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The scientometric world of Keith Pavitt
A tribute to his contributions to research policy and patent analysis

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Abstract

Keith Pavitt has made pioneering contributions to the study of science, technology and innovation. This paper aims to examine some of them on the basis of a bibliometric analysis of Keith Pavitt's work and the impact that he has had. First the paper follows how Pavitt's publication profile develops over time. Then we trace his most cited works and explore the sets of references in his papers. Author and journal co-citation maps illustrate the intellectual environment associated with Pavitt and the central role Research Policy played in this context. An analysis of the most frequently cited authors in Research Policy and Scientometrics underlines Keith Pavitt's role as both a shaper of, and a bridge between, science and technology policy and bibliometric analysis.

Keywords: Bibliometric analysis; Patent analysis; Keith Pavitt

1. Introduction

The study of the innovation process has benefited greatly from developments in science and technology indicators. Before the emergence of official S&T indicators, De Solla Price (1965a) and others pioneered the systematic study of science through the analysis of what came to be known as *bibliometric*, including scientometric indicators. The field of scientometrics evolved, mostly based on Eugene Garfield's efforts on citation indexing[1] and an increasing capability to carry

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[1] Eugene Garfield created the science citation index (SCI), and later expanded it to include the social sciences (SSCI) and the arts and humanities (AHCI). These databases are the main resource in scientometric work. This study also uses data from the SSCI. The Institute for Scientific Information (ISI), of which he was the founder and chairman, markets these databases.

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out computerized analysis on large-scale scientific literature databases.

Following the development of methodologies for the analysis of the science system based on indicators of the published output, similar methodologies emerged to measure or assess technological development. The parallel of such studies on technology with earlier work on science can find a basis in De Solla Price's (1965b) comparison of scientists' and technologists' outputs—while the former publish, the latter patent. Such a conclusion contributed to the development of what some have termed 'technometrics', including patent statistics and patent analysis to study the technological performance of products, firms and nations throughout the world.[2] Patenting data and scientific publication data have been used also in a growing number of econometric analyses.[3] These three fields (bibliometrics, technometrics and econometrics) are increasingly converging as patent and publication statistics are used more and more in economic and policy analysis.

The work of Keith Pavitt, often in collaboration with Pari Patel, has been a central contribution to this area of study. This paper will portray Keith Pavitt's contribution to the innovation studies literature using bibliometric data. In particular it will try to identify his role in bridging different approaches to the study of science, technology and innovation.

The initial part of the paper will consist of a scientometric examination of his work, based on an analysis of his published work, the network of co-authors, and the citing and cited behaviour. Such an analysis will provide an opportunity to map his position in the disciplinary 'landscape' of innovation studies, to which he was a leading contributor.

The second part of the paper will focus specifically on his contribution to scientometrics, in bridging studies focusing on science and on technology. Two journals will be used for this analysis, which can be considered to be representatives of these different foci, even if not exclusively so: *Scientometrics*, as a central journal in the area with a particular science focus, and *Research Policy* (of which Keith Pavitt was the main editor in recent years) for the technology focus. The role of Keith Pavitt's work in linking the two journals will be analysed. In addition, both patent and publication studies will be analysed

By reviewing his work in this paper we also intend to make a tribute to his contributions to the area of innovation studies and scientometrics, and its strong empirical focus, an essential bridge between the world of patent and innovation studies and that of bibliometrics and science policy. The paper is also a contribution to the development of analyses of individual researcher's publication trajectories, and to a better understanding of individual impacts in their own fields of study.

2. Methodology

2.1. Data

For our exploration of Keith Pavitt's work and its impact we first downloaded all his publications indexed in the *Social Sciences Citation Index* (SSCI) of Thomson-ISI.[4] We could identify a total of 62 publications which were ranked by their citation frequency. Subsequently we analysed the diffusion of his most cited work in the *SSCI*-indexed journal literature.

Furthermore, we identified a total of 1419 papers citing Keith Pavitt's *SSCI* papers as well as other works by him since 1972. Drawing on these records, we carried out a co-citation analysis at the levels of individual authors and journals. Co-citation maps based on the data were prepared.

Finally, *SSCI* records for all papers published in *Scientometrics* and *Research Policy* were retrieved. We covered all years from 1981 onwards. We used this data set to explore the role Pavitt played in linking the two communities. In particular, citations between the two journals were traced. We used the software tool *Bibexcel* for all our analyses.

