A Decade after Hicks & Katz: Interdisciplinary Research Re-Examined

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Abstract:

Following the innovative method from the SPRU-paper by Hicks & Katz in 1996 we investigate different aspects of the interdisciplinary trends in Europe. The paper uses Thomson/ISI-data covering the period from 1982-2003. The trend towards multi- and interdisciplinarity in the natural, medical and technological sciences is growing stronger over time. In our analysis we use number of publications and citations in different areas of research, countries, sectors and universities. This gives an overall picture of interdiscplinarity as a phenomenon. Detailed Swedish data is used as a case study. The paper concludes with a short discussion on interdisciplinarity and research level.

Introduction

In their innovative article from 1996 Hicks & Katz, then at SPRU, tested hypotheses that had been put forward by the Gibbons group (1994) and John Ziman (1994). Ten years ago many observers believed that interdisciplinary or even transdisciplinary research would become significant for almost all types of research. It is no coincidence that the Gibbons book was financed by one of the Swedish agencies for boundary-spanning research, the FRN (The Swedish Council for Co-ordination and Planning of Research). That agency, politicians and officials from the Ministry of Education and Science supported ideas of a transdisciplinary transition during the 1990's.[i] In Sweden, when the liberal government came to agency in 1991, a number of radical ideas on how to transform research in the direction of applicability and usability for industrial and political ends were brought to the political arena. Interdisciplinarity were among these ideas which were supported by the new research foundations created at that time. The regulations for these foundations stated that they should fund interdisciplinary research programs.[ii]

Since then the term for interdisciplinary research (IDR) is frequently used in Swedish governmental bills and investigations (Sandström 2005). Also, governmental directives to the research councils state that they should arrange for and give adequate support to IDR. The number of articles debating IDR-issues increased during the 1990s, but since 2002 interest seems to be decreasing somewhat.[iii] Approximately one percent of the articles in Web of Science (WoS) use IDR-terms (multi- inter-, transdisciplinary) in the title or abstract. The increase for these articles is 250 % between 1991 and 2005, while the total number of articles during the same period increased by only 40 %. The highest numbers of articles are found in the subject areas of clinical medicine (surgery, public health, rehabilitation etc.), environmental science and educational sciences.[iv]

Is there an increasing trend towards interdisciplinarity in modern science? This question will be investigated upon in this paper. The outline is the following:

First, taking for granted that the proposed Hicks & Katz-method of using multi-assigned journals is an interesting solution to the problem of how to measure interdisciplinary research we will discuss the guidelines and replicate their study using data from Thomson/ISI Web of Science.[v] Also, we will investigate the frequency of interdisciplinary publications after the period covered in the Hicks and Katz paper (i.e. 1991–2003).

Secondly, regarding interdisciplinary publications we perform a detailed analysis of Swedish universities by making comparisons between universities with a set of different faculty areas of science.

Thirdly, we summarise our reflections on possible flaws in the Hicks & Katz method.

Methods

In their work Hicks and Katz (1996) proposed a classificatory scheme using multi-assigned journals in the ISI database. For their purpose they created four different classes of research, of which three were defined as multi- or interdisciplinary (the categorisation is further explained in figure 1).

A. Single-field journals (medicine, biology, physics etc.)

B. Cross-field journals

B.1. Interfield	IFLI (life), IFNA (natural), IFENMA (eng &materials)
B.2. Interdisciplinary	LIENMA (life+eng&materials), LINA (life+natural), NAENMA (natural+eng&materials)
B.3. Multidisciplinary	MUL (life+natural+eng&materials)

