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Impact measures of interdisciplinary research in physics

ED J. RINIA,[1] THED N. VAN LEEUWEN,[2] ANTHONY F. J. VAN RAAN[2]

[1]*Foundation for Fundamental Research on Matter (FOM), Utrecht (The Netherlands)*
[2]*Centre for Science and Technology Studies (CWTS), Leiden University, Leiden (The Netherlands)*

In an evaluation of physics research programs in the Netherlands, held in 1996, assessments of research by expert panels were supplemented with bibliometric analysis. This latter analysis included the calculation of several bibliometric indicators, among which some taking journal impact measures as a baseline. Final outcomes of this evaluation provided an opportunity to re-examine the results of this assessment from the perspective of the degree of interdisciplinarity of programs involved. In this paper we discuss results of this latter analysis, in particular with respect to the relation between several citation based indicators and interdisciplinary research in Dutch physics.

Introduction

Should interdisciplinary research be reviewed the same way as disciplinary research? And if the answer is negative, which methods and indicators give reliable assessments of performance in interdisciplinary fields? This topic becomes increasingly important as in research policy more emphasis is put on problem oriented research which often encompasses traditional boundaries between disciplines. The topic has also been discussed in the context of a nation wide evaluation of research programs in academic physics and related subfields, held in the Netherlands in 1996.[1]

This evaluation was part of a regular quality assessment procedure of the universities in the Netherlands, which consists of a discipline wise judgement of research performance by international committees of independent experts. As part of the physics evaluation procedure, results of a bibliometric analysis had been supplemented to the expert committee, during the review procedure.[2]

After the evaluation, the outcomes were examined more closely. Among others the expert judgements for each program were compared with the outcomes of the bibliometric study.

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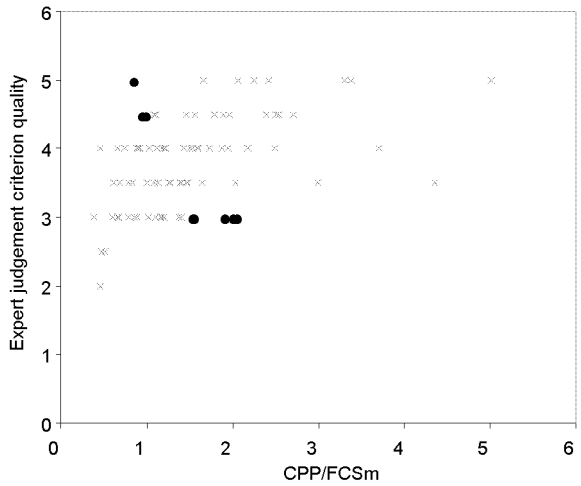

Figure 1. Scatterplot of expert judgements and relative citation rates for research programs in physics in the Netherlands.

In Figure 1 the correlation between the expert judgements for the criterion quality for programs in Dutch physics and the bibliometric indicator CPP/FCSm is shown.* The latter indicator normalises citation rates of publications of a program by the mean citation rates of the fields involved. Fields are defined by ISI journal categories. Quality scores given by the committee range from 1-5, with 5 being excellent. In this plot the scores of 95 physics programs at universities are given. In general, final expert judgements were found to be rather well in agreement with the outcomes of the selected bibliometric indicator, though not perfect. It should be noted, that the bibliometric data were made available to the committee during the review procedure. So, final judgements of the committee were not obtained independently from bibliometric results.

In spite of a general correlation, in some cases remarkable discrepancies between outcomes of the two methods are shown. Because such discrepancies may give insight in

* The bibliometric indicators used in this study are: the number of publications (P), the total number of citations (C), the average number of citations per paper (CPP), the average number of citations of journals in which is published (JCSm), the average number of citations of the fields in which is published (FCSm), the comparison of the citation average of publications with citation averages of journals involved (CPP/JCSm), the comparison of the citation average of publications with citation averages of the fields involved (CPP/FCSm) and the comparison of the citation averages of journals involved with those of the fields involved (JCSm/FCSm).

strengths and weaknesses of both methods, a small enquiry was held. Program leaders of eleven programs, showing strongly contrasting results, were asked for their comments. The programs concerned are marked. Seven programs obtained a low jury rating but high bibliometric impact scores. In four cases the opposite was shown.

