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Institutions and the map of science: matching university departments and fields of research [1]

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Abstract

It is an increasingly common practice within universities to use departments as units of research funding and there exists in the form of the extensive British Research Assessment Exercise (RAE) a national funding system which is essentially tied to departments as units of analysis. Yet the interdisciplinary nature of modern scientific research, where researchers in departments publish in journals across a range of fields outside their nominal disciplinary affiliation, is an acknowledged 'norm' in the university research community. This paper uses complete data for all Australian universities to explore the correspondence between the designations of departments and the designations of the fields and subfields to which members of these departments contribute through their publications. Previous studies of this aspect of knowledge production have centred primarily on micro-level data relating to particular specialities and departments. We suggest that the use of performance indicators at the level of university departments inevitably obscures important features of modern research. Any attempt to introduce a system-wide evaluation of research based on the university department would have particular disadvantages for interdisciplinary research and for those newer institutions which have not organised their academic structures along traditional departmental lines. We suggest in relation to research funding bodies, either internal or external to the university, that there should be an increased use of field-coded research information. © 1998 Elsevier Science B.V.

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1. Introduction

It is commonplace among working scientists that their research activities are organised around research groups which may have very little interaction with each other within departments and that these groups frequently cut across departmental and other boundaries established by academic structures. There was ample testimony to this effect from scientists who indicated their concern about attaching research rankings to departments to interviewers from the Science Policy Research Unit (SPRU) at the University of Sussex (Martin, 1996).

In this respect, scientists are testifying to the validity of longstanding research findings among sociologists, historians of science and library scientists. A considerable range of studies from these perspectives has scrutinised the degree to which research agendas transcend disciplinary boundaries

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[1] This paper substantially extends and amplifies issues first raised during a joint SPRU-ANU project (Bourke and Martin, 1992).

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and, in particular, the degree to which organisational units such as departments do not correspond to the actual sites of research. One standard procedure in this literature has been to deploy the 'citations outside' concept of Chubin—that is, monitoring the degree to which scientists cite findings outside their disciplinary speciality, as defined by journal clusters. Other approaches have included the study of the inclusion of cross-disciplinary publications in discipline indices and of the diffusion of the publications of single departments (Choi, 1988; Chubin, 1976; Porter and Chubin, 1975; Hurd, 1992; McCain and Whitney, 1994; Moed and Hesselink, 1996).

If this is familiar ground to working scientists and to students of the literature of science, a missing dimension is the implication for research policy of this disjunction between departments and the actual settings of research. It is increasingly common practice within universities to use departments as units of research funding and there exists in the form of the labour-intensive British Research Assessment Exercise (RAE) a national funding system which is essentially tied to departments as units of analysis. The fact that some researchers employed in the department of chemistry, for example, may be publishing in physics, mathematics, astronomy or biology and, conversely, that an institution's contributions to chemistry may be scattered across half a dozen departments or institutional structures poses important but largely unaddressed policy issues at both these levels.

It is our purpose in this paper is to extend earlier analyses which have largely been microstudies of particular specialities and departments and to focus them more directly on research funding policy matters. To do this, we will use Australian data to explore across all major fields within a modern university the correspondence between the disciplinary designations of university departments and the designations of the fields and subfields to which members of these departments contribute in their publications. We will then draw out the implications of these data for systems such as the RAE. We will suggest that the use of performance indicators at the level of university departments inevitably obscures important features of modern research, especially in the sciences, and that their use at this organisational level should be complemented by scrutiny of the intellectual structure and field orientations of the unit under study. We also seek to determine whether the 'map' of departmental publications has been changing. Recent theory associated with the work of Gibbons et al. (1994) has led to the claim that in recent years there has been a diversification of the sites of research production and an acceleration of transdisciplinary patterns as research groups, composed of a complex mix of fields, form and dissolve around convergent problems. In short, we will ask whether it may be shown that university departments are housing more transdisciplinary work.

Our paper focuses on journal publications indexed by the Institute for Scientific Information (ISI) in their Science Citation Index (SCI). It is important to acknowledge, of course, that universities publish a substantial amount of scientific research in local journals, in books, in reports and in conference proceedings, all of which are outside the catchment of the indices of ISI. However, we believe that the picture painted by the international journal literature is a reasonably accurate one, particularly as we confine our analysis to scientific disciplines.