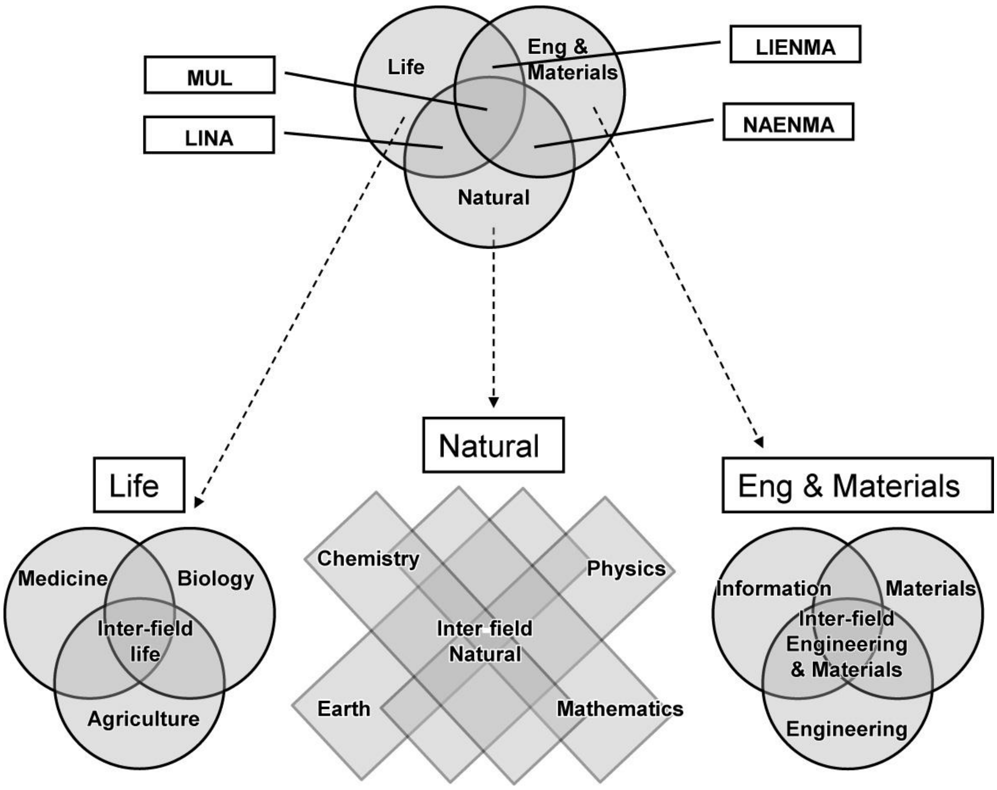

Figure 1. SPRU-method for classification of interdisciplinary journals (with minor corrections to Katz & Hicks 1997).

The logic behind the classification that creates cross-field areas is illustrated in figure 1. Articles are classified into scientific fields based on the journal in which they appeared. ISI classifies journals by using journal to journal citations patterns, expert assessment and other feed back. Hicks & Katz aggregated the subfields (micro-classes) into 11 fields (macro-classes) and three disciplines (life sciences, natural sciences and materials & engineering). Note that arts & humanities and social science were not included in the analysis. The ISI practices of multi-assignment of journals make it possible to create new subclasses of those journals that cross more than one field (interfield) and those that cross more that one discipline (interdisciplinary). Journals that were assigned to subfields that encompassed all three disciplines were called "multidisciplinary".

Hicks & Katz made three additions on an ac hoc basis: 1) journals classified to the ISI sub-field "environmental science" were included in the MUL (multidisciplinary) category; 2) journals classified as "multidisciplinary" by the ISI (e.g. *American Scientist, Current Science*, *Nature* and *Science*) were also included in MUL, and 3) five subfields were reassigned to "interfield".

In the present study we will employ the formal method of ISI multi-assignations; we see no theoretical reasons for the argument that some areas are multidisciplinary *per se*. For the same reason the ISI- category "multidisciplinary" is not included among cross-fields. As explained by Katz & Hicks themselves (1997) such journals cannot be considered as publishing interdisciplinary research. In the case that these journals do not have other assignments they will not be included in any of the cross-fields. Instead, journals like Science are considered as a single-field journal.[vi]

Today there are many more subfields in the ISI-database; 219 as compared with 154 in the beginning of the 1990's.[vii]. We have classified these to the macro-classes proposed by SPRU in the same manner as Hicks & Katz. It should be observed that the ISI-assignments are revised each year. Our analysis is based on articles and reviews only. Swedish addresses have been unified in a detailed process where all unique entries have been scrutinised by hand. Our set of data covers the period 1982 2003, while Hicks & Katz covers 1981-1991. This gives us the opportunity to study what has happened ten years after the analysis of Hicks and Katz.

Literature overview

For many observers today the question "Where is Science Going?" is closely related to the issue of multi- and interdisciplinarity (ARC 1999, NAS 2004). Recently, several articles have been published and an intensive scholarly discussion is now ongoing.[viii]

Morillo et al. (2003) describe and discuss many of the problems that are related to finding a solution to the question of how to measure interdisciplinarity in research. The Spanish group concludes that multi-assignation as a method is good enough for giving a broad picture. But, there are a number of problems on a more detailed level. Based on their research they propose a clustering technique for grouping of different areas of interdisciplinarity depending on the combination of on the one hand (number of) multi-assignations per area and on the other hand grade of external assignations per area.

The Spanish group has also published a study that consists of an interesting test of the multi-assignation method (see Morillo et al. 2001). Their study on chemistry areas reports a convergence between the ISI multi-assignations, percentage of extra-disciplinary citations, and the Chemical Abstracts multi-assignation by sections. A closer look reveals that there is no necessary relation between assignations and interdisciplinarity.

