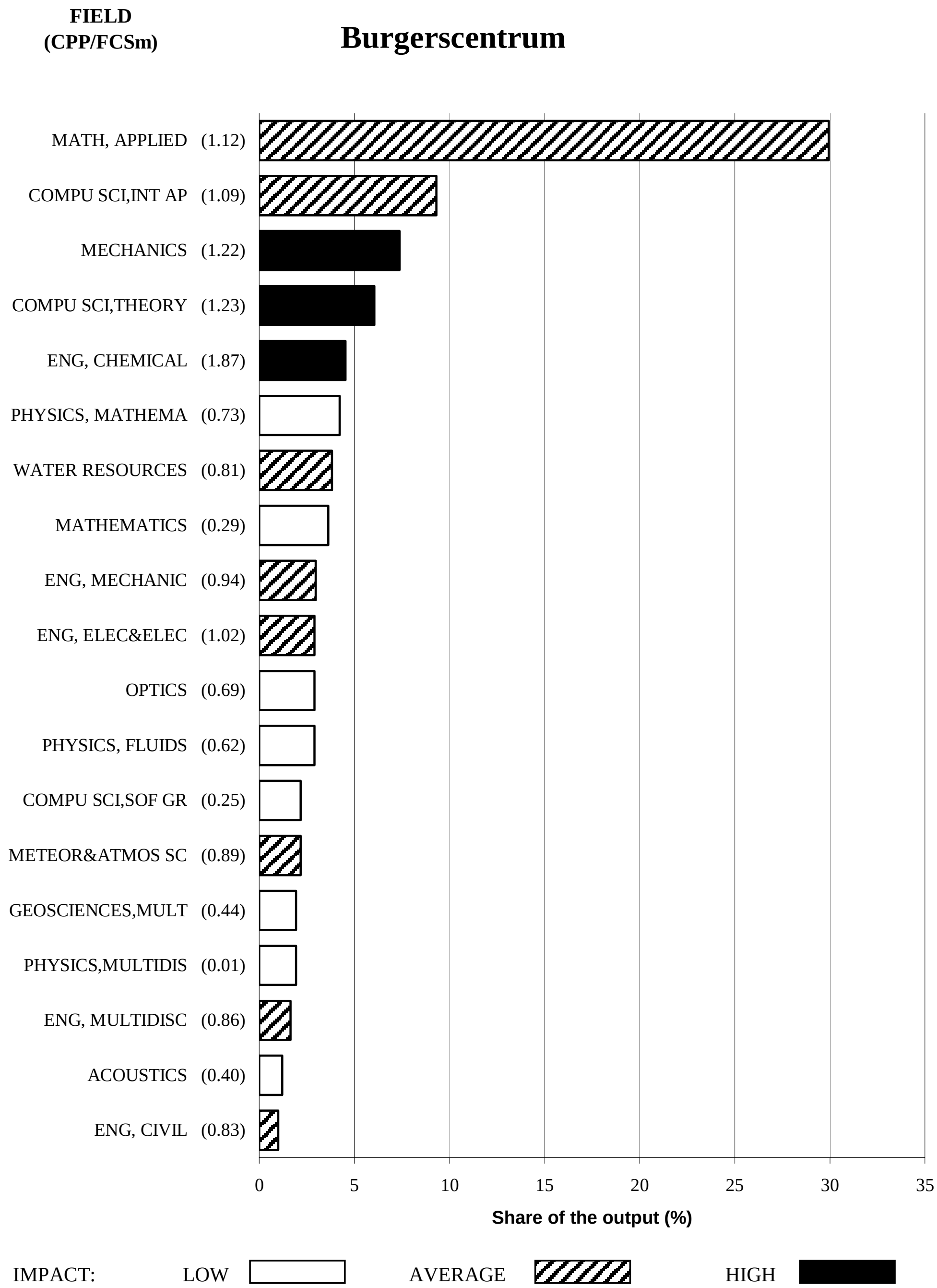


Figure 2f

Research profile
Output and impact per field
1994 - 2003

FIELD
(CPP/FCSm)

CentER

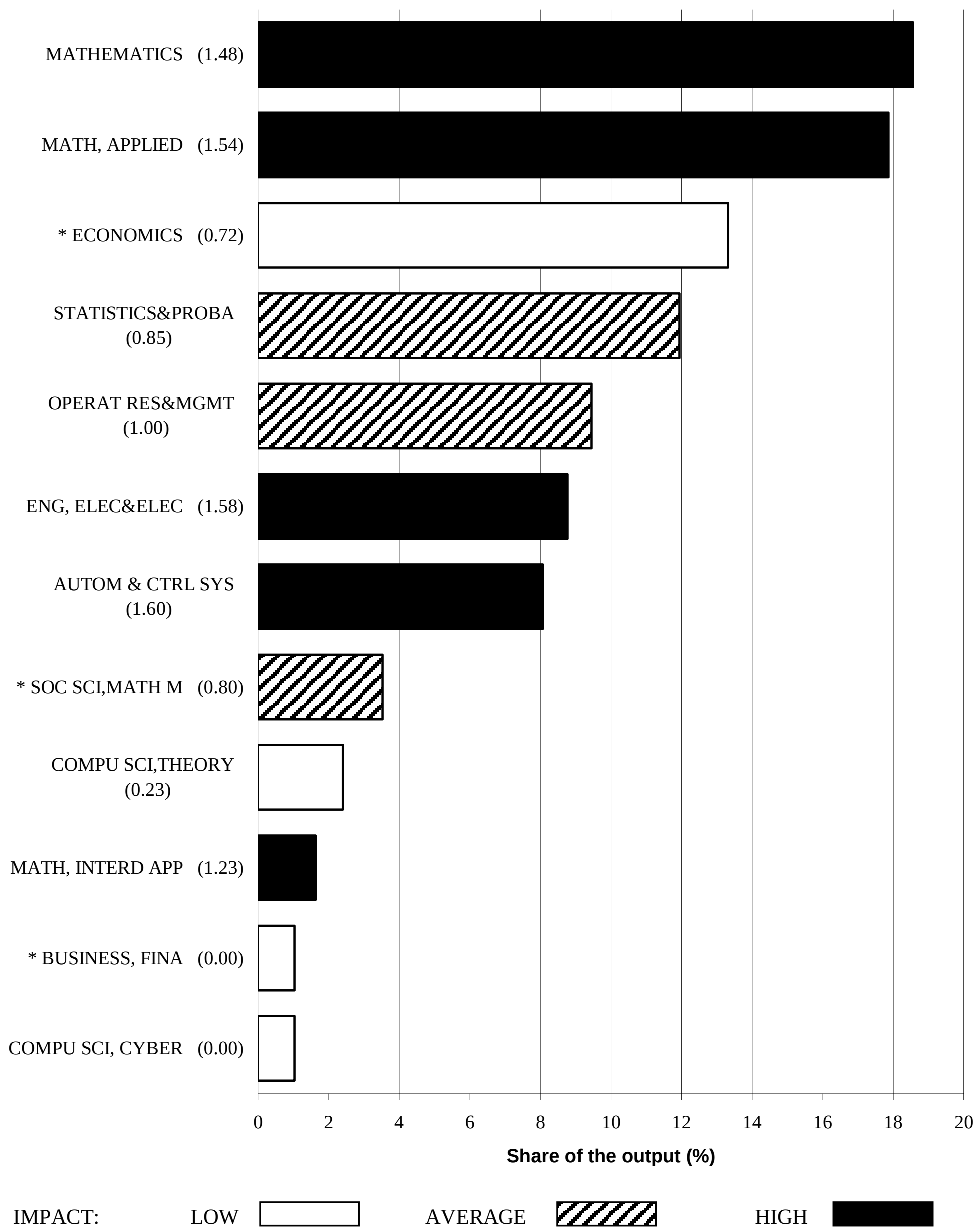
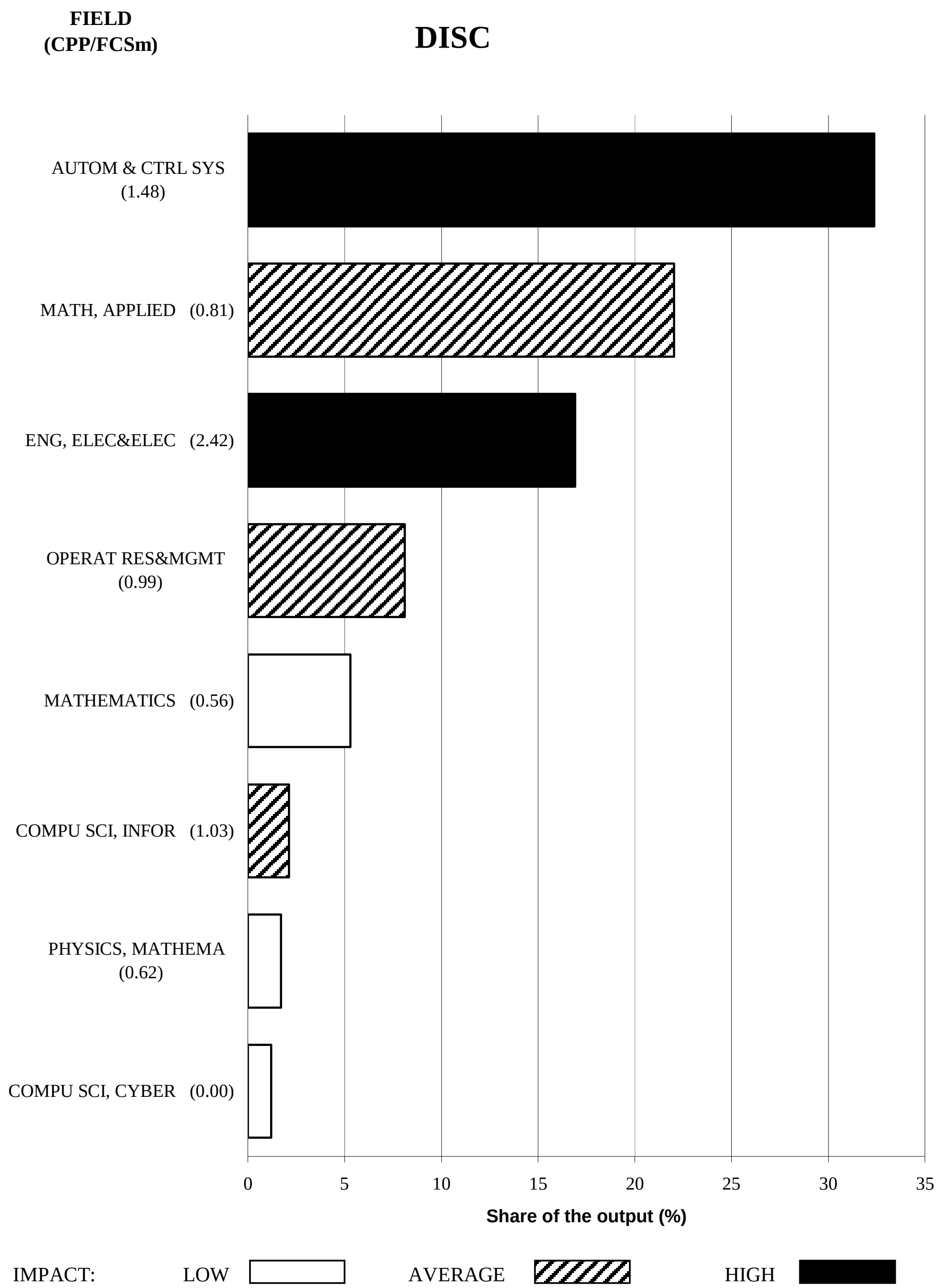


Figure 2g

Research profile
Output and impact per field
1994 - 2003



4.8 Scientific cooperation analysis of Dutch universities

Three types of scientific collaboration were distinguished (see Section 3.3). Publications with only one address were assigned to 'Single address publications'. Publications with multiple addresses, all from the same country, were assigned to '*national collaboration*'. Finally, all publications with at least one address outside the Netherlands were marked with collaboration type '*international*'. In the figures 3a - 3c, the results of the analyses of scientific cooperation types are shown.