[2] The field of *technometrics* also has roots in the area of technological forecasting, emerging in the 1950s and 1960s (see Granstrand, 1994).

[3] See for example Griliches (1990), Hall et al. (2001) and Jaffe and Trajtenberg (2002).

[4] Some of these publications are also indexed in the *Science Citation Index*. Only one publication was found to be indexed only in the *SCI*, a paper in *Nature* published in 1963 on 'Research, Innovation and Economic Growth', from early on a strong focus of his work. For the purposes of this paper, however, we only considered data from the *SSCI*.

Table 1
Publications by Keith Pavitt

Type of publication	Keith Pavitt's personal list of publications	Keith Pavitt's publications in SSCI
Journal articles	53	38 (71.7%[a])
Books, reports, written and edited	19	N/A
Book chapters	68	N/A
Other publications and papers (including book reviews)	56	25 (44.6%[a])

[a] The share of indexed publications amongst complete publications.

2.2. Limitations

When analysing and interpreting the results we present below one needs to bear in mind that not all of Pavitt's important contributions can be tracked adequately. A comparison of Pavitt's *SSCI*-indexed publications with his publication list indicates this (see Table 1).

This is due in particular to the lack of coverage of a key journal, *Industrial and Corporate Change*, in which he published a number of key articles.[5] Journals need to demonstrate a certain track record before they are included in the *Social Sciences Citation Index*. First, they need to be continuously and regularly published over a period of years and then need to have a significant impact in terms of citation counts. This means they need to go through and pass a 'qualification period'. In the case of *Industrial and Corporate Change*, this has taken 10 years. Last year's volume was indexed in the *SSCI*. For the same reason, we cannot trace the reception of his contribution in *Industrial and Corporate Change* and other relatively young yet important journals without restrictions.

While this type of qualification period is a limitation in terms of coverage, it can also be seen as an indicator of the quality of the journals in which Keith Pavitt chose to publish his work. More than 71% of Pavitt's articles and still almost half of his other journal publications were indexed in the *SSCI*.

Similarly, the citation analysis presented here cannot fully cover the influence of his work, in part because it only covers citations in *SSCI* publications, but also some citations may not have been identified due to well known limitations of citation analysis. Furthermore, citations to his work have naturally continued to grow (this paper is just another example) and the citation analysis presented here can only be seen as a temporary window on the influence of his work on others.

3. Findings

3.1. Keith Pavitt's publication activity

Keith Pavitt's work in the area of science, technology and innovation can be traced back to his work at the OECD in the 1960s.[6] With initial anonymous contributions to OECD reports (the first being a report on *Policies for Science and Education: Yugoslavia*, 1962) he published in 1963 a paper in *Nature* (Pavitt, 1963), following an OECD report on *Science, Economic Growth and Government Policy*, published in the same year, and other publications with the OECD.

As identified above he also contributed chapters to several books (which will not be analysed here), the first published in 1969. Keith Pavitt's recorded publication activity in the *SSCI* starts in 1969 with a paper in *Long Range Planning* on the need for a world perspective for reflecting on technological innovation in Europe. The concern with the European approach to technology policy was a theme that remained present throughout his subsequent work (for example Pavitt, 1998b).

Fig. 1 indicates he published at an almost constant rate with an early start. This rate did not decline in the later stages of his career, namely at tenure point when this often happens. This is typical for high achievers as described, for instance, by Granstrand (2003) in a recent study. The publications identified include collaborations with 28 authors. Among these must be highlighted the editors of *Research Policy*, who have co-

[5] For instance, Pavitt (1998a). Note that Table 2 only indicates one article since the journal (*Industrial and Corporate Change*) was only recently included in the SSCI. Earlier articles published in *Industrial and Corporate Change* are not added after inclusion into the index.

[6] From his personal CV, thanks to Susan Lees. Recent work by Benoit Godin, on the history of S&T Statistics, has also identified some of his contributions to work developed at the OECD on S&T indicators; see for example Godin (2003).