However, an area that has a documented widespread relation to other areas did not appear to be multidisciplinary according to the SPRU-method and vice versa. Still, the method is interesting due to good research economy.

Morillo et al. (2003) concludes that the method of using multi-assignations as a proxy for interdisciplinarity is valid in an overall sense. However, they do not consider multi-assignation in categories "as an appropriate indicator, since it is artificially limited by the needs of the classification" (Morillo et al. 2001). Due to this position they did not apply any trend analysis (publications over time) according to the ideas of Hicks & Katz. Even if the Morillo group are perfectly correct in their characterisation it would be interesting to see what happens if the database is used for these purposes.

Another limitation is that they only touch upon the question of whether there are other structural dimensions involved. The statement by van Raan (2000) that *"technology acts as a bridge between the different scientific disciplines, and without technology domains of human knowledge would remain largely isolated*" gives a hint of the problem involved. This observation is an invitation to conduct an analysis of the role of applied engineering & materials science in the process of interdisciplinarity.

Results: increased interdisciplinary research

Morillo et al. (2003) have reported a number of descriptive data on multi-assignations in the ISI database, for example half of the journals within each category are multi-assigned. Also, there are small but significant differences between macro-classes: the area of clinical medicine has a lower rate of multi-assignations, while other areas seem to be rather much alike in this aspect.

Figure 2 shows the percentage of cross-field documents in the ISI database during the 22-year period 1982-2003. While single-field articles have an yearly average growth of 3,07 percent articles in cross-field journals have a growth of 8,27 percent per year (geometrical mean). While the U.S.A. levels off the EU-countries (EU 15+Norway) show a steady increase of "interdisciplinary" articles. Sweden follows the EU trend.[ix]

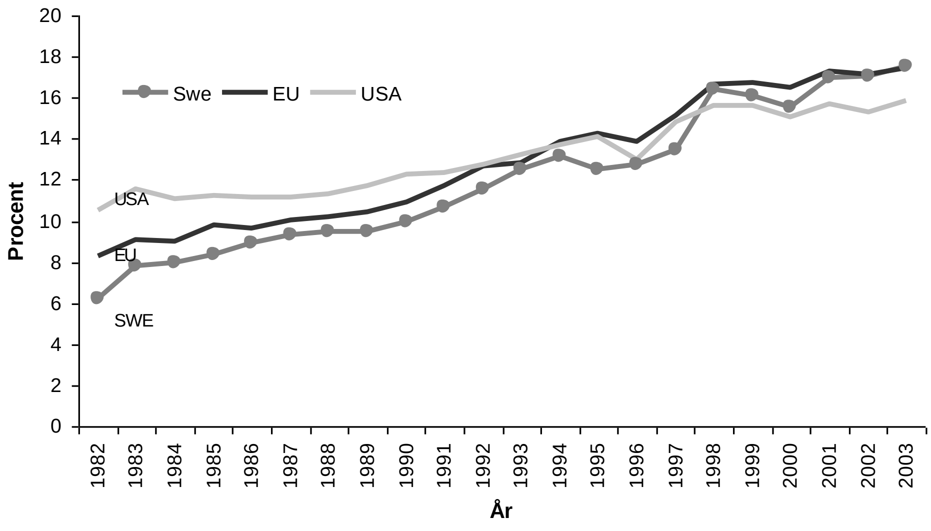

Figure 2. Percent articles in cross-field categories of total articles 1982-2003.
Source: Thomson ISI Web of Science

By looking closer at the assignment of sub-fields it appears that perhaps the ISI were lagging in their procedures during the 1980s. During the first half of that decade about 10 percent of the journals have blank sub-fields (approx. 400 journals). Later, until the beginning of the 1990s, they assigned almost all of the journals to one or more subfields. During that decade the growth of journals in the database was continuously growing and a number of European journals were added. In 1997 ISI decided to rearrange the sub-fields so that a number of new categories were introduced, e.g. ISI created in almost all fields a category for interdisciplinary journals, (see Table 1). From 1991 and onwards journal issues in the category "Multidisciplinary sciences" had a yearly decrease of almost 6 percent (from over 1000 to around 500). To a large extent this explains the marked increase of articles in 1998. Also, this illustrates some of the problems associated with using a database where categorisation is a dynamic process influenced by the studies of science policy. It is most likely that Hicks & Katz (1996) was an impetus for ISI to rearrange and develop new sub-fields.

Table 1. Examples of sub-fields introduced into the ISI database from 1998.

