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A Criticism of the Use of Citation Analysis in Studying the Science–Technology Relationship

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This paper raises some doubts as to the general applicability of studies of citation patterns in chemistry which purport to show that scientific research in the universities has little impact on technological innovation. A parallel study of biologically oriented chemical literature shows that conclusions from the chemistry data can be completely reversed. Citation analyses, therefore, have little of the policy implications which the authors of these studies claim for them.

There is always the danger, in any rapidly expanding field, that certain assumptions are made about the subject matter which, in the light of a subsequent reappraisal, are shown to be less than adequate. Such is the case in that area of enquiry known as "research on research" which seeks to understand the relationships between science, technology, and innovation. For some investigators, science is taken to mean "university science",[1] and it is the aim of this paper to raise some doubts as to the general applicability of studies of citation patterns in chemistry which, it is alleged, point to the fact that university research has little impact on innovation in industry.

The question of the relationship between science and technology has been a major preoccupation of a number of research groups in the U.S. and U.K. since the early 1960's. In general, case studies from the whole spectrum of scientific and technological activity have been used to illuminate the relationship between science and technology; in the two major U.S. studies, Project Hindsight[2] and TRACES,[3] a distinction was made between curiosity oriented research (science) and mission oriented research (technology). Of the two major British studies, one, the Queen's Award Study,[1] used an institutional definition of research in which the locus of the research defined its nature (university research, government research, industrial research, etc.); the other, Project SAPPHO,[4] concentrated on the wider aspects of innovation and did not attempt to correlate the institutional source of ideas with success in innovation. This paper is solely concerned with extrapolations from the Queen's Award Study.

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Table I. Institutional Sources of Cited Papers in Seven Reviews in *Reports on the Progress of Applied Chemistry*[5,7]

Review	Industry		Government		University		University industry collaboration		Not available
	U.K.	Abroad	U.K.	Abroad	U.K.	Abroad	U.K.	Abroad	
Phenolic resins	3	19	2	4	0	0	0	1	29
Microbiological techniques	6	2	2	2	7	2	2	0	14
Water treatment	9	38	27	34	5	45	2	0	42
Plastics	5	1	0	0	0	0	0	0	4
Polyolefins	12	71	0	0	2	12	3	2	41
Synthetic detergents	1	27	4	1	0	1	0	0	17
Poultry & eggs	2	0	10	6	2	19	0	3	24
Totals	38	158	45	47	16	79	7	6	171
Totals as % of 567	7%	27%	8%	8%	3%	13%	1%	1%	30%
Total as % of 396	10%	40%	11%	12%	4%	19%	2%	2%	—

Table II. Institutional Sources of Cited Papers in Five Biological Reviews in *Reports on the Progress of Applied Chemistry*

Review	Industry		Government		University		University industry collaboration		Not available
	U.K.	Abroad	U.K.	Abroad	U.K.	Abroad	U.K.	Abroad	
Prostaglandins	0	5	0	4	7	34	0	5	4
Enzymes	2	34	6	26	9	51	1	5	18
Microbial insecticides	0	2	2	20	2	11	0	0	3
Antiviral agents	5	15	1	6	9	10	0	1	3
Anabolic steroids	0	12	0	1	0	4	0	2	6
Totals	7	68	9	57	27	110	1	13	34
Totals as % of 326	2%	21%	3%	18%	8%	34%	0%	4%	10%
Totals as % of 292	2%	23%	3%	19%	9%	38%	0%	5%	—

The Queen's Award team studied 51 innovations which had won the Queen's Award to Industry, an honor granted to British business firms for outstanding achievements in technological innovation. The authors concluded from their analysis of the key technical ideas used in the 51 innovations that the role of the universities as a source of ideas for innovation was fairly small.