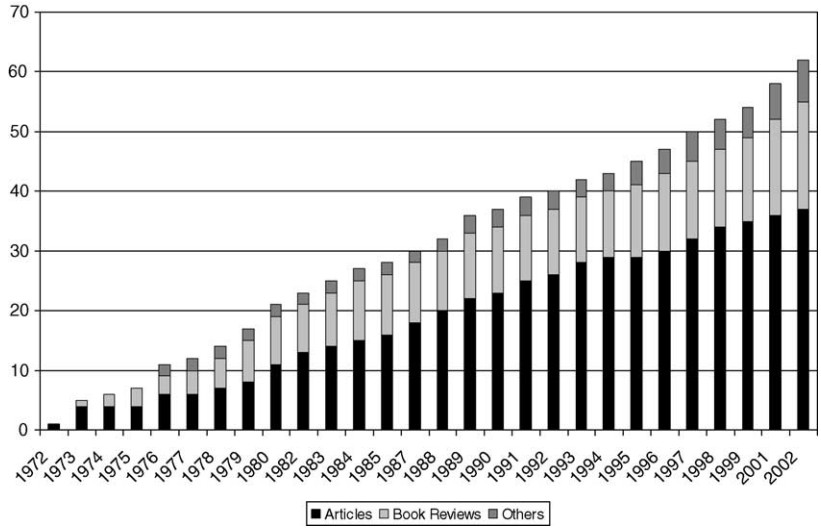

Fig. 1. Evolution of Keith Pavitt's publication activity (accumulated counts).

authored editorials, and among them Chris Freeman, with whom Keith Pavitt also had earlier co-authored publications, and particularly, the productive collaboration with Pari Patel, which corresponds to 6 of the publications identified here (but totals 38 such co-authorships in his publication list).

The journal publication profile does not identify a specific pattern other than the natural first choice in publication in *Research Policy*, where Pavitt published more than in any other journal. *Minerva* received more book reviews and *Futures* was the choice for publication in the earlier papers (all his articles in *Futures* were published before 1980), but *Research Policy* became clearly the central journal for the publication of his work, in the second half of his publication history, along with his role as editor of the journal.

The journals where Pavitt published include disciplinary journals beyond the thematic journals related to science, technology and innovation, such as journals in economics, management, political science and general science. Nevertheless, the second half of his publication activity (from 1988 onwards) has seen his work move more clearly outside the more strictly policy field towards a wider impact at discipline level, namely in management studies (particularly if his publications in *Industrial and Corporate Change* are considered), as Table 2 indicates.

3.2. Works cited by Keith Pavitt

An analysis of the works cited by Keith Pavitt is presented in the following tables. The data illustrates how Pavitt cited people close to him in terms of organization (SPRU, e.g. C. Freeman or P. Patel) and initially more remote people gravitating towards SPRU. Pavitt clearly cites (non-orthodox) economists more than others.

Table 3 presents a list of Pavitt's most cited references, authors and journals. The data are divided into two periods (citations in his publications until 1987 and from 1988 onwards). These data reveal the intellectual indebtedness of Pavitt's work to three main authors, who can be considered to have been central to the development of the Innovation Studies literature: Chris Freeman, Richard Nelson and Nathan Rosenberg, as well as their seminal books.[7] It is also worth noting the importance of work produced by the OECD for Keith Pavitt's research, reflecting his strong interest in policy-oriented research, and also his own trajectory (having

[7] It should be noted that the citation analysis is based on first author only. We indicate only the first author to make such methodological limitation clearer, as it was not feasible, in the context of this research note, to fully identify all authors. Nevertheless, among the most cited works, the co-authorship of Sidney Winter with Richard Nelson, and of Ron Johnston with Michael Gibbons, should be emphasised, as well as Keith Pavitt's significant collaborative activity with Pari Patel (as also mentioned above).

Table 2
Keith Pavitt's publication activity (by document type and journal)

	Articles	Book reviews	Total[a]	Until 1987	From 1988
Research Policy	11	4	18	4	14
Futures	6	1	7	7	
Omega-International Journal of Management Science	2		3	3	
Scientometrics	2		3	1	2
California Management Review	2		2		2
R&D Management	2		2	2	
Minerva	1	7	8	8	
Administrative Science Quarterly	1	1	2		2
Journal of Evolutionary Economics		2	2		2
Others[b]	11	3	16	6	10
Total	38	18	62	31	32

Source: SSCI.

[a] Includes other publications, such as editorial material.

[b] We listed only journals with at least two publications. Keith Pavitt also published articles, book reviews, or other material in the following SSCI journals: Academy of Management Review, Economic Journal, Futuribles, Industrial and Corporate Change, Journal of Common Market Studies, Journal of Industrial Economics, Journal of International Business Studies, Long Range Planning, Management Science, Manchester School of Economic and Social Studies, National Westminster Bank Quarterly Review, PNAS, Research-Technology Management, Sloan Management Review, World Bank Economic Review, World Politics.

worked at the OECD at the beginning of his career). This is particularly clear in his first publications.