2. Methodology

2.1. REPP database

The Research Evaluation and Policy Project (REPP) has constructed a large database of all Australian publications in ISI-indexed journals, covering the period 1981–1994. It includes all publications with an Australian address in the three major ISI Indices: SCI, Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A and HCI). The database also contains the yearly counts of citations to each of the Australian publications. The full features of the database are described in detail in other REPP publications (for example, Bourke and Butler, 1993) and on the REPP webpage [2].

The focus of the database is the departmental and the institutional address(es) given for each publication rather than the names of authors. The initial task

[2] The REPP webpage is: http://coombs/anu.edu.au/Depts/RSSS/REPP/repp.htm.

in the project was to 'clean' the addresses in the database sufficiently to enable analysis to be done at different levels of aggregation. This meant ensuring that all variations of the same address were identified and that all publications with variants of that address were allocated a single 'standardised address'. The standardised addresses for all Australian universities, for the Commonwealth Scientific and Industrial Research Organisation and for other major research institutions were set up in a hierarchical format, from the institution down through faculties or institutes to the department, enabling tabulations at these different levels of aggregation to be produced.

2.2. Classifying departments

Incorporated in the process of cleaning addresses is the classification of each level of address to the Australian Standard Research Classification (ASRC) [3]. Wherever possible, faculty and department-level addresses were given a two-character ASRC subfield code. Where an address spanned two or more subfields in the same field, it was given a field code.

A number of addresses could not be assigned to a specific code and these were labeled 'not classified' (nc) in our tabulations. There are various reasons for this but the most common one has to do with the structure of some of the newer universities, such as La Trobe University, Deakin University and Macquarie University, which house major science disciplines within broad school designations. The category also covers those publications carrying only a general university address.

2.3. Classifying publications

The journals in which Australian universities publish have been classified by field of science. This is an acceptable, although imperfect procedure for classifying scientific publications. Journals do not coincide precisely with fields and subfields of science and care must be taken about boundaries and overlaps. Important work on the use of keyword classification and other mapping devices has been produced in recent years, but these are not yet sufficiently refined for use in the study of a whole system such as we attempt here (Lewison, forthcoming).

ISI has its own descriptive classification system placing journals into subject categories. REPP has, as a first step, translated these categories into the fields and subfields of the ASRC. However, this system needed further refinement. While most ISI subject categories could be directly allocated to a subfield of research in the ASRC structure, a few categories spanned two or more subfields within the same field or spanned more than one field. In addition, journals can be assigned to more than one subject category. We used the procedure first employed by Katz and Hicks (1995), to take account of these journals. They created one higher level in the classification hierarchy, the discipline, and added interfield and interdisciplinary classifications. All journals are assigned to one unique journal set in the following classification scheme.

- Natural Sciences
  - Mathematical Sciences (Ma)
  - Physical Sciences (Ph)
  - Chemical Sciences (Ch)
  - Earth Sciences (Ea)
  - Interfield, Natural Sciences
- Applied Sciences
  - Information, Computer and Communication Technologies (In)
  - Applied Science and Technology (Ap)
  - Engineering (En)
  - Interfield, Applied Sciences
- Life Sciences
  - Biological Sciences (Bi)
  - Agricultural Sciences (Ag)
  - Medical and Health Sciences (Me)
  - Interfield, Life Sciences
- Interdisciplinary Sciences
  - Natural Sciences–Applied Sciences
  - Natural Sciences–Life Sciences
  - Applied Sciences–Life Sciences
  - Multidisciplinary

Under this scheme, the basic structure of the ASRC is retained, while at the same time the interfield/discipline nature of journals is accounted for. These journals are, as a group, a prime focus of

[3] The ASRC was prepared by the Australian Bureau of Statistics for use in the measurement and analysis of research and experimental development undertaken in Australia.

interest in considering the general issues raised by Gibbons et al. (1994).

2.4. Data coverage

In this paper, our analysis examines all the entries in the SCI from Australia's 37 universities. We have produced cross-tabulations showing for each of 44 000 publications in the 5-yr period, 1990–1994, the classifications of both the journal in which the article appeared, and the classification of the department(s) from which the publication emanated. We have limited the publications included in our counts to the ISI classifications of articles, notes, reviews and proceedings papers and have confined our discussion to the sciences. In the cases of the Social Sciences and Humanities, a large proportion of publications show only the name of the institution, not the departmental address and the analysis offered in this paper unfortunately becomes very problematic in those areas. As can be seen from the data that follows, this is not a major problem for any of the science fields. Over 90% of science publications are identified by a departmental address and those appearing only under the rubric of the institution are unlikely to affect the results of the analysis.