ISI sub-field
AGRICULTURE, MULTIDISCIPLINARY
CHEMISTRY, MULTIDISCIPLINARY
ENGINEERING, MULTIDISCIPLINARY
GEOSCIENCES, MULTIDISCIPLINARY
INTEGRATIVE & COMPLEMENTARY MEDICINE
MATERIALS SCIENCE, MULTIDISCIPLINARY
MATHEMATICS, INTERDISCIPLINARY APPLICATIONS
PHYSICS, MULTIDISCIPLINARY
PSYCHOLOGY, MULTIDISCIPLINARY

Source: Thomson/ISI Web of Science.

Citations to multi-assigned journals

When one analyses cross-field articles it is necessary to relate these to single-field articles by various aspects. First, let us display the distribution over time of different types of articles before we start an analysis based on citations. It seems that the cross-field articles are a growing category, but what types of categories are losing their shares? Splitting the single-field category into two with the large ones (Chemistry, Medicine and Physics) on the one hand, and the smaller ones (Agriculture, Engineering, Earth sciences, ICT, Materials science, Mathematics etc.) on the other hand, shows that the smaller ones are holding their share and the large ones are losing (see figure 3).

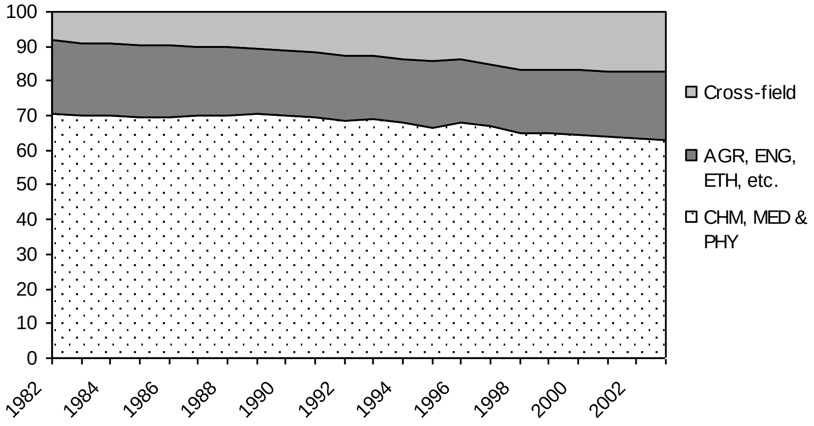

Figure 3. Percentage of articles (EU 15) distributed over categories, cross-field, and two set of single-field 1982-2003.

If we relate this to citations we get a rough picture of trends in the quality dimension. To do so we use the ratio between citations and articles in the respective SPRU macro-classes. The categories with chemistry, medicine and physics are slightly increasing, which indicates that articles in those categories receive more citations per article. Apart from the last two years the cross-field categories are quite stable, and the small single-field categories have a negative trend since the middle of the 1990's.

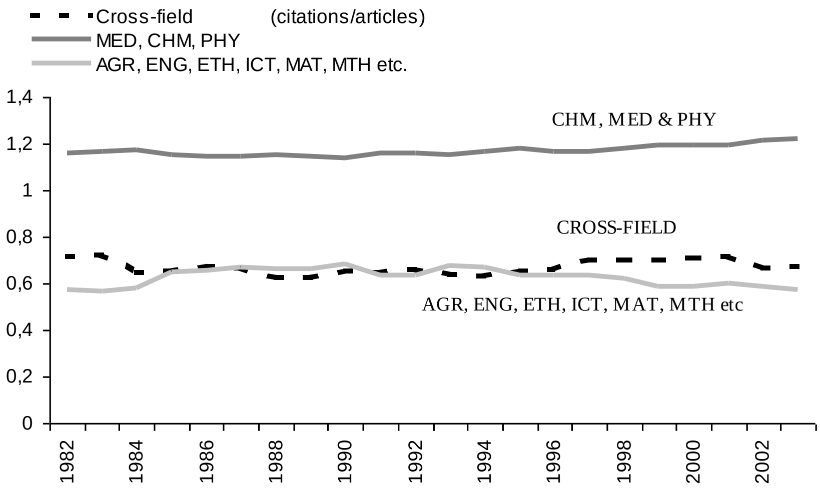

Figure 4. Ratio between citations and articles for three groups of SPRU macro-classes 1982-2003 (EU 15).

Table 2. Percentage of articles (fractionalised) and citations (fractionalised) in cross-field journals of total articles for six countries.