In **Figure 3a**, we find the output shares per university in the output class 'Single address publications'. We observe a strong variation among the universities, from 17% (UM) to 43% (UU) of the output. Also, the impact scores fluctuate among universities: high scores are found for UU and KUN, among others, while relatively low impact scores are observed for EUR, UT, and UM.

Next, in **Figure 3b**, we find the results for the output class 'National cooperation'. Again, we see considerable variation in output shares among the universities. Among the impact scores for publications produced in national cooperation, we also find such a variation: high impact scores are obtained by UU, TUE and UvA, while we find relatively low impact scores for UM, KUN, and EUR.

Finally, the result of the analysis on the output class 'International cooperation' is shown in **Figure 3c**. We find large output shares in this type for UM and VU, with a relatively low and an average impact score, respectively. Other relatively low impact scores are found for UvT, and KUN, while the highest impact scores are found for UvA, UU, and LEI.

Figure 3a

Scientific research profile

Output and impact per type

1993 - 2002

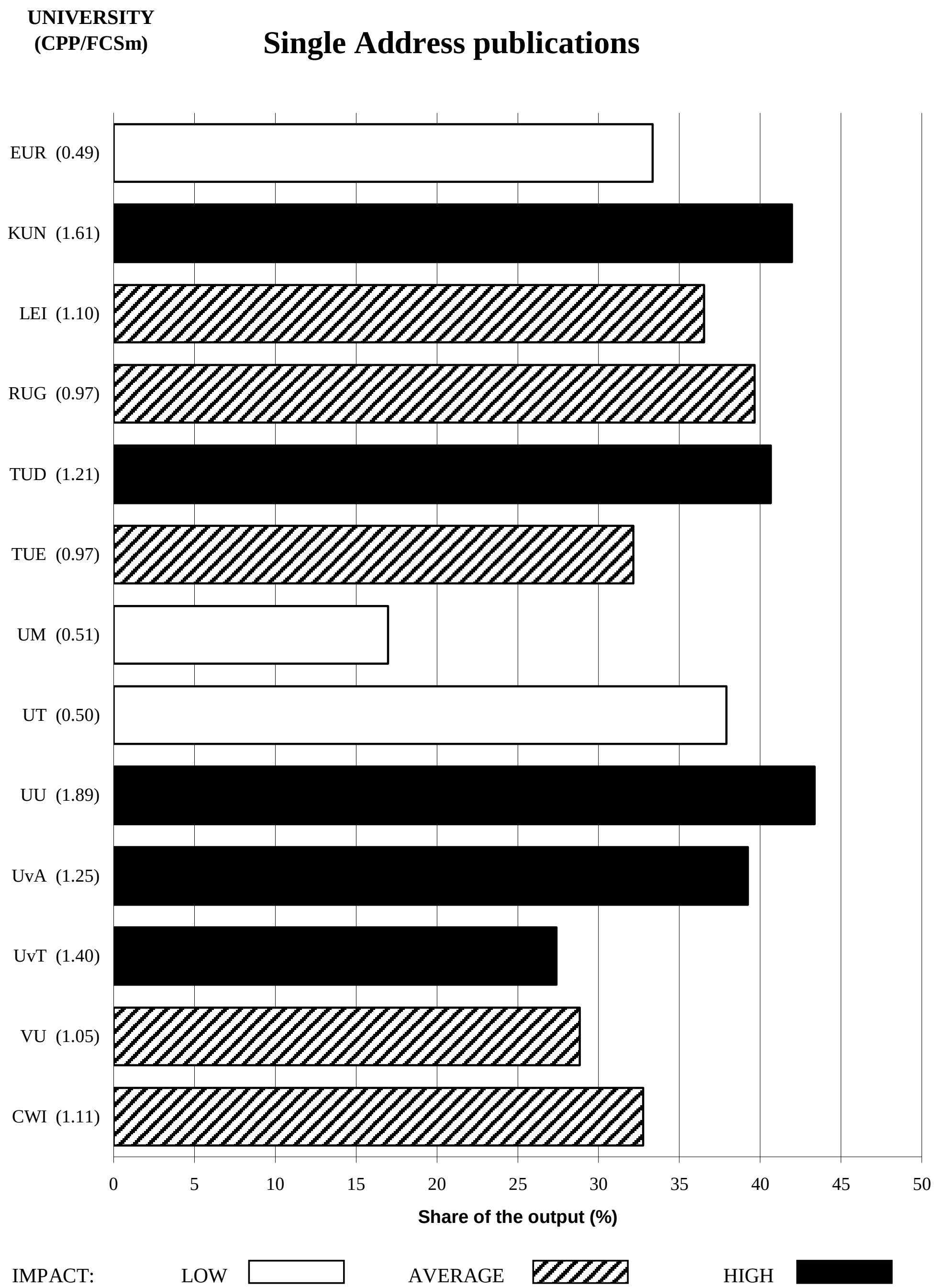


Figure 3b

Scientific research profile
Output and impact per type
1993 - 2002

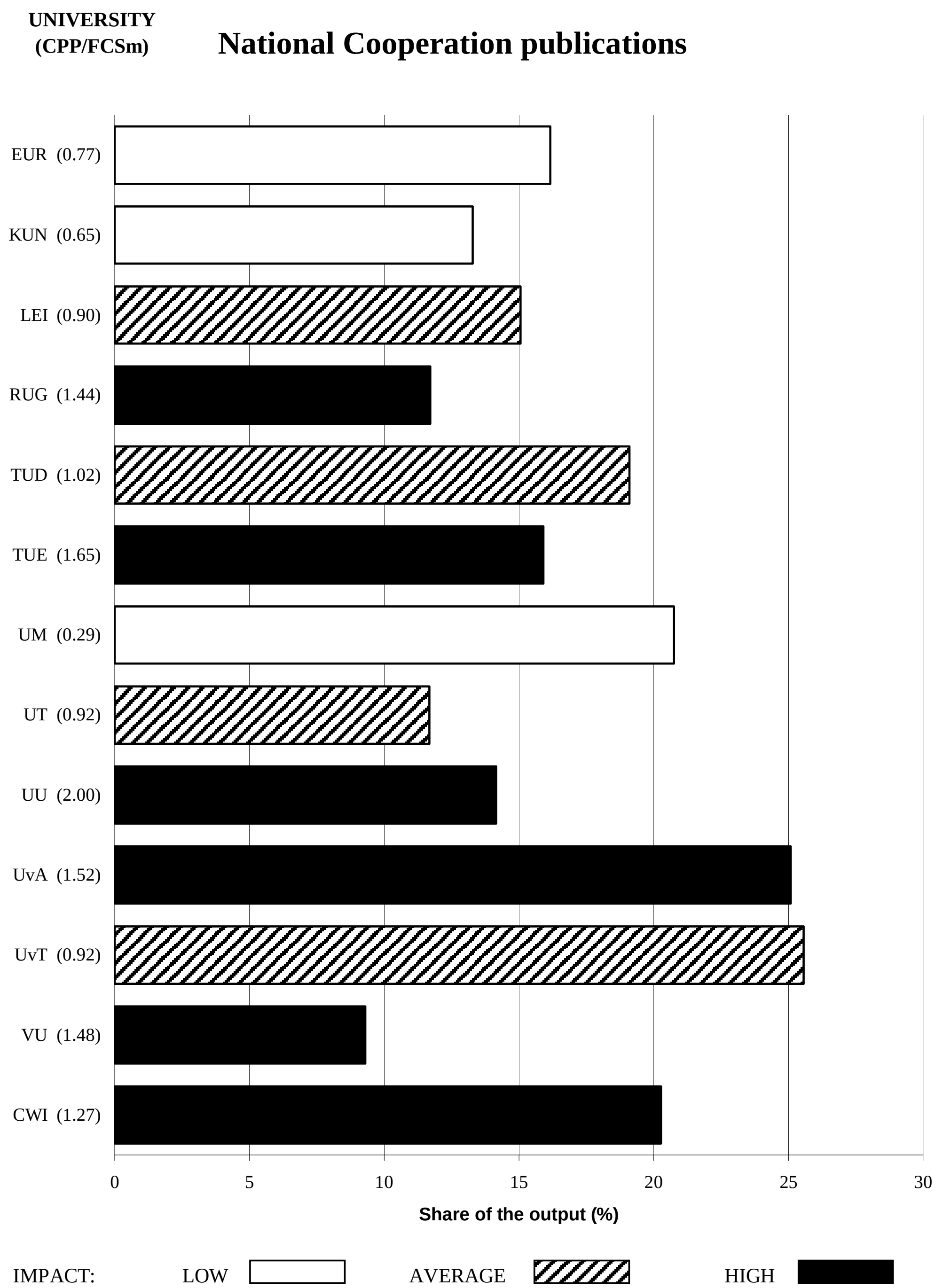
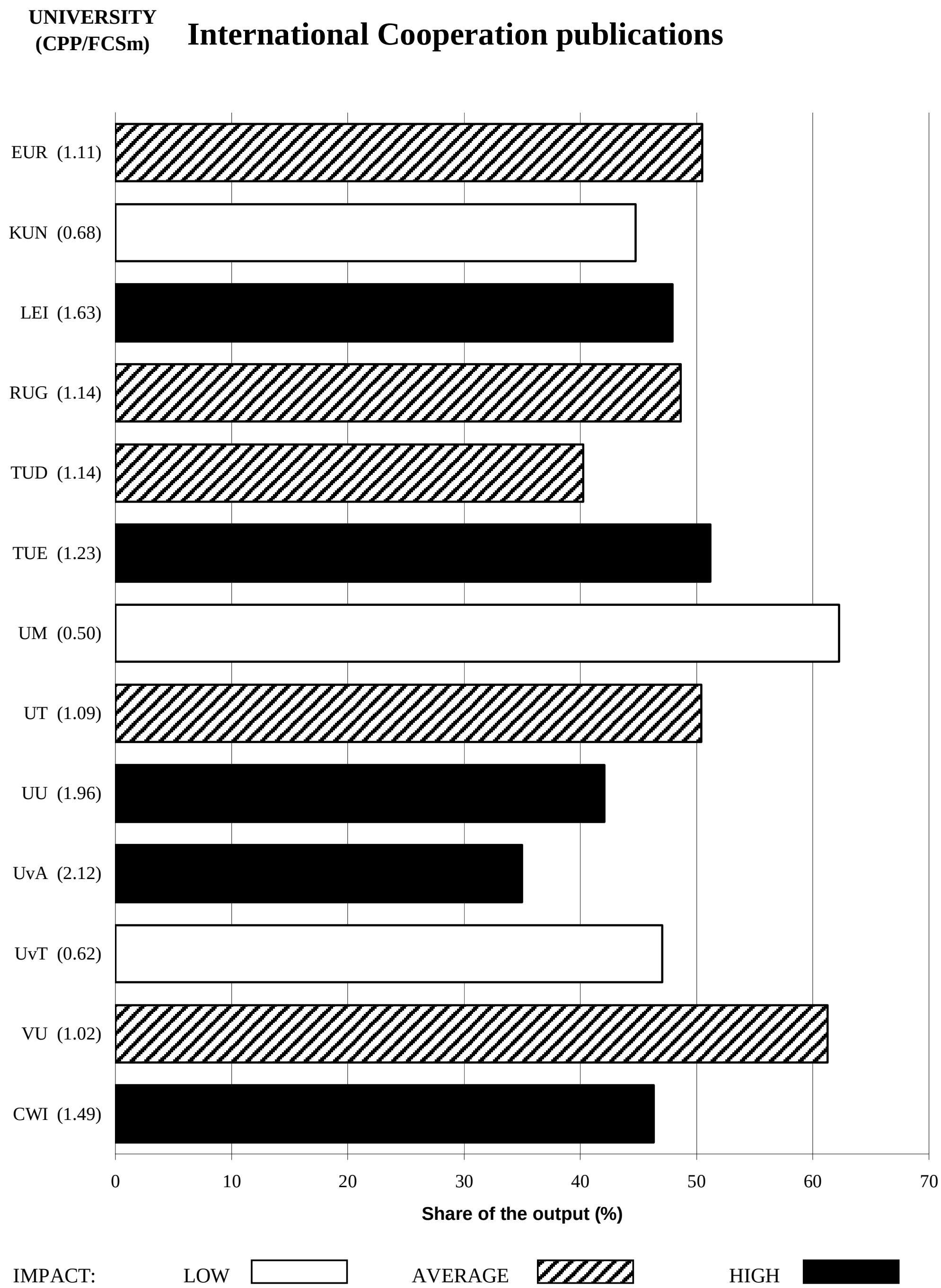