3. Results

Table 1 distributes all Australian university publications in the SCI for the period 1990 to 1994 across the departments producing the publications and the journals in which they appeared. Departments are classified using the standard ASRC, while journals are classified with the modified ASRC scheme detailed above.

Table 1 can be used to answer two broad questions.

Table 1
Classification of science publications from Australian universities by department and field of research, 1990–1994

Field of research	Department										nc[a]	Total
	Natural Sciences				Applied Sciences			Life Sciences				
	Ma	Ph	Ch	Ea	In	Ap	En	Bl	Ag	Me		
Natural sciences												
Mathematical Sciences	716	2	2	1	55		21	2	4	7	138	948
Physical Sciences	479	2720	397	14	91	165	288	50	3	56	356	4619
Chemical Sciences	88	194	3465	52	8	51	141	124	17	231	554	4925
Earth Sciences	56	163	32	1807	3	3	46	41	19	2	79	2251
Interfield	40	75	143	8	1	5	24	5		4	56	361
Applied sciences												
Information, Computer and Communication Technologies	3				56		9		1		10	79
Applied Science and Technologies	19	57	45	7	28	113	350	5	25	5	48	702
Engineering	58	53	53	13	73	22	808	4		10	73	1167
Interfield	26	25	8		83	11	273	6	1	24	35	492
Life Sciences												
Biological Sciences	69	68	220	219	8	8	19	3392	638	1149	477	6267
Agricultural Sciences	12	5	10	55	1	23	25	180	1477	80	152	2020
Medical and Health Sciences	122	58	70	9	16	9	38	976	285	9366	884	11833
Interfield	4	17	35	31		13	11	1042	617	1192	335	3297
Interdisciplinary												
Natural–Applied	148	373	163	129	50	116	616	15	6	19	132	1767
Natural–Life	61	31	180	211	4	3	87	415	92	540	198	1822
Applied–Life	3	5	17	8	5	34	68	184	64	57	59	504
Multidisciplinary	41	52	46	105	7	5	73	149	40	152	75	745
Total	1945	3898	4886	2669	489	581	2897	6590	3289	12894	3661	43799

[a] nc = Not classified.

(1) What proportion of a department's publications appear in journals with the same field designation? For example, what proportion of the publications from Chemistry departments appear in journals classified as Chemistry?

(2) What proportion of university publications in journals of a given field of research come from departments of the same classification? For example, what proportion of publications appearing in Chemistry journals come from Chemistry departments?

Table 2 calculates percentages of the column totals to look specifically at question 1, while Table 3 calculates percentages of the row totals to look at question 2. The cells where the classifications of department and field of research coincide are highlighted as bold text.

The composite picture presented in Table 2 shows that the 'spill' outside the field grouping of the relevant departments is lowest in the field of Medical and Health Sciences where 73% of research is published in journals classified to the same category. The spill in the fields of the Natural Sciences, other than Mathematical Sciences, is also comparatively low at around 30%. As would be expected by its very nature and description, the fields in the Applied Sciences exhibit a large spill across a diverse range of fields of research. The distributions shown here present the 'map' for the whole Australian university system. Elsewhere, we have shown that individual institutions can exhibit quite different distributions for any given department (Bourke and Butler, 1993).

It is important to make clear that the spill of publications outside departments is not grossly exaggerated by the type of journal classification used in the analysis. It cannot be assumed that all publications in interfield/discipline categories can be ascribed to related departments. If the simplified ASRC classification system, allowing journals to be as-

Table 2
Percentage distribution of publications from university departments classified by field of research, 1990–1994

Field of research	Department										nc	Total
	Natural Sciences				Applied Sciences			Life Sciences				
	Ma	Ph	Ch	Ea	In	Ap	En	Bi	Ag	Me		
Natural Sciences												
Mathematical Sciences	**37**	0	0	0	11		1	0	0	0	4	2
Physical Sciences	25	**70**	8	1	19	28	10	1	0	0	10	11
Chemical Sciences	5	5	**71**	2	2	9	5	2	1	2	15	11
Earth Sciences	3	4	1	**68**	1	1	2	1	1	0	2	5
Interfield	2	2	3	0	0	1	1	0	0	0	2	1
Applied Sciences												
Information, Computer and Communications	0				**11**		0		0		0	0
Applied Sciences and Technologies	1	1	1	0	6	**19**	12	0	1	0	1	2
Engineering	3	1	1	0	15	4	**28**	0		0	2	3
Interfield	1	1	0		17	2	9	0	0	0	1	1
Life Sciences												
Biological Sciences	4	2	5	8	2	1	1	**51**	19	9	13	14
Agricultural Sciences	1	0	0	2	0	4	1	3	**45**	1	4	5
Medical and Health Sciences	6	1	1	0	3	2	1	15	9	73	24	27
Interfield	0	0	1	1		2	0	16	19	9	9	8
Interdisciplinary												
Natural–Applied	8	10	3	5	10	20	21	0	0	0	4	4
Natural–Life	3	1	4	8	1	1	3	6	3	4	5	4
Applied–Life	0	0	0	0	1	6	2	3	2	0	2	1
Multidisciplinary	2	1	1	4	1	1	3	2	1	1	2	2
Total	100	100	100	100	100	100	100	100	100	100	100	100