Period	1984-87	1988-91	1992-95	1996-99	2000–03
A	Articles	Articles	Articles	Articles	Articles
Denmark	7,35	9,40	12,25	15,88	16,93
Finland	8,01	10,43	12,19	14,10	16,93
Sweden	8,65	9,91	12,41	14,67	16,79
Netherlands	12,15	12,41	14,17	16,23	16,63
Germany	11,01	11,74	13,70	14,76	16,04
United Kingdom	8,81	10,13	12,82	15,06	15,80
B	Citations	Citations	Citations	Citations	Citations
Denmark	5,70	6,67	8,56	11,17	11,86
Finland	5,95	7,18	8,01	9,69	12,80
Sweden	6,16	6,81	8,27	10,49	12,23
Netherlands	8,28	8,18	9,57	10,98	11,39
Germany	7,42	7,55	8,70	10,07	11,46
United Kingdom	5,23	6,13	7,94	10,30	10,23
	B/A	B/A	B/A	B/A	B/A
Denmark	0,78	0,71	0,70	0,70	0,70
Finland	0,74	0,69	0,66	0,69	0,76
Sweden	0,71	0,69	0,67	0,72	0,73
Netherlands	0,68	0,66	0,68	0,68	0,69
Germany	0,67	0,64	0,63	0,68	0,71
United Kingdom	0,59	0,61	0,62	0,68	0,65

Source: Thomson/ISI Web of Science (1984-2003)

With this background we move on to an analysis based on countries and focused on comparisons that are relevant for Swedish science. Out of the fifteen European countries we have selected six for a more detailed analysis, three Nordic countries (Denmark, Finland and Sweden) and three West-European countries (The Netherlands, Germany and the UK). Table 2 indicates that there are few differences between the countries in the last period (2000–2003). Obviously, the countries display different historical trends as is seen in the table. Denmark, Finland and Sweden go from a low share in the first period to a high share of cross-field publications in the last period, 2000–2003. Articles from Finland and Sweden are at the same time the countries which received the highest share of citations. Consequently, the ratios for these countries are a bit higher than those for the others. United Kingdom as well as U.S. has much lower ratios. (U.S., which is not displayed, is well under 0.6 up until 1998). Among the explanations to this it can be mentioned that the engineering sciences tend to have a lower ratio.

Interdisciplinarity at Swedish Universities

As mentioned above, Hicks & Katz established seven categories of cross-field publications. Figure 5 shows the publications rate of Swedish universities in these fields during the period 1988–2003. The interdisciplinary fields of NAENMA (natural, engineering & materials), LINA (life sciences and natural sciences) and IFLI (interfield life sciences) have the largest share of total output and a steady growth. The other cross-fields seem to have a modest increase during this period. This indicates a wide scope of interdisciplinary publications in the country.

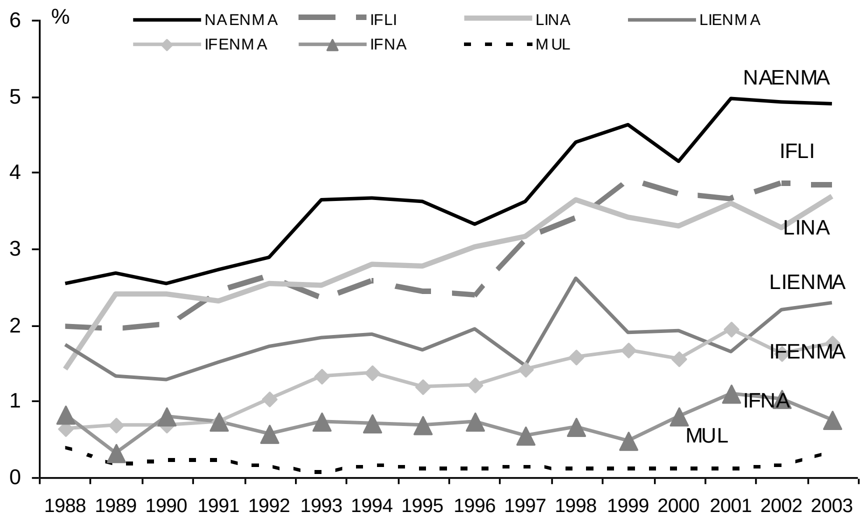

Figure 5. Distribution of cross-field publications as share of total output from Swedish Universities during 1988-2003. For definitions of crossfields see figure 1.
Source. Thomson/ISI Web of Science (1988-2003). Note: Fractionalised data.

Table 3. Distribution among cross-fields per performing sector in Sweden 2001-2003.

	Industry	Res Institutes	Universities	Univ hospitals
NAENMA	26,0	18,7	30,0	0,0
IFENMA	11,5	12,4	8,1	2,6
LIENMA	9,6	10,8	9,7	22,0
IFLI	7,8	18,4	26,7	47,0
LINA	41,8	22,9	17,9	26,0
IFNA	2,6	15,8	6,9	0,4
MUL	0,7	0,9	0,8	2,0
total	100,0	100,0	100,0	100,0

Compared to other performing sectors like institutes and companies, university research might have a certain profile – more basic than applied and perhaps more disciplinary that interdisciplinary. In this section of our paper we will use data from Sweden, a country for which we have corrected addresses. The objective is to illustrate whether there are differences between the performing sectors. From a Swedish perspective it is surprising that the research institute sector, which has a close relation to industry driven “collective research”, seem to emphasise publications in the crossfield area of LINA (interfield natural science). The share of cross-field publications in that sector is around 25 percent (2001-2003) and the growth in numbers is almost 9 percent per year.