Figure 3c

Scientific research profile
Output and impact per type
1993 - 2002



4.9 Scientific cooperation analysis of Dutch mathematics research schools

The results of the analysis on scientific cooperation types among Dutch research schools in the field of mathematics are displayed in Figures 4a - 4c.

In **Figure 4a**, the output shares among research schools in the 'Single address' publications shown. Here, we observe less variation among the research schools: roughly between 30% and 43% is covered by this type. However, the only schools with high impact in this type are MRI and CentER, while the only one with a relatively low impact is Beta.

In **Figure 4b**, we find the results of the analysis of the class 'National cooperation' among Dutch mathematics research schools. Here, the variation is somewhat larger, ranging from nearly 10% to 35 %. Here, four schools have an average impact, while high impact is now found for CentER, DISC, and EIDMA.

Finally, **Figure 4c** displays the analysis of the international co-publications of Dutch mathematics research schools. The output shares vary from 25% to above 50% of the output. For three schools, we find high impact scores resulting from international scientific co-publishing: DISC, Stieltjes, and EIDMA.

Figure 4a

Scientific cooperation profile
Output and impact per type
1993 - 2002

Single address publications

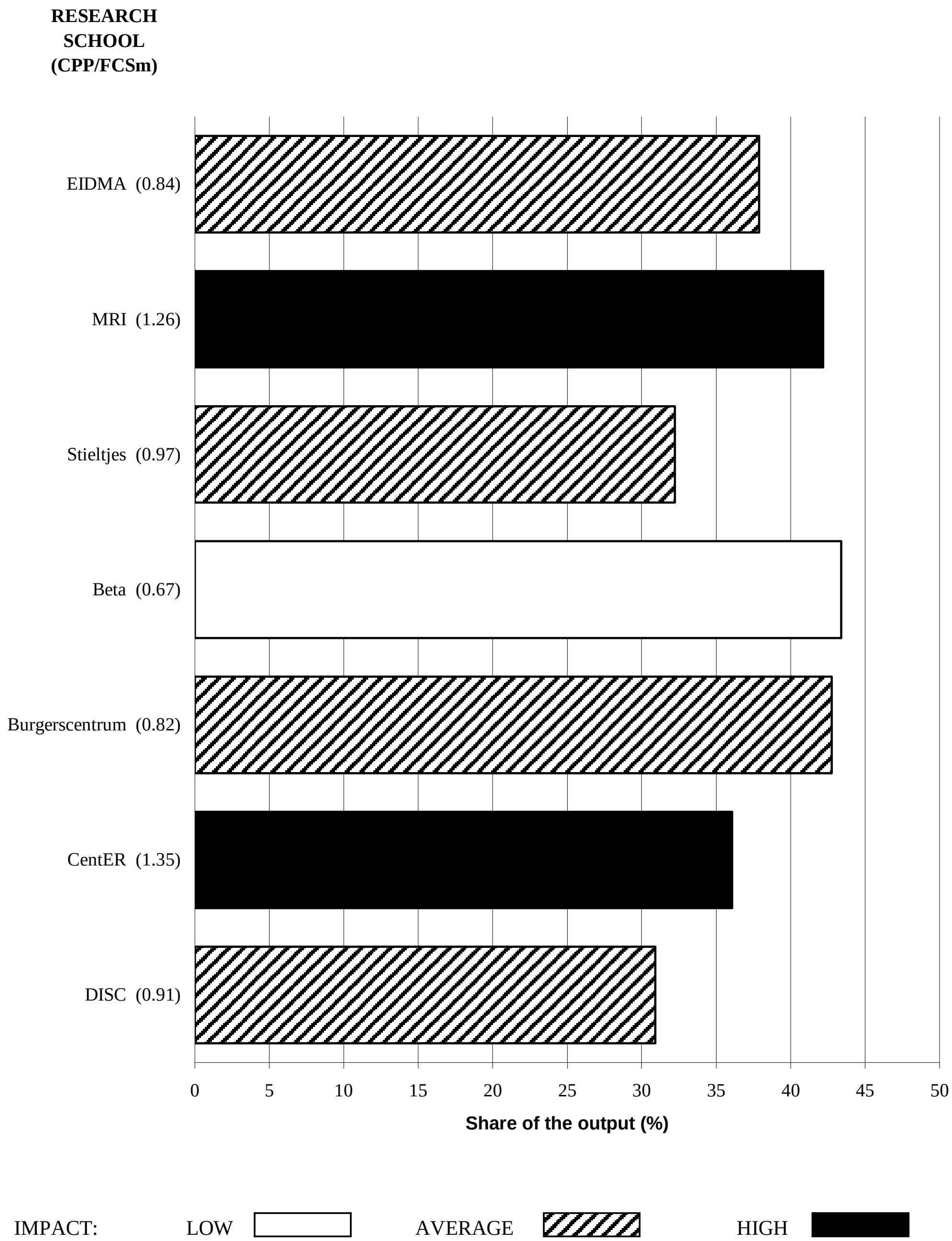


Figure 4b

Scientific cooperation profile
Output and impact per type
1993 - 2002

National cooperation

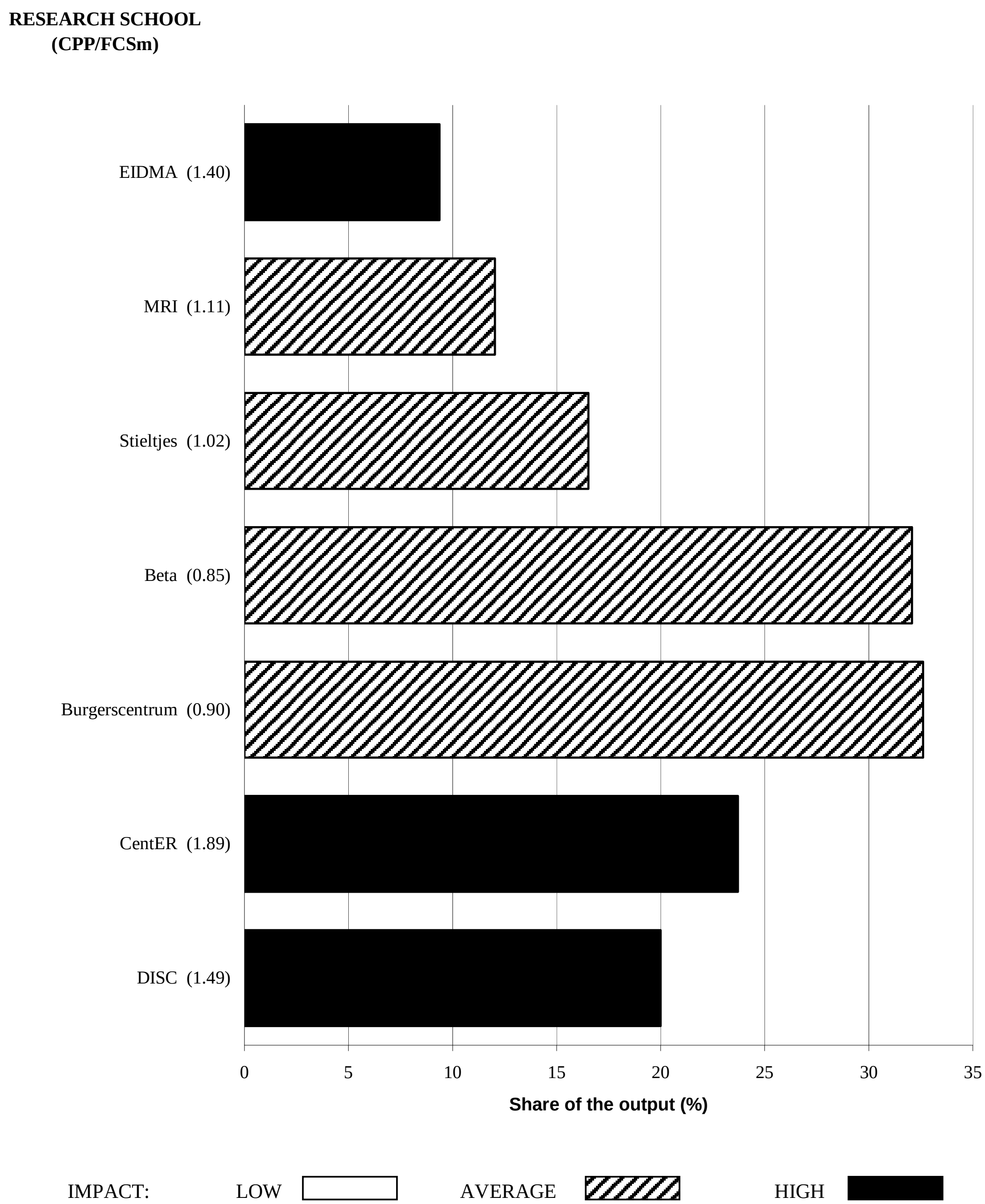