CITATION STUDIES

The case histories which were used by the Queen's Award teams ranged widely over the physical, chemical, and engineering sciences. In an attempt to substantiate the view that ideas from the universities have little impact on technological innovation, the principal author of the Queen's Award Study has carried out a number of citation studies of the literature in chemistry,[5-7] of which we shall concentrate on only one.[5]

On the assumption that reviewers from industry will cite university research which they consider to be of relevance to industrial activity in the area of their reviews, Langrish has chosen for analysis seven review articles written by British industrial chemists in the 1967 volume of *Reports on the Progress of Applied Chemistry*. The reviews cover developments in the following fields: phenolic resins, microbiological techniques in manufacture, water treatment, plastics, polyolefins, synthetic detergents, and poultry and eggs. The results showed that the papers which the reviewers considered most relevant to technological developments in these fields were largely of non-university origin. Of the citations, 18% came from the universities, 34% from industry, 16% from government sources, and 30% were not traceable (see Table I). From these data the author concluded that "the small contribution of ideas from university science to innovations and the lack of interest shown by industrial chemists in the publications of academic chemists should make it more difficult for policy makers to think that "basic research provides most of the original discoveries from which all other progress flows (Council for Scientific Policy, Second Report on Science Policy 1967)." We wish to challenge this conclusion, not because we believe in the so-called "linear" relationship between university scientific research and technological innovation, but because we do not believe the author has made a case. First, the areas chosen for analysis have not been demonstrated to be representative of the type of research being conducted in university laboratories, and it is very likely that they are not. It is hardly surprising that citations to research activity in "poultry and eggs" or "detergents" from the universities are rather low. Without some indication of the amount of work being carried out in each of the fields in the various performance sectors, the data collected are quite meaningless. Second, in one category of research, microbiological techniques in manufacture, the influence of the universities was shown to be dominant. To the author, this result indicated that the universities' main use is in the provision of "techniques" for use in industry. We believe, however, that the answer lies in the nature of the subject: that the biological sciences do not necessarily display the same citation patterns nor, indeed, the same relationship to technology as the physical, chemical, and engineering sciences. If this is the case, then it should be obvious that no generalizations across the whole spectrum of scientific activity can be made.

CITATION PATTERNS IN BIOLOGICAL REVIEWS

In order to test our hypothesis that particular branches of science may exhibit citation patterns which do not conform to those found by Langrish in his study of the various

Table III. Comparison between Total U.K. Citations and Total U.K. Expenditure on Research and Development (1969–1970)

Sector	Citations: Langrish data	Citations: Data of this study	Total citations	% of total citations	% of total expenditure 1969–70[9]
Industry	38	7	45	30	65
Government	45	9	54	36	24
University	16	27	43	29	8
Other	7	1	8	5	3

reviews in Table I, we studied the citations in five review articles, chosen for their biological bias and in well-established areas of enquiry. Three of the reviews were chosen from the same (1967) volume of *Reports on the Progress of Applied Chemistry* as used by Langrish in his study; two others were taken from the 1968 volume of this journal. It must be emphasized that the contents of the review articles reflect a desire by the authors not merely to review the current "state of the art", but to go beyond this and emphasize the relevance of such work to industrial research and development.

Our results are shown in Table II. In terms of citations, the universities outstrip every other sector. Further, in the case of the British Universities at least, a study of cost effectiveness shows that, on the basis of citations to university research, the universities are the most cost-effective; they use 8% of the resources for research, yet their contributions, in terms of citations of potential importance to industry, is almost the same as the industrial sector, which consumes 65% of the funds (Table III). We put forward the argument on cost effectiveness to demonstrate the absurdities which can emerge from the use of citation data in this way. Clearly, citations as a measure of productivity in industrial research are not valid since much of industrial research never reaches the pages of the primary or secondary journals. Even though we have shown that, in the five biologically oriented reviews, references to university research dominate, we cannot with any certainty suggest that university research in the areas covered in our citation study is more "useful" than similar research in other performance sectors.

CONCLUSION

The policy implications of his citation work have been stressed by Langrish and, whereas one cannot be certain that policy makers have been influenced by the results of the various studies of the science-technology relationship, it certainly appears as if they have. In its Third Report, the British Council for Scientific Policy retreated from its position of defender of basic science and, in a remarkable turnaround, concluded that ". . . curiosity orientated research is only rarely the mainspring of substantial innovation".[8] The fact that we have been able to obtain such widely differing results in our small citation study raises serious doubts as to the value of citation analysis in providing data upon which science policy decisions can be made.

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