Looking more closely at the University sector in Sweden we find that universities with Schools in Engineering (Royal Institute of Technology KTH, Chalmers CTH and Linkoping LIU) have a large part of their publications in NAENMA, LIENMA and IFENMA. This makes sense as these categories seem to be dominated by areas of engineering science and technology. Universities with a higher share of natural science – Stockholm, SLU (Agricultural University), Uppsala, Lund and Gothenburg) are stronger in LINA, and universities with a medical faculty (Uppsala, Lund, Gothenburg, Karolinska and Umea) are strong in IFLI. This is in accordance with the actual faculties at these universities. In this respect the indicator and the categorisation is relatively accurate.

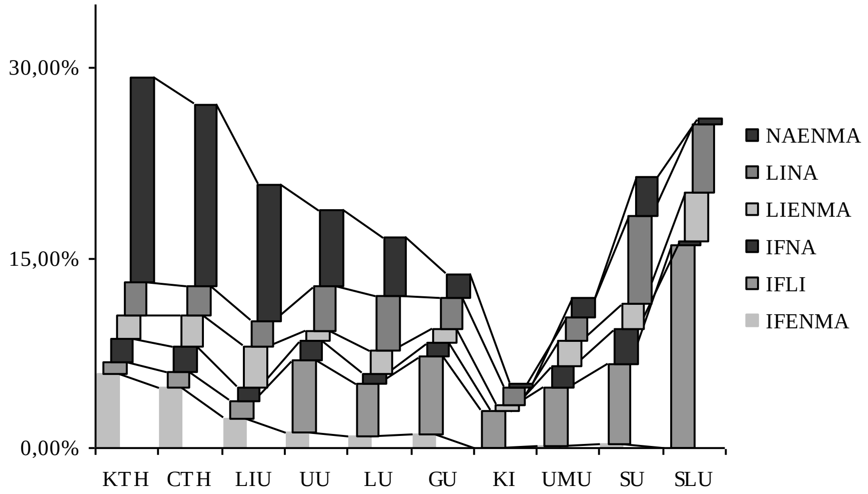

Figure 6. Cross-field publications as share of total publications during the period 2000-2003 at Swedish universities. Note: KTH=Royal Inst of Tech; CTH=Chalmers; LIU=Linkoping univ; UU=Uppsala univ; LU=Lund univ; GU=Gothenburg univ; KI=Karolinska Inst; UMU=Umea univ; SU=Stockholm univ and SLU=Univ Agricultural Science.

Relative Citation Index for Cross-field Areas

We now move back to an analysis of different countries in a European perspective. The interesting issue of interdisciplinarity can also be analysed from a qualitative point of view. The measure used here will be the actual field normalised impact (two year windows) relative to the mean for EU (15), see appendix for a further explanation. Our calculations follow the method for what is referred to as the crown indicator proposed by the Leiden group (van Raan 2005). Added to that is an index of relative specialisation based on figures for Europe (cf. Glänzel 2000:129 f.). In figure 7 the results of this analysis are summarised. At the top right in the figure are the engineering areas where Sweden and the Netherlands seem to be rather strong in impact and specialisation. At the bottom toward the left of the figure we see a stronger concentration on life science and general multidisciplinarity. According to this analysis Finland and the U.K. are the strongest players on the publication market for that sort of interdisciplinary research. Again, the result of this exercise is a bit surprising. We would have expected Finland to be stronger in the engineering areas, but their best quality publications are in the natural sciences. Both Sweden and Holland have strong areas of “big interdisciplinarity” (LIENMA and LINA). The U.K. has strongholds in areas that can be described in terms of “small interdisciplinarity” (IFLI and IFNA).

A closer look at tendencies reveals that countries have different historical developments in these areas. In figure 8 we disclose the time trend over periods for three large cross-fields (NAENMA, IFLI and LINA). Countries such as the Netherlands and Sweden stand out as good performers even if both are coming closer to the EU average. The Danish activity in interfield life science is high, but the rate of citations only average. UK is steadily going in the direction of the average, but the performance in IFLI is very good. As seen from figure 8, Finland and Germany have a lower performance, but are moving in a positive direction.