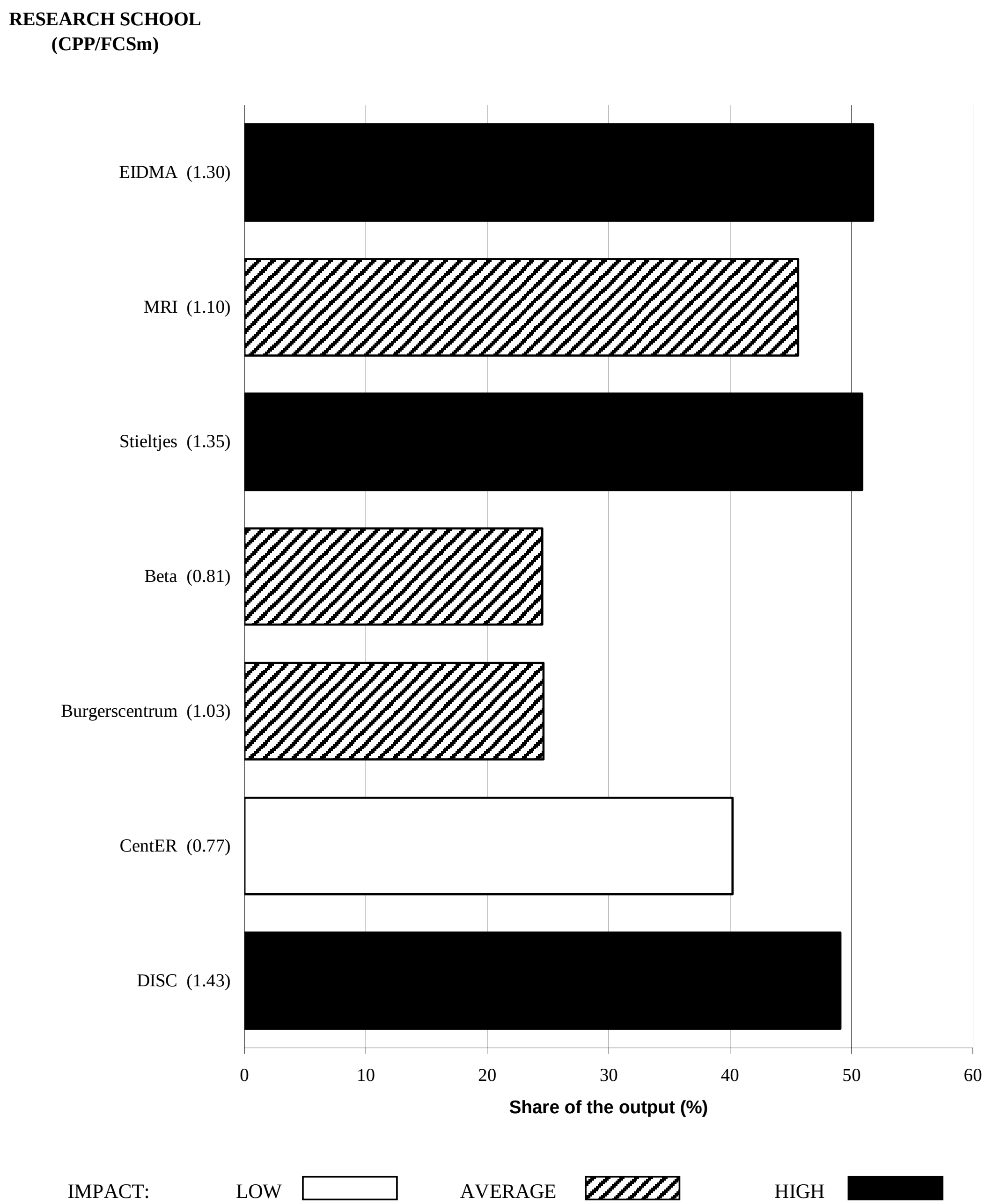


Figure 4c

Scientific cooperation profile
Output and impact per type
1993 - 2002

International cooperation



4.10 A survey of output and impact results for universities and research schools

In Figures 5a – 5b, the output (in absolute numbers) is displayed in combination with the impact (***CPP/FCSm***) related to this output, for universities and research schools.

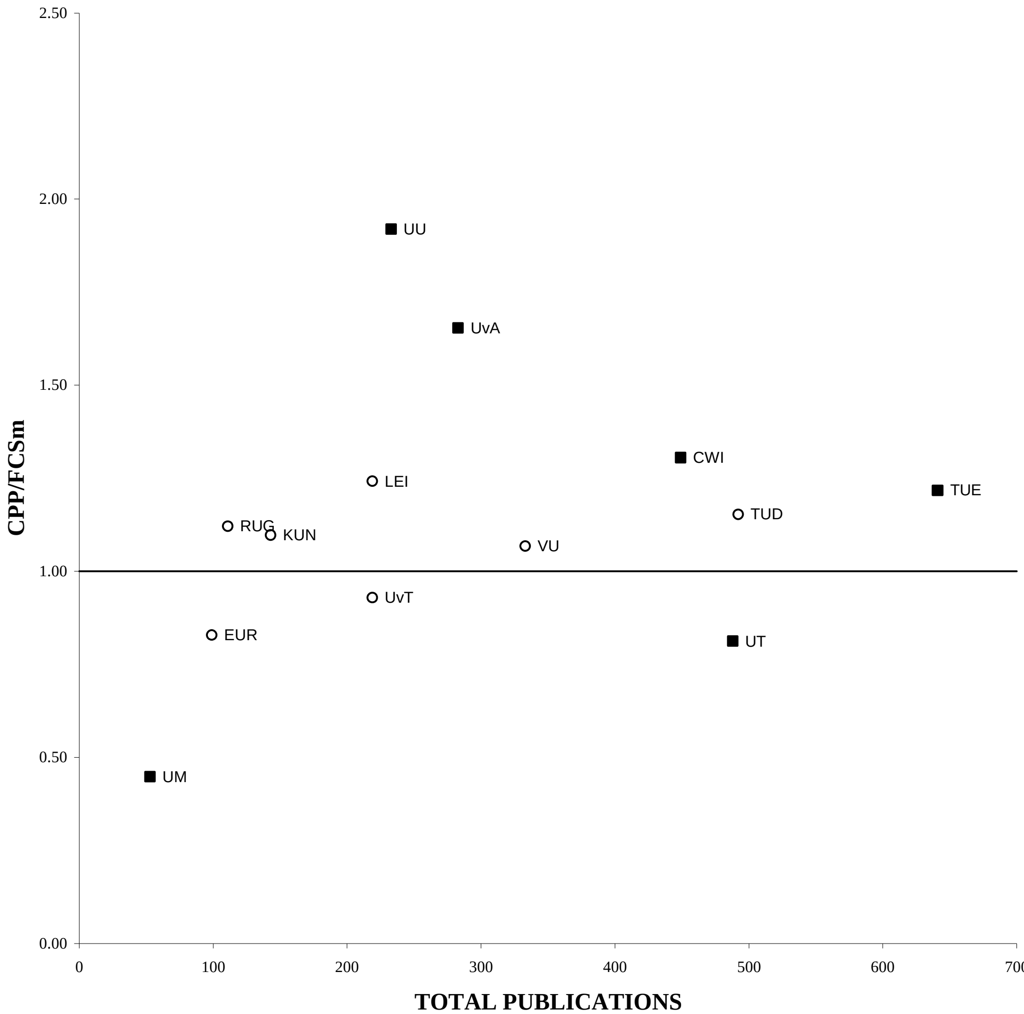
In **Figure 5a**, the output in Dutch mathematics research across universities is related to the field-normalized impact (CPP/FCSm). First, we observe strong differences in terms of the output per university. For four universities, we find more than 400 CI journal publications in a ten-year time-period (TUE, TUD, UT, and CWI). For two universities, we find impact scores significantly below world average level (UM and UT). However, for four universities, we find impact scores significantly above world average level (in order of descending number of papers, TUE, CWI, UvA, and UU).

In **Figure 5b**, we display a similar analysis for research schools in the Dutch mathematics landscape. As stated above, Stieltjes has an exceptional number of publications, and is by far the largest school in the Netherlands in terms of output. Only two research schools have impact scores somewhat, but not significantly, below the international field average, while the other five are well above world average level (with Stieltjes, MRI, and DISC having an impact that is significantly above world average level).