Part of the comments were related to specific conditions of this evaluation and are not discussed here. Among the more general topics, several program managers mentioned the fact that their programs were situated at the borderline between physics and other disciplines. In some cases this was said to have been playing a role in the expert judgements, in other cases in the outcomes of bibliometric indicators. In the latter case among others, the use of ISI-journal categories as reference standard was mentioned to be less adequate in case of interdisciplinary programs.

In order to see to what degree this explanation was valid, and also on the basis of earlier indications, the results of the evaluation procedure were examined more closely from the perspective of interdisciplinarity. Main results of this analysis, also with respect to outcomes of the peer review procedure and implications in the context of research policy have been discussed elsewhere.[3] In this paper, we discuss results of this examination especially with regard to the appropriateness of (aggregates of) journal citation impact measures as a standard for comparison of the citation impact of interdisciplinary research programs.

Method

The bibliometric analysis, which formed part of the evaluation procedure, included data for about 200 research programs, mostly at physics faculties and institutes, covering more than 15,000 publications over the period 1985-1994.[2] These bibliometric data, gathered for the original evaluation procedure, were used again in order to determine the degree of interdisciplinarity of each program. Interdisciplinarity was determined on the basis of a ‘research activity profile’, which shows the distribution of the publication output of a research program among different subfields.[4] Subfields are defined by journal classification according to the journal categories included in the *Science Citation Index* (SCI) of the Institute of Scientific Information (ISI).

Interdisciplinarity is defined as the extent to which articles are published in journals attributed to other disciplines than those belonging to the main discipline of a program. In most cases this main discipline is Physics, being the key discipline in this evaluation procedure. We define the percentage of non-main discipline papers as the degree of interdisciplinarity.

In determining (main) disciplines, two disciplinary classification systems were used. One is a more narrow classification and attribution of subfields to disciplines, based on the first six characters of an ISI-category. In this way, for instance, only the eight ISI-categories starting with the term 'Physics' are assigned to the discipline of Physics. By using this definition, 25% of the programs included in this evaluation, have their main field outside the discipline of Physics.

In the other, more broad classification system, 17 main disciplines are distinguished. For instance, apart from the eight specific Physics ISI-categories, also the categories of Acoustics, Astronomy & Astrophysics, Crystallography, Instruments & Instrumentation, Microscopy, Optics, Spectroscopy and Thermodynamics are assigned to the discipline of Physics. This latter discipline-classification has been used before in science indicators reports in the Netherlands. By using this classification, for 18% of the programs involved, the main discipline is another one than Physics.

In summary, two variants of defining interdisciplinarity are examined here: the percentage of publications outside the main discipline in a restricted sense (A) and outside the main discipline more broadly defined (B). Interdisciplinarity, defined as such, was then compared with the outcomes of the physics evaluation. The analysis was restricted to 185 programs, the average number of publications per program being 96.

Results

Interdisciplinarity of the programs concerned, is confined in most cases to fields rather closely related to physics, such as materials sciences or chemistry. However, the assessment procedure also included programs with a much more diverse publication output, distributed among a larger number of disciplines. Numbers of programs are more or less equally spread among classes of degree of interdisciplinarity. Only two programs have a degree of interdisciplinarity of over 80%. The average degree of interdisciplinarity varies, depending on the discipline classification used, from 36% (A) to 33% (B).