Table 3
Percentage distribution of publications in fields of research by type of department, 1990–1994

Field of research	Department										nc	total
	Natural Sciences				Applied Sciences			Life Sciences				
	Ma	Ph	Ch	Ea	In	Ap	En	Bl	Ag	Me		
Natural Sciences												
Mathematical Sciences	**76**	0	0	0	6		2	0	0	1	15	100
Physical Sciences	10	**59**	9	0	2	4	6	1	0	1	8	100
Chemical Sciences	2	4	**70**	1	0	1	3	3	0	5	11	100
Earth Sciences	2	7	1	**80**	0	0	2	2	1	0	4	100
Interfield	11	21	40	2	0	1	7	1		1	16	100
Applied Sciences												
Information, Computer and Communication	4				**71**		11		1		13	100
Applied Sciences and Technologies	3	8	6	1	4	**16**	50	1	4	1	7	100
Engineering	5	5	5	1	6	2	**69**	0		1	6	100
Interfield	5	5	2		17	2	55	1	0	5	7	100
Life Sciences												
Biological Sciences	1	1	4	3	0	0	0	**54**	10	18	8	100
Agricultural Sciences	1	0	0	3	0	1	1	9	**73**	4	8	100
Medical and Health Sciences	1	0	1	0	0	0	0	8	2	**79**	7	100
Interfield	0	1	1	1		0	0	32	19	36	10	100
Interdisciplinary												
Natural–Applied	8	21	9	7	3	7	35	1	0	1	7	100
Natural–Life	3	2	10	12	0	0	5	23	5	30	11	100
Applied–Life	1	1	3	2	1	7	13	37	13	11	12	100
Multidisciplinary	6	7	6	14	1	1	10	20	5	20	10	100
Total	4	9	11	6	1	1	7	15	8	29	8	100

signed to more than one field, had been used the spills would still have been extensive and the relativities between fields the same [4].

Table 3 highlights the fact that, if one is wishing to examine the performance of Australian research in a given field, then studying only departments bearing the name of that field will overlook a large proportion of the research. At the very least, 20% of publications in a field come from departments outside that field, and the figure can be as high as 84%.

An examination of the data shown in Tables 2 and 3 clearly indicates that any attempt to analyse a university's performance in a particular field of science by analysing the publications from a department with the same classification can be seriously misleading. Limiting the analysis to the department that bears the 'right' name can miss a large proportion of the university's research in the field; and limiting the analysis of a department to publications in the field that matches its title can miss a significant proportion of its output.

To highlight this point we will use the data presented for mathematics and assume for the moment that it is typical of any university mathematics department. While most of the publications in mathematics journals do come from the department (see Table 3), using an analysis of the publications from this unit as a surrogate for the performance of the university in Mathematical Sciences could be seriously misleading as it has publications in many other fields, most notably Physical Sciences (see Table 2). If citation per publication (cpp) rates were calculated

[4] Using the simplified journal scheme would have resulted in percentages of convergence between departments and fields of: Mathematical Sciences, 43; Physical Sciences, 80; Chemical Sciences, 79; Earth Sciences, 77; Information, Computer and Communication, 30; Applied Science and Technology, 30; Engineering, 58; Biological Sciences, 66; Agricultural Sciences, 58; and Medical and Health Sciences, 82.

for this department and compared to the ‘world’ average for Mathematical Sciences, it would probably appear in a very good light. The average cpp rate for Mathematical Sciences is approximately 2.8 for a 5-yr window, while the cpp rate for Physical Sciences is 7.8 [5]. Any mathematics department that has 25% of its output in physics journals will almost certainly compare well against one with a more limited field coverage.