Figure 5a

Impact compared to world subfield average
1993- 2002

Dutch academic research in Mathematics

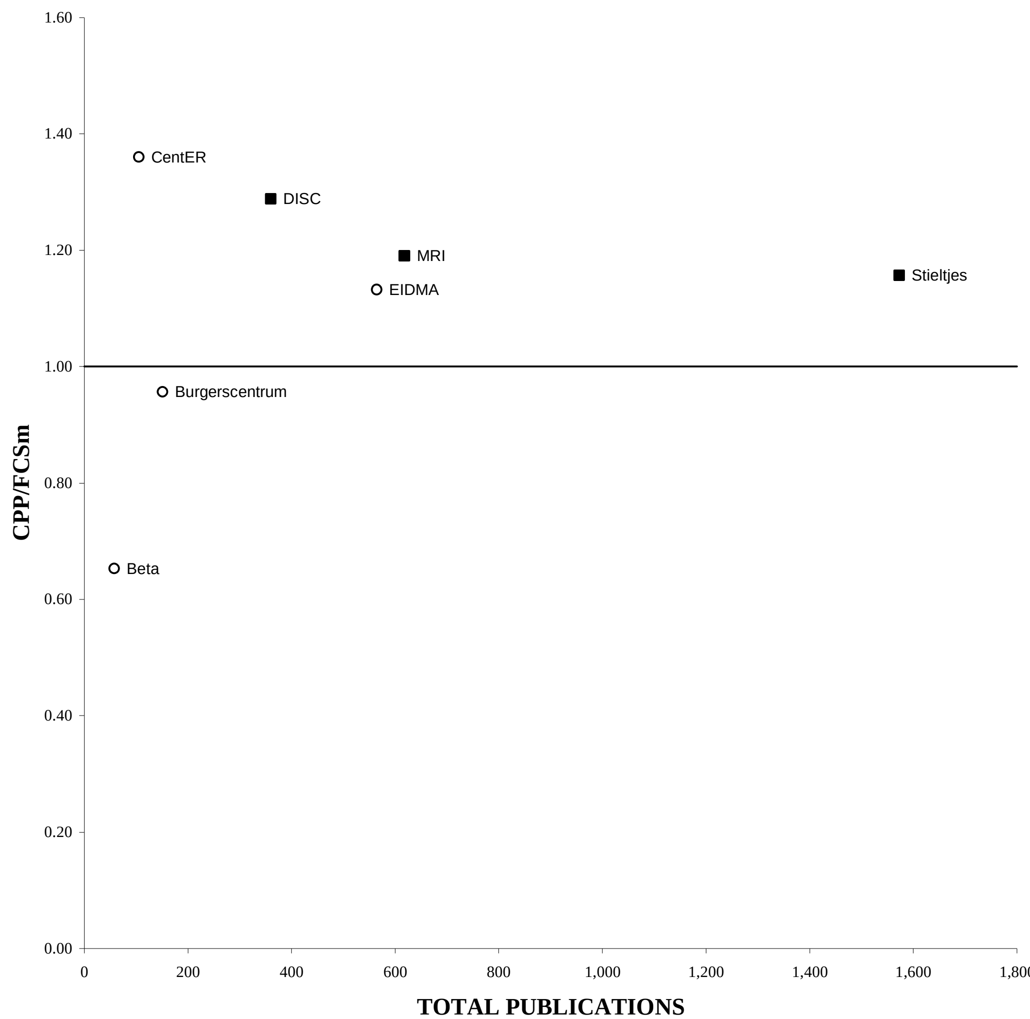


Black coloured squares above (below) the horizontal reference line represent groups for which the impact (CPP) is significantly above (below) world average (FCSm)

Figure 5b

Impact compared to world subfield average
1993- 2002

Dutch research schools in Mathematics



Black coloured squares above (below) the horizontal reference line represent groups for which the impact (CPP) is significantly above (below) world average (FCSm)

4.11 Knowledge users of Dutch mathematics research

To identify users of published Dutch mathematics research knowledge, a ‘knowledge user profile’ is calculated for Dutch mathematics research. A knowledge user profile is a breakdown of the publications citing Dutch mathematics research papers. These citing publications are categorized into subfields of science (based on the CI subject categories, see Section 3.3). A citing publication is categorized only once, even if it cites more than one Dutch mathematics research paper. Self-citations are excluded from the analysis.

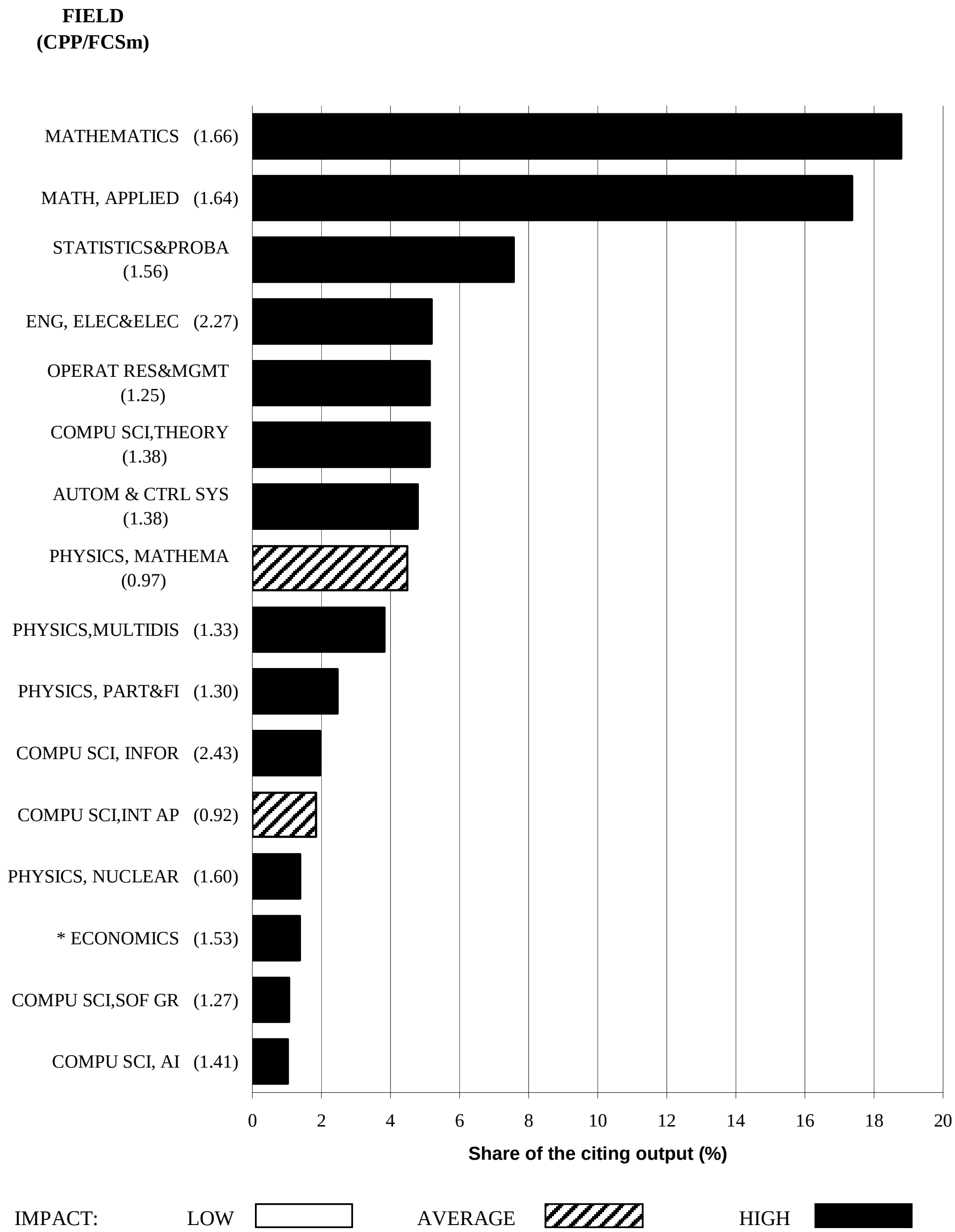
Figure 6 shows that Dutch mathematics research is cited most often in three mathematics and statistics fields: *Mathematics*; *Mathematics, applied*; and *Statistics & probability*. Other important citing fields are related to engineering, ICT research and physics research. Other prominent citing fields include *Operations research & management* and *Economics*. Remarkably, the total number of citations to Dutch mathematics research from fields outside the core domain of mathematics research exceeds that from the mathematics and statistical journals.

Only two of the citing fields display an average impact score, all other citing fields have high impact scores. This indicates that the CI output of Dutch mathematics researchers is noticed by high impact researchers, performing at the edge of the research frontier.

Figure 6

Knowledge user profile
Output and impact of citing fields
1993 - 2002

Fields citing Dutch mathematics research



5. Results of the non-CI analyses

The present study offers an analysis of the total scientific output of Dutch mathematics researchers participating in the present study, representing not only the share of the output as could be retrieved from the Citation Indices (*CI publications*), but also the part of the scientific output that appeared in other media, such as journals not-covered by the CI as source journal, books, book chapters, monographs, contributions to conference proceedings, and so on (*non-CI publications*). Publications directed primarily at a non-scientific public were not included. For the non-CI analysis, we searched for citations to non-CI publications in the source journals of the Citation Indices (see Section 3.7). An important difference with CI analysis is that the self-citation analysis for non-CI source items could only be conducted for first authors, as we do not always have the complete list of authors. Therefore, the resulting percentage of self-citations for non-CI items will often be considerably lower than that in the CI analyses where self-citations from all (co-) authors are removed.

As is indicated in Section 3.7, the results from the non-CI analysis should be considered as indicative, since we lack the proper data to make a full comparison. We recommend care in drawing conclusions from the present non-CI analysis.
Below, we will present the results of the impact analysis of Dutch mathematics output not covered by the previous sections, and make a comparison between the non-CI and CI based results. The impact scores for the non-CI publications are included for both institutions and research schools.

In **Table 6a**, we find the non-CI results per university. For the corresponding CI results we refer to Table 4.2. The university with by far the largest number of non-CI publications is the University of Technology Eindhoven (**P** = 1,648), followed by four universities with over 700 non-CI publications (University of Technology Delft, University Twente, University of Amsterdam, and the Free University of Amsterdam). However, the volume of non-CI output varies greatly among the universities. For some universities, we observe rather low numbers of non-CI publications (EUR (P = 63), KUN (P = 100), RUG (P = 112), and the UM (P = 148). The other universities and the CWI produce between 200 – 512 non-CI publications.

In general, the non-CI publications generate a considerable number of citations (as counted in the reference lists of publications included in the CI journal literature covered by the Citation Indices).

Table 6a: Results of the non-CI analysis for Dutch mathematics research, universities, 1993 - 2002

	P	C	C+sc	CPP	% sc *
CWI	512	1,049	1,184	2.05	11%
EUR	63	41	71	0.65	42%
KUN	100	407	461	4.07	12%
LEI	200	794	874	3.97	9%
RUG	112	253	330	2.26	23%
TUD	736	873	1,082	1.19	19%
TUE	1,648	3,083	3,556	1.87	13%
UM	148	167	213	1.13	22%
UT	764	1,187	1,413	1.55	16%
UU	250	1,250	1,366	5.00	8%
UvA	757	1,159	1,423	1.53	19%
UvT	250	337	407	1.35	17%
VU	720	1,814	2,031	2.52	11%

* The self-citation analysis for non-CI publications could only be conducted for first authors.
Therefore, the percentage of self-citations including those by co-authors will usually be much higher.

Table 6b: Results of the non-CI analysis for Dutch mathematics research, research schools, 1993 - 2002

	P	C	C+sc	CPP	% sc *
EIDMA	446	1,113	1,205	2.50	8%
MRI	562	1,831	2,096	3.26	13%
Stieltjes	1,351	2,297	2,726	1.70	16%
Beta	57	55	72	0.96	24%
Burgerscentrum	267	423	513	1.58	18%
CentER	118	188	227	1.59	17%
DISC	642	823	978	1.28	16%

* The self-citation analysis for non-CI source items could only be conducted for first authors.
Therefore, the percentage of self-citations including those by co-authors will usually be much higher.

The impact as expressed by the total number of citations (**C**) varies strongly among the universities (C between 41 (EUR) and 3,083 (TUE)).The universities with a relatively large volume of non-CI publications tend to generate many citations, although this does not necessarily lead to high mean impact scores (**CPP**) as well. We observe the highest impact mean impact scores for three universities with relatively small numbers of non-CI publications (UU (CPP = 5.00), KUN (CPP = 4.07), and LEI (CPP = 3.97)). The citation scores including (first-author) self-citations (**C+sc**) tend to be not a great deal higher than the citation total without self-citations. The percentage of self-citations varies between 8% (UU) and 42% (EUR).