It was found that for 93 programs for which a quality judgement was given by the expert committee, there was no significant correlation between these expert judgements and degree of interdisciplinarity. A Spearman rank correlation of r_s=-0.13 (A) and r_s =-0.11 (B) respectively, was found. It shows that interdisciplinary programs were not judged differently by the experts and that, according to the peers, the quality of interdisciplinary programs in Dutch physics on average is equal to that of mono-disciplinary ones.[3]

A comparison was made between the outcomes of bibliometric indicators per program and the degree of interdisciplinarity for 185 research programs included in the bibliometric analysis. A more detailed explanation of the bibliometric indicators concerned can be found elsewhere.[5] Linear correlation coefficients of the logarithmic values of a number of indicators and degree of interdisciplinarity were calculated.[6] A distinction was made between classes of program size in terms of numbers of publications. A class with 'smaller' programs (10-50 publications), a medium class (50-100 publications) and a class with 'larger' programs (>100 publications) was distinguished. Each class contains about 60 research programs.

It was found that a number of 'elementary' bibliometric indicators correlate slightly but significantly negative (at a confidence level of 99%) with the degree of interdisciplinarity of a research program. This means that with increasing interdisciplinarity a lower score of the bibliometric indicator concerned is obtained. An exception is the number of publications which shows no relationship with interdisciplinarity. However**,** the total number of citations (C) and the average number of citations per paper (CPP), show a small but significant negative correlation in almost all cases, ranging from r=-0.36 to r= 0.53. Only for the class of small programs (10-50 publications) and using the more restricted discipline classification (A), no significant correlation was found for both indicators.

Correlation coefficients show even more strongly that work in interdisciplinary programs in Dutch physics is published in journals with a lower average citation rate (JCSm). In each class of program size and for both discipline classifications a significant negative correlation is found between this journal impact measure and interdisciplinarity (ranging from r=–0.43 to r=–0.56).

The average citation rate of subfields (based on journal sets) in which a group publishes (FCSm), on average also appears to be lower for interdisciplinary research programs. In most cases (except for the class of large programs and using the more restricted discipline classification), the field citation mean correlates slightly but significantly with interdisciplinarity, with linear correlation coefficients ranging from –0.30 to –0.45.

The correlation found between degree of interdisciplinarity and a number of 'elementary' indicators may be partly related to the well known fact that citation characteristics vary by journal and subfield. For instance, in fields of applied physics the average citation rate is generally below the one in more basic fields, for example elementary particle physics. The tendency in interdisciplinary programs to publish in journals and subfields with lower average citation rates, in this analysis was found to be

stronger for programs at departments of applied physics than for programs in other physics departments. In the first case correlation coefficients range between –0.46 and –0.59, in the second case between –0.16 and –0.41.

Journal and field impact measures as reference standard

Relative impact indicators, which compare citation rates of papers with a world average of journals (CPP/JCSm) or fields (CPP/FCSm) involved, may be expected to correct for specific differences in publication and citation characteristics. In the analysis of the influence of interdisciplinarity on an evaluation of research programs in Dutch physics, we found that to a large degree this is the case. The indicator which compares (observed) citation rates with (expected) citation rates of the journals involved (CPP/JCSm), shows no relation with the degree of interdisciplinarity. Also when a split up is made between classes of program size and using both discipline classifications, in no case a significant relationship is found between this indicator and the degree to which research is done at the periphery of physics (correlation coefficients range from 0.0 to –0.28). It appears that normalising citation rates on journal impact measures, takes into account the more inter-disciplinary character of physics research programs in the Netherlands.

When the citation average per publication is compared with the citation average of the fields involved (CPP/FCSm), only in the case of large programs (>100 papers) we find a slight relation between impact normalised to field average and degree of interdisciplinarity.