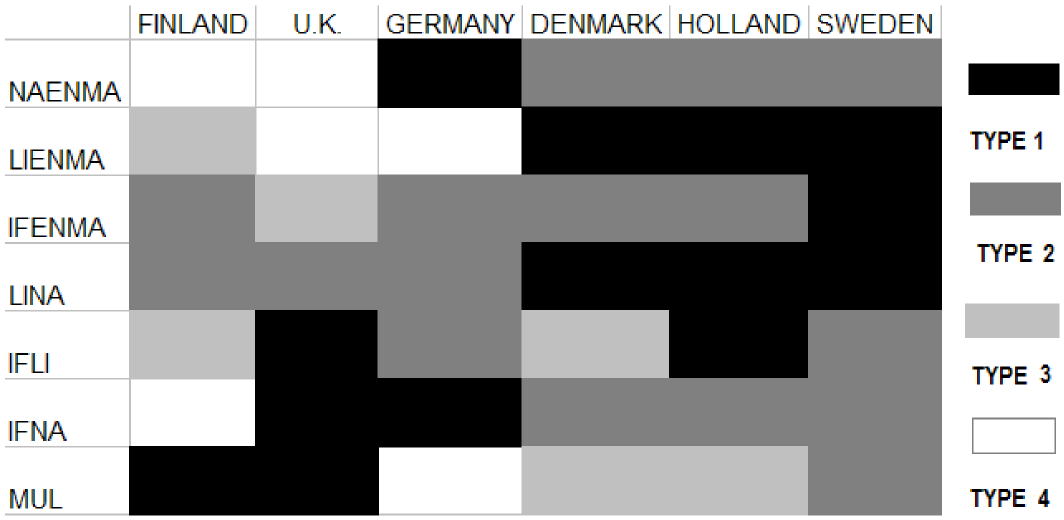

Figure 7. Field normalised relative impact and relative specialisation per country and cross-field during 1996-1999 (2-year window).
Type 1=strong specialisation, high impact; Type 2=weak specialisation, high impact,
Type 3= strong specialisation, low impact; Type 4= weak specialisation, low impact

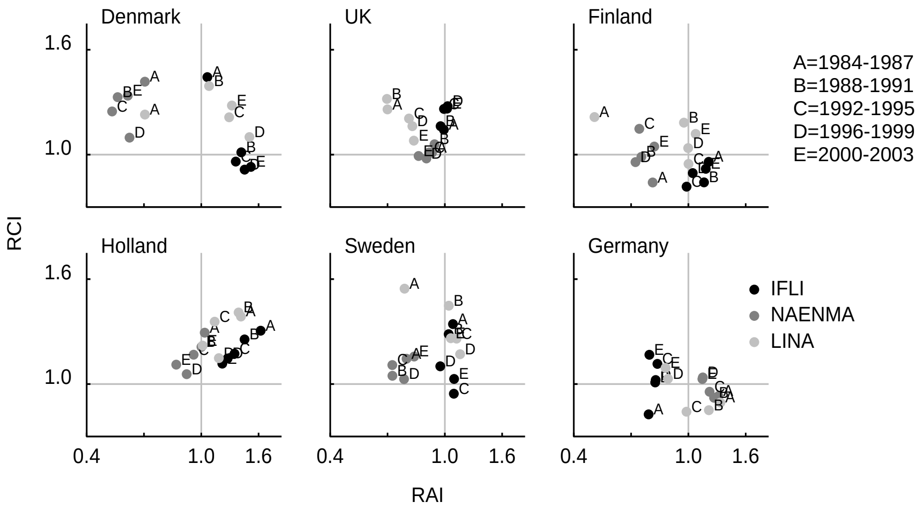

Figure 8. Relative Activity Index and Relative Citation Index for three large cross-fields during five time periods. 1 is the normalised (average) RAI and RCI-position for EU (15) and 1,6 is 60 per cent above average.

Conclusion: Applicability or Interdisciplinarity?

In this paper we report a number of investigations on interdisciplinarity following the Hicks & Katz method. Although the method has been criticised by Morillo et al. (2003) we would argue that there are still many interesting aspects that could be further developed. In this paper we have illustrated this simple point. First, it is a method that makes it possible to get the overall picture without too many time-consuming arrangements. Secondly, the method is to a large extent in line with our intuitive guesses, e.g. when analysing countries or universities or sectors. Thirdly, the method gives a chance to use time-series analysis, an aspect that certainly could be further developed in our analysis.

As previously mentioned, an interesting dimension of the Morillo (2001) paper can be described in terms of basic and applied research, i.e. the research level dimension. Bibliometric studies indicate that areas strongly related to other fields of research, via citations and references, seem to have a high level of interdisciplinarity. Rinia et al (2002) show that applied areas, to a large extent, are dependent on results and references from more fundamental areas of research. Therefore, applied areas will tend to appear as multi- or interdisciplinary when citation indicators are used.