When we consider the non-CI output of the research schools, we notice a strong variation across the Dutch research schools. **Table 6b** shows that the largest number of non-CI publications is found for Stieltjes, followed by DISC, MRI, and EIDMA. The highest impact (CPP) is found for MRI and EIDMA. In general, the non-CI output is concentrated in a number of universities and research schools.

Next, we compared the distribution of CI and non-CI publications over universities (**Figure 7**). While some universities, including EUR and KUN, display a strong preference for CI-covered journals, other universities show a relatively large output in non-CI media (e.g., TUD, TUE, UM, UT, UvA, and the VU). **Figure 8a** clearly shows that the impact generated by the two types of scientific publishing is not directly linked to the preference of publishing in either one of these two types: of the three mainly-ISI oriented universities, two (LEI, KUN) show a higher impact for their non-CI publications, while of the six strongly non-ISI oriented universities, four (TUD, TUE, UT, UVA) display a higher mean impact scores for their CI output.

In general, seven out of the thirteen institutes have a higher impact (CPP) for their CI publications than for their non-CI publications. However, the impact of non-CI publications is particularly important for KUN and LEI, as it is nearly twice that of their CI publications. This is less clearly so for UU, due to the relatively high impact of its CI publications. It should be noted that these three universities do not fare badly at all in the CI analyses, as they all have field-normalized impact scores (CPP/FCSm) that are somewhat to significantly (10% - 92%) above world average (Section 4.2). For the other ten institutes, either their CI publications have the higher impact or the difference in impact between CI publications and non-CI publications is limited to about 0.5 citations per publication. **Figure 8b** shows that the latter difference can be neglected, as it is due to the more stringent deletion of self-citations for CI publications (i.e., all self-citations by first author and co-author(s)) than for non-CI publications (i.e., deletion of self-citations only for the first author). In Figure 8b, for both CI publications and non-CI publications, the number of citations per publication (CPP) has been computed including self-citations.

Figure 7: Comparing CI-covered and non-CI covered output per university, 1993 - 2002.

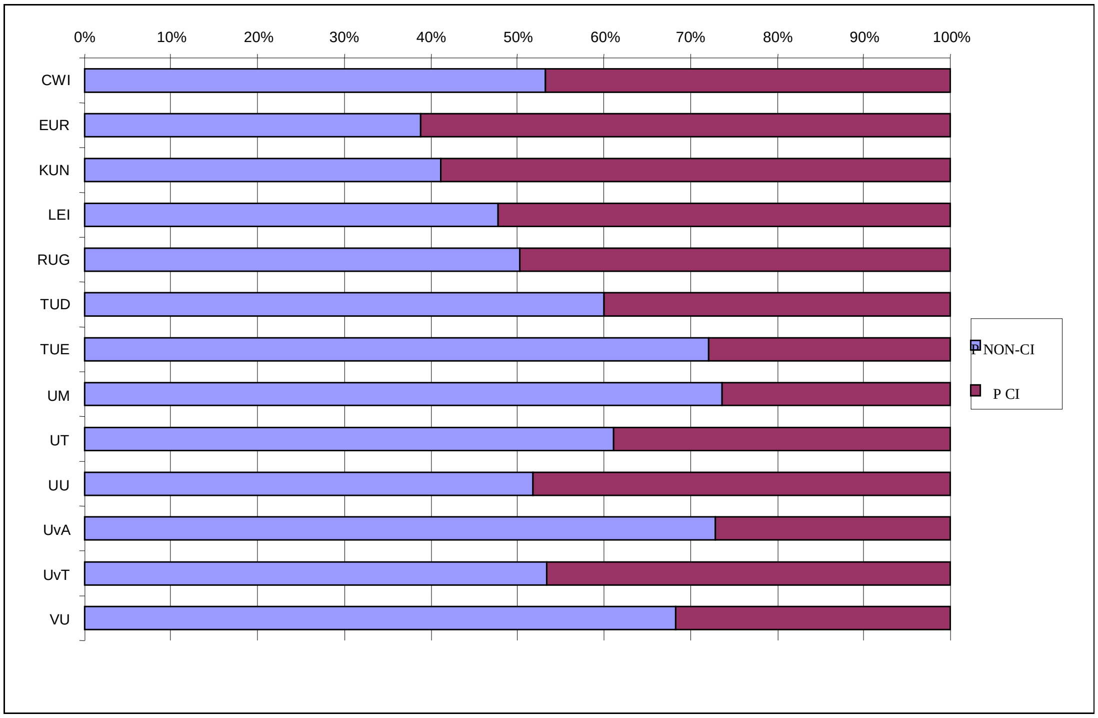


Figure 8a: Comparing CI-covered and non-CI covered mean impact (CPP) scores per university, 1993 - 2002.

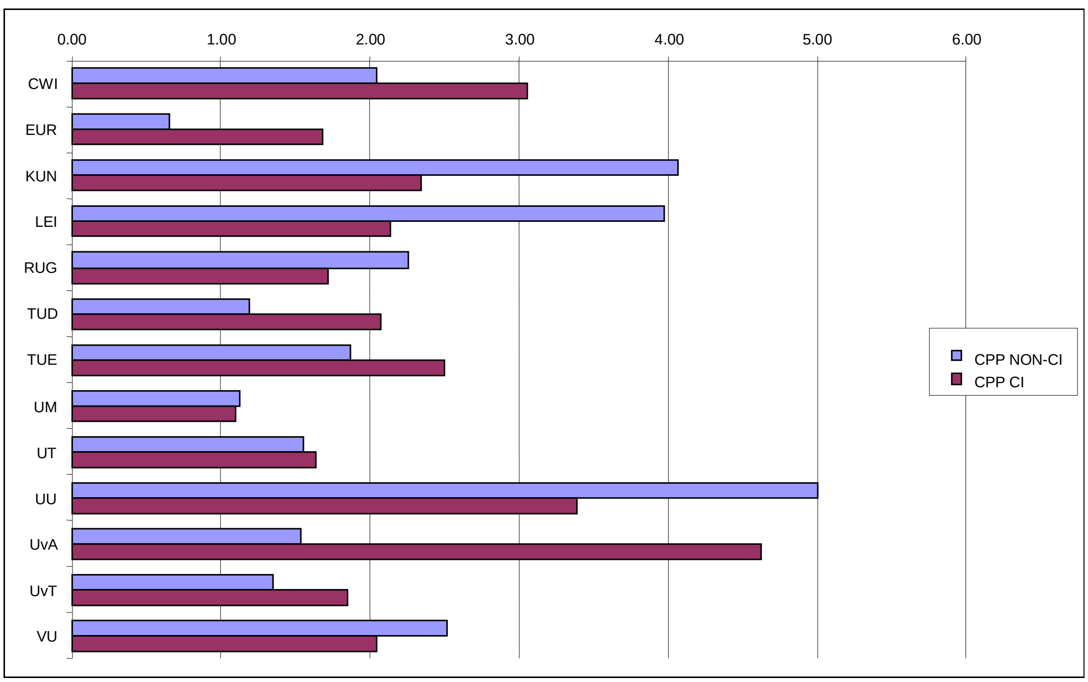
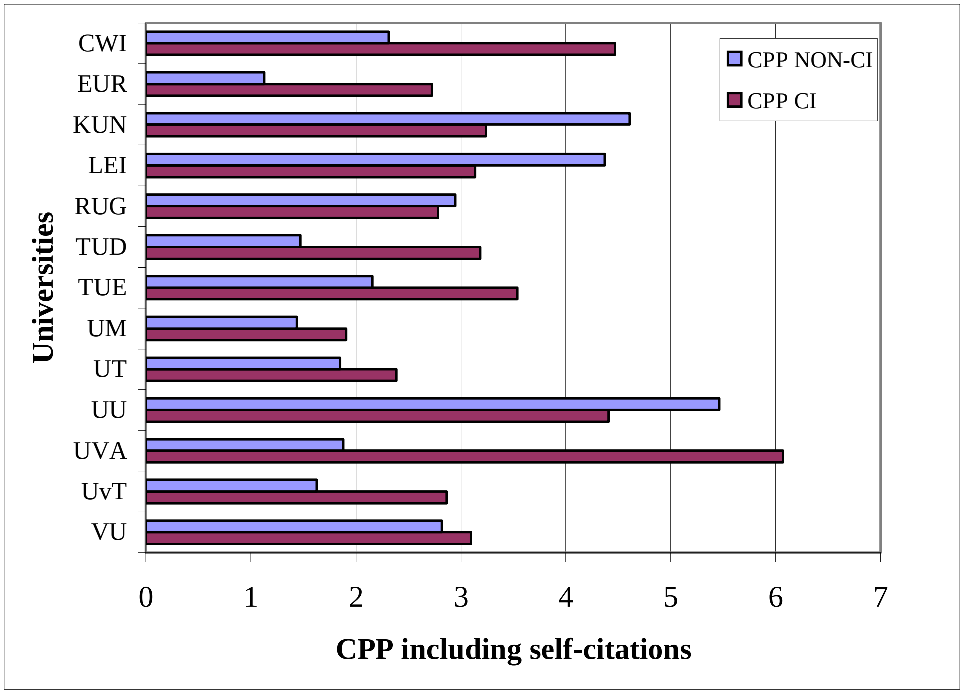


Figure 8b: Comparing CI-covered and non-CI covered mean impact scores per university including self-citations, 1993 - 2002.



The CPP scores do not take into account many important factors including the (differences in) age distribution of the various publication types, and differences in (distribution of) document types, such as high impact reviews for CI publications and high impact monographs for non-CI publications. Also, the impact of non-CI publications has not been compared to international reference values. Of course, CPP scores could only be computed on the basis of references contained in CI source journals. Conceivably, this might a disadvantage for non-CI publications, which might be cited to a greater extent in non-CI sources. With the present data, this possible disadvantage cannot be substantiated. However, the present citation impact scores also provide a considerable advantage to non-CI publications. It has been mentioned before that self-citations of co-authors have been removed from CPP scores on CI publications, but were retained for non-CI publications.

In sum, the findings show that:

1. Non-CI publications contribute considerably to the scientific output of Dutch mathematicians in terms of numbers;

2. The impact of non-CI publications is considerable, although it tends to be lower than that of CI publications. This is as expected, as the Citation Indices prefer to cover media with the highest impact level. Therefore, the results should not be interpreted as

indicating that the CI-analysis overestimates the impact of mathematics research in the Netherlands;

3. For two to three out of thirteen universities, the impact of non-CI publications is considerably higher than of their CI publications. However, these universities do not fare badly in the CI analyses. For the other ten universities, impact of CI publications is either higher than or about equal to that of their non-CI publications.

In general, the findings from the limited non-CI analysis seem to accord reasonably well with results and conclusions obtained in the CI analysis. The non-CI analysis shows limitations of the CI analysis as it allows a more extensive insight into impact and particularly output of mathematics research in the Netherlands. In subsequent research, it may be useful to conduct a more extended non-CI analysis. Recently, CWTS has started to develop methods to provide international reference values for non-CI publications (e.g., Visser et al., 2003). Here, separate worldwide reference values are computed for serial non-CI publications and for all other non-CI publications.