4. Change over time

The question of whether departments have been broadening the scope of their research interests is addressed by determining whether the proportion of their publications appearing in journals of the same classification has decreased over time. We looked at two earlier time periods, 1981–1984 and 1985–1989, and compared these to the 1990–1994 data and have limited our analysis to those fields that do not already exhibit strong elements of interdisciplinarity.

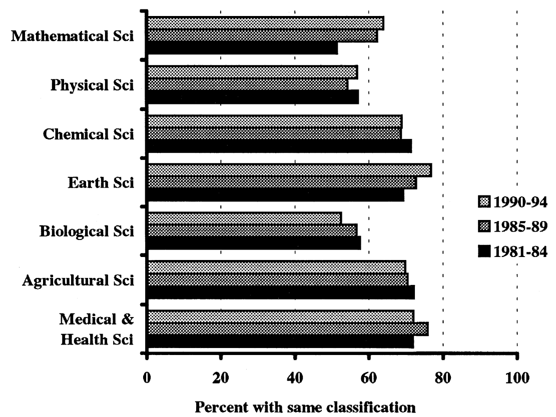

Chart 1: Convergence of Departmental and Journal Classifications.

The picture emerging from Chart 1 is complex. Certainly some fields, such as the Chemical, Biological and Agricultural Sciences, are exhibiting a trend towards increased interdisciplinarity. Mathematical, Physical and Earth Sciences, however, are apparently becoming less so and Medical and Health Sciences has changed little. Even where change is apparent, the movement is for the most part marginal. Changes in the nature of scientific discourse do not happen overnight and we suspect that the time period we are able to study is too short for such changes to be noticeable. In addition, the methodology we have employed here may have some inherent problems that limit its usefulness in answering this question: we are not able to measure the extent to which journals may be changing by widening the focus of the research they publish. We are currently expanding our study of this issue by examining a number of additional indicators. As well as looking at the journals in which departments publish, we are also analysing changing patterns of collaboration and changing patterns in the journals citing departmental publications. For these two additional indicators, we are also extending our studies to the Social Sciences and Humanities where we will no longer be hampered by the lack of departmental addresses.

5. Policy implications

In considering the policy implications of these data, we need to emphasise that no single conclusion applicable to all fields of science can be derived from what we have presented. And it should be noted that the Social Sciences and Humanities are not covered in this study.

For all of that, this information does suggest the importance, when evaluating largescale fields of research, of focusing on research clusters or groupings rather than principally on cost centres such as departments which retain their main function in the organisation of teaching. The policy implications of this have emerged to prominence in two spheres of British research evaluation.

Firstly, it was the subject of submissions to the National Committee of Enquiry into Higher Education in the UK (the Dearing Committee) emphasising that the departmental focus of the British RAE system had disadvantaged interdisciplinary research and obscured the importance of intra- and transdepart-

[5] The cpp rates quoted here were calculated from ISI’s Index of Expected Citations for Journals, 1981–1995. We counted publications that appeared in journals classified to the two specified categories in the period 1991–1995 and the citations these publications earned in the same period.

mental groups as the main sources of research. In the event, the Dearing Report did not take up this point, no doubt because it is very difficult to conceive of a system-wide research evaluation exercise based on looser, shifting group structures. We do not minimise that difficulty but the findings of this paper, limited so far to Australian data, reinforce the submissions to Dearing and the need for continued work on identification of the actual clusterings of research.

Secondly, it is a matter of considerable importance for research councils and other direct granting bodies. Such bodies are usually organised into broad discipline categories and they must arrive at allocations of shares of the total 'pie' between their respective subfield divisions. These divisions are frequently given institutional form as permanent standing committees or panels consisting of representatives of clusters of departments. This may be the *least unsatisfactory* way to proceed where the consideration of individual grant proposals and individual researchers is concerned, but it may not be appropriate for broader issues of strategic planning. In relation to research funding bodies, we suggest that the increased use of field-coded research information might encourage the development of strategic mapping of research as a way of breaking out of the essentially department-driven working of research policy.

As bibliometric procedures stand, the most useful approach to such large-scale evaluation maps are Field of Research (FOR) and subfield classifications based on journal sets of the kind we have used here. These clusters encourage scrutiny of the work of whole institutions or sectors through the construction of FOR profiles and it is not difficult to conceive of ways to allow funding decisions to follow such FOR reviews (Bourke, 1997). Universities will, of course, always have important grounds for wanting to study departments. These may have to do with issues of management, with resource use, with staff development and with the wide range of matters arising in relation to teaching and training. We suggest, however, that these incentives should not be confused with the taking of sophisticated and informed decisions, at the institution-wide level, about research.

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