Contrary to the empirical results of Rinia et al. (2002), the findings of Morillo et al. were negative when multi-assignations were correlated to research level data (Morillo 2003, p. 1240). That part of their study was not accounted for in detail. Therefore, it is not possible for us to evaluate their results. Our impression, using a number of different aspects of the data, is that there is a connection between applicability and interdisciplinarity lying behind the multi-assignations.

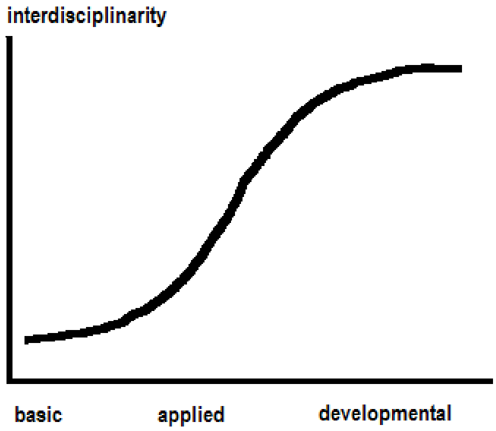

Figure 9. Interdisciplinarity as a function of research level.

It is a common mistake to mix up type of research with the question of interdisciplinarity between fields of research. A theoretical illustration of the problem is given in figure 9 which underlines the need for discrimination between two different types of policies in relation to single-field and cross-field research. One type of policy would be to move basic research in an upward direction; another type would be to move the research towards development (to the right). The result would be much different, but it is not obvious that it would be possible to follow the former policy by using the Hicks & Katz method as basis for prioritisation.

In conclusion, the Hicks and Katz method using multi-assignations as an indictor of interdisciplinarity is innovative and gives valuable empirical results. Due to good research economy and clear-cut definitions the method is replicable. The main problem is the validity. Further analysis is needed in order to investigate the relation between applicability and interdisciplinarity.

Appendix A. Calculations of relative activity (RAI) and relative citation (RCI) indices

To calculate the publication activity, the number of publications produced in different subject areas in each country was counted. To estimate impact the number citations per paper during a 2-year period following publication was also counted. The publications and citations per paper were fractionalised with respect to the countries among the contributing authors. Thus, if all authors of a paper come from one country the paper-score is 1 while if e.g. three addresses had country A and one address had country B, A get the score 0,25 and B 0,75. Articles and rewiews only are included in the analysis.

Considering a hierarchical classification of subject categories i.e. from fine graded (ISI-Subfield categories) to larger disciplines (five major categories), it is possible to construct normalised measures of citation rates and activity. For each country and subfield group a country- subfield index was computed as the paper profile (PP_{AREA}) and citations per paper (CPP_{AREA}).

PP_{SWE} = Sum of paper-scores in the subfield / Sum of paper-scores for the nearest upper hierarchical level

CPP_{SWE} = Sum of citation-scores in the subfield / Sum of paper-scores in the subfield

Similar ratios were computed for Europe:

$PP_{EU} = P_{EUROPE\text{-}SUB} / P_{EUROPE\text{-}DIS}$

$CPP_{EU} = CIT_{EUROPE\text{-}SUB} / P_{EUROPE\text{-}SUB}$

The relative activity (RAI) and relative citation (RCI) indices were then computed for each country and subfield as the ratio between CSI and ESA indices:

$RAI = (PP_{SWE} / PP_{EU}) - 1$

$RCI = (CPP_{SWE} / CPP_{EU}) - 1$

In figure 8 the logarithm of values

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Endnotes:

[i] The history of Swedish policies for interdisciplinarity is analysed in Sandström et al. (2005).
[ii] Benner & Sandström (2000).
[iii] Cf. Sandström et al. (2005).
[iv] Source WoS, 1,372 articles in 2002-2003, see Sandström et al (2005), cf. Braun & Schubert (2003).
[v] Certain data included herein are derived from the Web of Science prepared by Thomson Scientific Inc. (ISI), Philadelphia, Pennsylvania, USA. Copyright Thomson Scientific Inc. 2005. All rights reserved.
[vi] Cf. Morillo et al (2003), p. 1239.
[vii] Please, observe that Social Science and Arts & Humanities are excluded from our investigations.
[viii] Bordons et al. (2004), Braun & Schubert (1999), Laudel (2002), Pierce (1999), Qin et al (1997), Rhoten (2002), Rinia et al (2002a), Sandström et al (2005), Schummer (2004), Small (1999), Weingart (2000).
[ix] It should be mentioned that the ad hoc method of Hicks & Katz gave a figure of 18 % cross-field articles already during the 1980’s (see Hicks & Katz 1996, p. 388).