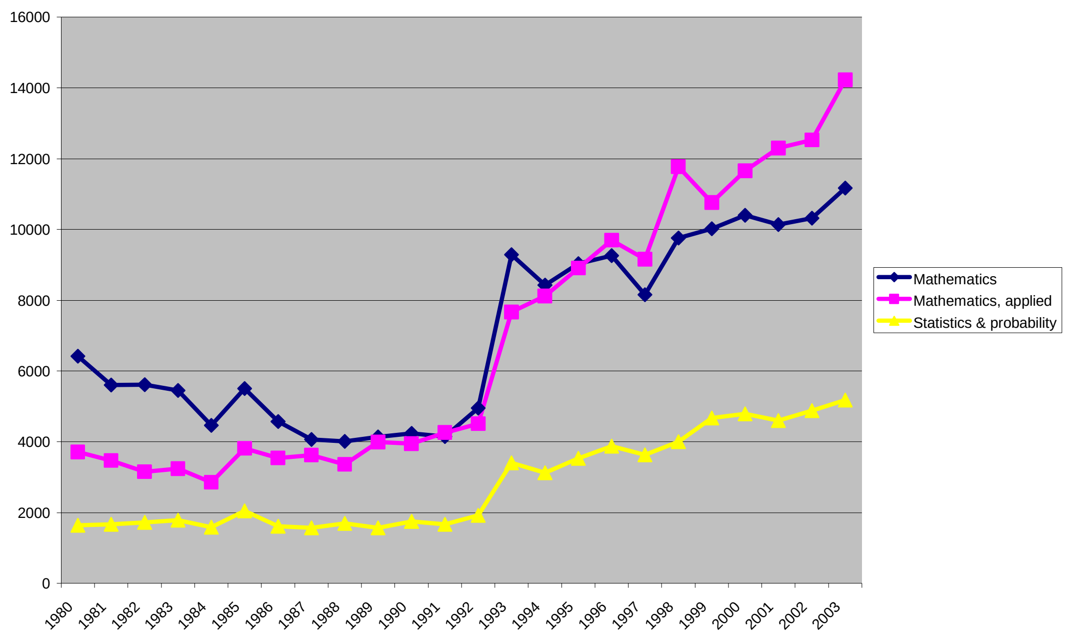
6. General characteristics of mathematics and statistics research

In this section we examine a number of general characteristics of mathematics research, as covered in the CI databases and as dealt with in this study. This analysis serves as background information against which some of the findings can be held for comparison.

The CI fields that are dealt with are *Mathematics*, *Mathematics - applied*, and *Statistics & probability*. These are the three most important CI fields in terms of number of publications in the present study. Topics that will be dealt with are changes in publication coverage, in external citations, and in self-citations over time, and the development of multiple-authorships in mathematics research during 1980 – 2003.

In **Figure 9**, the output numbers for each of the three fields *Mathematics*, *Mathematics - applied*, and *Statistics & probability* are displayed as they are found within the databases covered by ISI in the Citation Indices (CI). The strong increase in covered CI output since 1993 is related to the introduction of the so-called CompuMath Citation Index, a specialty citation index that deals mainly with the fields of mathematics and computer sciences.

Figure 9: Numbers of publications in *Mathematics*, *Mathematics - applied*, and *Statistics & probability*, 1980-2003



In **Figure 10**, the number of received citations is displayed for publications in each publication year between 1980 and 2003. Here, citations refer to the aggregated citation numbers received externally (that is, excluding self-citations) by the three fields combined. In Figure 10, we can observe two phenomena. In the first place, and related to the data in Figure 9, there is an increase of the number of citations received by the output of the 1980's, from 1991/1992 onwards. This is caused by the fact that the citing volume is increased significantly from then on by the addition of Specialty Citation Index CompuMath to the CI.

The second remarkable aspect that can be observed in Figure 10 is the relatively stable level of received citations over time. In general, we observe a peak in the number of received citations four to five years after publications appeared in the journals. Thereafter, the number of citations remains relatively stable, whereas in other fields of science, we observe a stronger decrease of the number of citations over time.

Figure 10: Numbers of external citations to publications in *Mathematics*, *Mathematics - applied*, and *Statistics & probability*, combined, 1980-2003

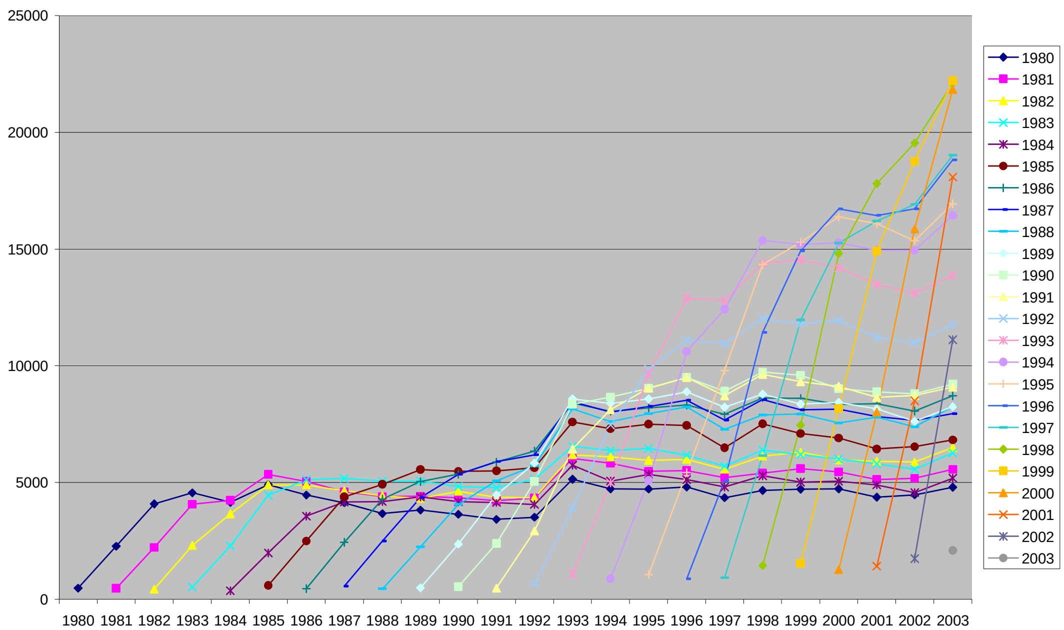
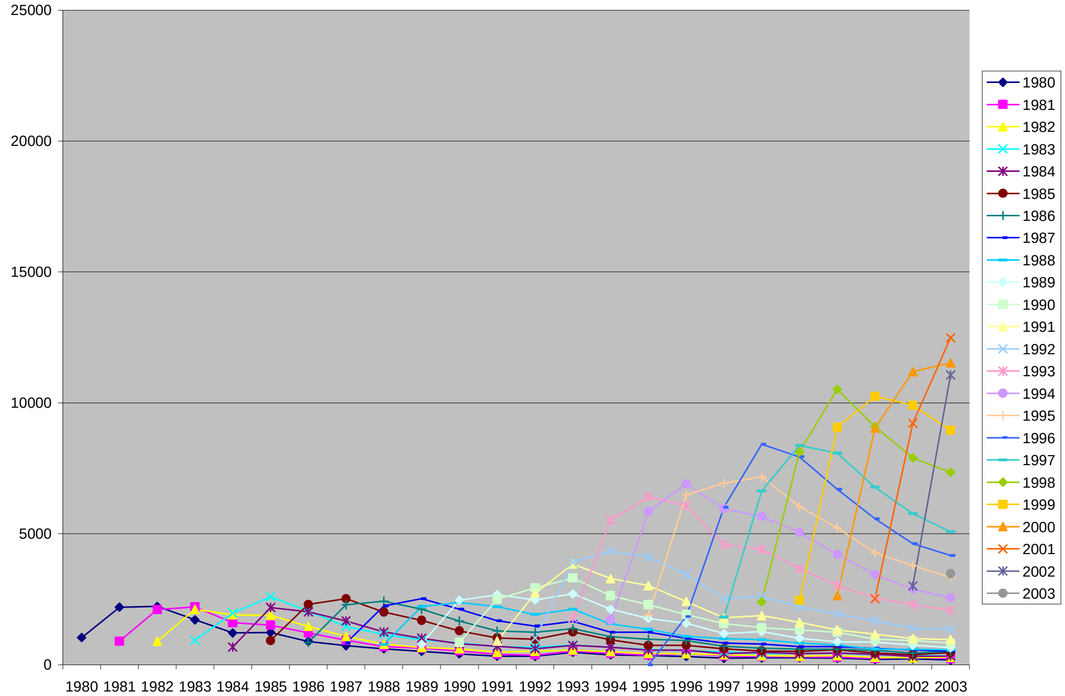


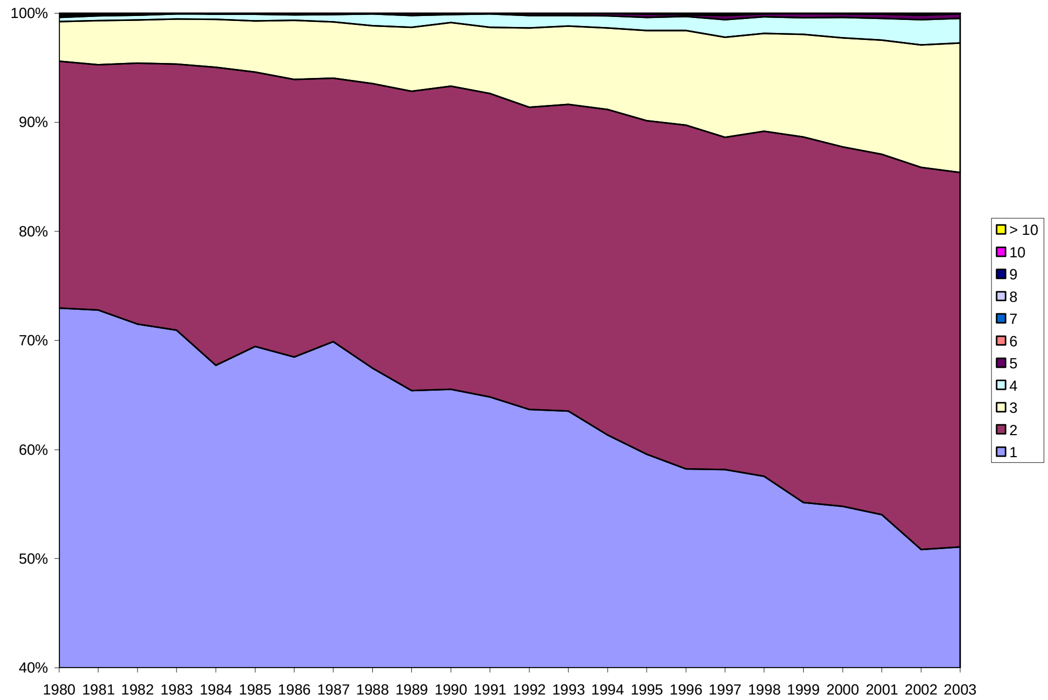
Figure 11: Numbers of self citations to publications in *Mathematics*, *Mathematics - applied*, and *Statistics & probability*, combined, 1980-2003



In **Figure 11**, we find the number of self-citations to the publications over time. Again, publications are combined for each publication year between 1980 and 2003. Here, in contrast with the development visible in external citations, we clearly see a strong decrease in citation impact shortly after the moment of publishing.