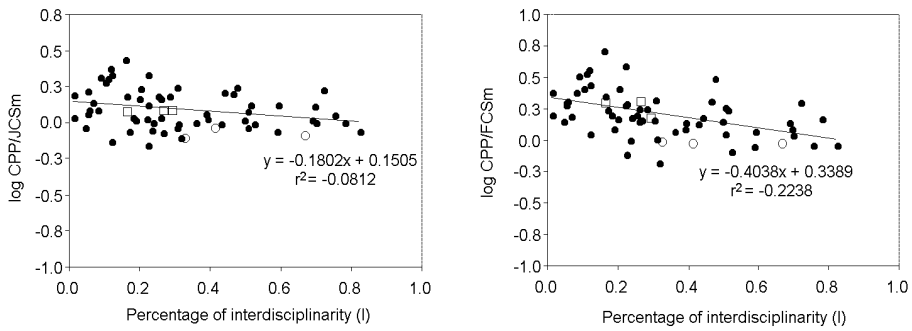

Figure 2. Degree of interdisciplinarity and relative citation rates for 63 large research programs in physics in the Netherlands. The selected programs which showed remarkable discrepancies between expert judgement and bibliometric indicators are separately distinguished. Programs with a high jury rating and a low bibliometric score are indicated with open circles, programs with a low jury rating and a high bibliometric score are indicated with open squares.

This is found both when a more narrow discipline classification (A) is used (r=0.47) as, to a slighter degree, when the more broad classification (B) is taken (r=0.35).

In the other two program classes no significant relation between the indicator CPP/FCSm and interdisciplinarity was found, except a very slight correlation for small programs (10-50 papers), when using the broad discipline classification (r=0.35).

The relative indicator (CPP/FCSm) compares the citation rate of a paper with the average citation rate of the specific ISI-category to which the journal in which it appears belongs. An explanation for the slight bias found for larger programs may be that in such cases world average citation rates of (sub)fields, may not be fully representative for the field(s) in which interdisciplinary groups are active. Possibly, field averages in that case are dominated by larger monodisciplinary journals. Fields (defined as larger journal sets) in such cases probably may be too broad to reflect the interdisciplinary character.

Some support for this presumption is found when for each program the indicator comparing the average citation rates of journals to average citation rates of fields involved (JCSm/FCSm) is analysed from the perspective of interdisciplinarity. The comparison of these two citation means gives a measure of the 'status' of the journals used by researchers in a program. In almost all classes of program size, correlation coefficients show that researchers active in subfields at the periphery of physics, publish in journals with an impact which generally is below the average impact of the fields involved. A more detailed analysis of the journals involved was not carried out. However, correlation coefficients of the degree of interdisciplinarity and the indicator JCSm/FCS (which vary between –0.36 and –0.49) give an indication that interdisciplinary research in Dutch physics is generally more often published in lower impact journals'.

Conclusion

Re-examination of results of an evaluation of physics research programs in the Netherlands shows that outcomes of relative indicators, applied in a bibliometric analysis, are not biased in case of interdisciplinary research. Programs at the periphery of physics receive slightly but significantly lower outcomes on some elementary bibliometric indicators, like total number of citations or average citation rate. This can be explained to a large degree by the well known fact that citation characteristics vary between journals and fields. Variations in these characteristics also will play a role in the small but significant relation found between degree of interdisciplinarity of a program and the average citation rate of journals and the average citation rates of fields in which researchers in these programs publish.

The correlations found between elementary indicators as the average citation rate of a program and degree of interdisciplinarity are a warning against uninformed use of citation data, especially in the case of interdisciplinary research. Also the correlations found between interdisciplinarity and journal impact measures may be a warning against the uninformed use of citation-based characteristics of journals, like ISI's journal impact factors.

Relative indicators correct for differences between journals and fields by using (aggregates of) journal citation impact measures as a standard for comparison of the citation rates obtained by research programs. It was found that in case of interdisciplinary research programs in Dutch physics, the indicator normalising citation rates to the average of journals involved, is the most appropriate bibliometric measure.

Finally, we conclude that further research on journal impact measures in relation to interdisciplinary research, defined by bibliometric and other measures, will be needed.

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Address for correspondence:
ED J. RINIA
Foundation for Fundamental Research on Matter
P.O. Box 3021, 3502 GA Utrecht, The Netherlands
E-mail: ed.rinia@fom.nl