In **Figure 12**, we present the results of an analysis on the occurrence of multiple authorships in the combined fields of *Mathematics*, *Mathematics - applied* and *Statistics & probability*. For this analysis, we counted the number of authors per publication, and divided publications over eleven classes, indicating the number of authors attached to a paper. The last class exists of 'Ten authors or more'. One clearly observes that the percentage of papers with only one author decreases strongly between 1980 and 2003, while multi-authored papers account for a much larger share of the output in the field, especially papers with two or three authors.

Figure 12: Multi-authorships in publications in *Mathematics*, *Mathematics - applied*, and *Statistics & probability*, combined, 1980-2003



7. Conclusions and discussion

7.1 Bibliometric indicators

We start this final section with a few general comments on the use of bibliometric indicators for the assessment of research performance. It is our experience in previous studies on research performance in the natural and life sciences, medicine, the humanities, and in the social and behavioral sciences, that bibliometric indicators provide useful information to a peer review committee evaluating research performance. These studies revealed a fair correspondence between the results of bibliometric analyses on the one hand, and judgments on scientific quality by peers on the other hand. In our view, a quality judgment on a research unit, department or institute can only be given by peers, based on a detailed insight into content and nature of the research conducted by the group or institute in question. The citation-based indicators applied in this study, measure the impact at the short or middle-long term of research activities at the international research front, as reflected in publication and citation patterns. Impact and scientific quality are not necessarily identical concepts.

Bibliometric indicators cannot be interpreted properly without background knowledge on both the research units that are evaluated, and the subfields in which the research units are active. In fact, in previous studies we have encountered a few cases in which a bibliometric indicator pointed in one direction (e.g., a low impact), while statements by peers or even other indicators pointed in another direction (e.g., a high quality). Analyzing such discrepancies from a bibliometric point of view, specific limitations related to the bibliometric methodology applied in the study in question may be identified. While in most cases such limitations do hardly affect the results or have no effect at all, in exceptional cases the bibliometric outcomes may provide an incomplete or even distorted picture. For instance, the classification of journals into subfields ('journal categories') may be less appropriate for some research units, particularly when they are active in topics of a multidisciplinary nature. Then, in the calculation of the impact compared to the world subfield citation average, this world average may not be representative for the subfield in which such a research group or institute is active. If there are strong indications that the definition of the (sub)field in terms of CI journal categories is inadequate, then the journal-based world average (***JCSm***) is more appropriate. In particular, this latter case pertains to developing new interdisciplinary fields.

A second limitation concerns the coverage of the Citation Indices (CI). In specific subfields, particularly in applied or technical sciences, the CI coverage may be less adequate. Section 6 showed the improvement of CI coverage over time, especially for the CI fields *Mathematics, applied* and *Statistics & probability*. A second point concerns non-CI publications (e.g., articles in journals that are not or no longer covered by CI). For a number of research units, valuable additional information may be obtained by retrieving impact data for non-CI publications, as shown in Section 5.

Another example of a limitation of bibliometric analysis relates to time delays. It may take several years for a collection of papers to generate a high impact. We have analyzed research units that had generated only a moderate impact at the time. Confronted with the bibliometric results, several peers stated that these research units had recently made important contributions to the field. When we updated the results after a few years, several research units indeed showed a sharply rising impact curve.

We do not wish to imply that all discrepancies between bibliometric indicators and peer judgments are necessarily due to problems or limitations of the bibliometric methods applied (Nederhof, 1988). Equally, it would not be appropriate to attribute such discrepancies only to peers expressing incorrect or biased views on the scientific quality of a research unit. Still reasoning from the point of view of the bibliometrician, discrepancies between bibliometric indicators and peer judgments often constitute a research problem in itself and often, a considerable effort is required to examine a discrepancy in sufficient detail.

Nevertheless, also peer review has its disadvantages (Van Raan 1996). Therefore, the appropriate combination of peer-based qualitative assessment and quantitative, particularly bibliometric indicators appears to be the most successful approach in order to reinforce objectivity, transparency, comparability and reproducibility in the assessment of research performance.

Publications were excluded of retirees and of researchers no longer or not yet present in either a permanent or a tenure track position on September 1, 2003 (see Section 1). Also, relevant work of junior scientists publishing without their mentor may not always have been included. Scientists or units may have previously participated in one of our bibliometric studies. In some cases, different results are obtained. Reasons for differences between the present study and a previous one include changes in (status of) participating scientists, differences in publications that are included, and a difference in the period during which citations are collected.

7.2 Bibliometric results

In the current study, a number of remarkable aspects are worth referring to.
For the total set of publications, covering all publications classified as Dutch mathematics research, we find a decrease of the citation impact in the last period of the analysis (Section 4.1, Table 1). This phenomenon can be related to a number of universities, namely the Universities of Technology Delft and Eindhoven, but more importantly, the University of Amsterdam. Previous studies have shown cases in which a small number of papers, or even a single paper, could influence the bibliometric profile for a unit under study. Partly, this was due to the measuring method, which excludes particular highly cited publications, but here we have the situation that the impact was high, up until the period 1997 - 2001, followed by a sharp decrease in impact in 1998 – 2002. The observed decrease is largely due to the exclusion of three specific publications in *Nuclear Physics B* in 1997, which together receive 266 citations. These three publications are present in all 5-year blocks of publications in the trend study (starting with 1993 – 1997), except for 1998 - 2002.

In general, in academic mathematics research, we find large differences among the universities in the Netherlands, both in terms of the output as well as in terms of the impact (Section 4.2). Among the research schools, we find similar strong differences in output and impact (Section 4.3). One has to bear in mind that three research schools are purely mathematics oriented, while the other ones cover several disciplines, mathematics being one of these disciplines. One research school in particular, Stieltjes, is taking a dominant position in the Netherlands mathematics landscape.

With respect to the research profiles, dominant fields include the mathematics CI fields (*Mathematics* and *Mathematics, applied*), *Statistics & probability*, and *Operations research & management* (Section 4.6). In some of the research profiles, we clearly see links with either physics-related research, or with the technical sciences. Especially in case of the latter, for some mathematicians we have found high impact scores.

Concerning the types of scientific cooperation, we do not find any particular pattern across Dutch mathematics, with varying impact scores (Section 4.8). With respect to international cooperation across universities, we normally find high impact scores for the resulting output, but in this case we find both varying output shares (ranging from 35% to 60%) and varying impact scores (field-normalized impact ranging from 0.50 to 2.12). For the research schools, we obtain similar findings, although we find less low impact output here (Section 4.9).

The analysis of the CI and non-CI publications indicates that their number is more or less equal (Section 5). However, at the level of universities important differences are obtained. We find that some universities have a (much) larger share of their output in non-CI covered sources than in CI sources. In general, however, we observe a higher mean impact for CI publications than for non-CI publications. One has to keep in mind that citations received by both types of publications are retrieved from the Citation Indices, which makes it difficult to estimate to which extent both types of publications are cited by those sources that are not covered within the Citation Indices. In sum, the findings show that:

1. Non-CI publications contribute considerably to the scientific output of Dutch mathematicians in terms of numbers;
2. The impact of non-CI publications is considerable, although it tends to be lower than that of CI publications. This is as expected.
3. Only or two to three out of thirteen universities, the impact of non-CI publications is considerably higher than of their CI publications. However, these universities do not fare badly in the CI analyses.

The non-CI analysis allows a more extensive insight into impact and particularly output of mathematics research in the Netherlands. In general, the findings from the limited non-CI analysis do not seem to accord reasonably well with the results and conclusions obtained in the CI analysis.

The analysis of the bibliometric characteristics of mathematics and statistics research as covered in the journals processed for the Citation Indices shows the differences and similarities of these fields with other science fields (Section 6). The citations received by mathematics and statistics research papers over time indicate that the papers from these fields have in general a longer life cycle than for example the publications from biochemistry or molecular biology. In other words, publications from mathematics and statistics research get cited over a much longer period, and the highest number of citations is reached usually after four or five years. However, the self-citation pattern of the publications from mathematics and statistics shows a strong similarity with other research fields: researchers tend to cite their own work frequently in the short run, with self-citations fading out after a short period following publication. Yet another important resemblance with other fields is the increasing number of authors involved in writing papers in mathematics and statistics. This development is similar to international trends, where we observe an increasing internationalization, resulting in more authors per paper.

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Appendix

Statistical Test

Explanation of the significance test used by CWTS

The significance test used by CWTS is developed by W. Glänzel.
This test indicates whether the impact of a research units publication output differs significantly from all the publications in the journal(s) or the subfields(s) in which the research unit was active.
Citations have a skew distribution, but the average citation-scores within a distribution are approximately normally distributed. Being empirical data, citation data are subject to statistical ('random') influences. Their random error (which can be determined from the number of publications and from the citation-frequency distribution) must be taken into account when citation-averages are compared with each other, or with given 'fixed' values. The standard error *d(x)* of the mean citation-score *x* of a certain research unit depends of the size of the research unit and the variance of the citation distribution:

$$d(x) = D / \sqrt{n},$$

where *n* represents the number of papers published by the research unit, and *D* represents the standard-deviation of the citation distribution. We say that *x* is significantly larger / smaller than a given fixed value *a* at a confidence level of 95%, if *(x-a)/d(x)* is larger than 1.96, respectively smaller than -1.96. This method can be applied in the comparison of actual (***CPP***) with 'expected' scores (***JCSm***, ***FCSm***). Since the 'expected' scores ***JCSm*** / ***FCSm*** are based on rather large data sets, their 'random' error is much smaller than that of the value CPP, and can therefore be neglected. Thus, for comparisons the ***JCSm*** and ***FCSm*** can be treated as fixed values.

The shape of the citation frequency distribution is best represented by a *negative binomial distribution* (cf. Schubert & Glänzel, 1983). An important variable to estimate this distribution is the percentage of uncited publications. As a consequence, it may happen that the average impact of one research unit is not significantly different from ***JCSm*** or ***FCSm***, whereas a research unit with a lower number of publications and a lower volume of citations, but with a different percentage of uncited publications does yield a significant finding against similar ***JCSm*** or ***FCSm*** values.

Previous research at CWTS has shown that similar results are obtained by using a non-parametric statistical test. Only for small numbers of publications and citations, the Glänzel test may render a significant result where the non-parametric test is more conservative. However, the Glänzel test is robust when the number of publications and citations is not very small.