The journal distribution of his citations is clearly centred on *Research Policy*, with a very wide distribution thereafter, led by *The Economic Journal*. The third most cited journal is *Scientometrics*, indicating the importance of this line of research for Pavitt, also reflected in some of the individual citations. It is worth noting here that among his most cited journals, in the most recent period, is *Industrial and Corporate Change*, which was not indexed in the SSCI, as already mentioned.

Keith Pavitt initially developed an extra-disciplinary publication profile, graduating originally with a degree in Physics, and in the 1980s and 1990s developed an inter-disciplinary profile. This was due much to his problem orientation but also to his method orientation (implying creating and exploiting patent and innovation databases). Thus he did not migrate between disciplines but rather served as a stable link and gatekeeper. This was also related to his role as editor and is also substantiated by the analysis of Table 3, and of the differing citation profiles, in the two periods identified.

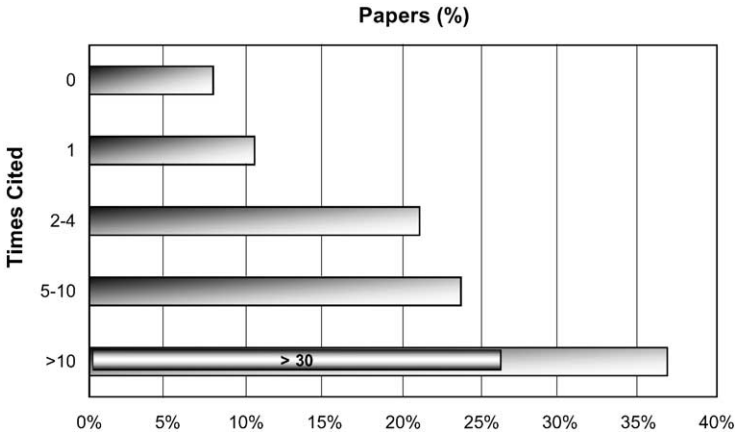

Fig. 2. Citation profile.

Table 3
References cited by Keith Pavitt

Works cited by Keith Pavitt
- Freeman C., 1974 and 1982, EC Ind Innovation (13 citations)
- Nelson R., 1982, Evolutionary Theory (12 citations)
- Rosenberg N., 1976, Perspectives Technol (12 citations)
- Gibbons M., 1974, V3, P220, Res Policy (10 citations)
- Schmookler J., 1966, Invention EC Growth (9 citations)
- Freeman C., 1982, Unemployment Technic (7 citations)
- Vernon R., 1966, V80, P190, Q J ECON (8 citations)
- EADS G, 1971, V19, P405, Public Policy (7 citations)
- Scherer F., 1982, V11, Res Policy (7 citations)
- Fagerberg J., 1987, V16, P87, Res Policy (7 citations)
- Fagerberg J., 1988, V98, P355, Econ J (7 citations)
- Porter M., 1990, Competitive Advantag (6 citations)

In Pavitt's 1972–1987 publications
- Freeman C., 1974 and 1982, EC Ind Innovation (8 citations)
- Gibbons M., 1974, V3, P220, Res Policy (10 citations)
- Rosenberg N., 1976, Perspect Technol (5 citations)
- Schmookler J., 1966, Invent EC Growth (5 citations)
- Vernon R., 1966, V80, P190, Q J Econ (5 citations)
- Freeman C., 1974 and 1982, EC Ind Innovation (8 citations)

In Pavitt's 1988–2002 publications
- Nelson R., 1982, Evolut Theory (9 citations)
- Rosenberg N., 1976, Perspect Technol (7 citations)
- Fagerberg J., 1988, V98, P355, Econ J (7 citations)
- Fagerberg J., 1987, V16, P87, Res Policy (7 citations)
- Porter M., 1990, Competitive Advantag (6 citations)

Authors cited by Keith Pavitt
- Pavitt K (90 citations)
- Nelson R (46 citations)
- Freeman C. (42 citations)
- Patel P (39 citations)
- OECD (34 citations)
- Rosenberg N (32 citations)
- Soete L (27 citations)
- Scherer F (26 citations)
- Rothwell R (21 citations)
- Mowery D (18 citations)
- Fagerberg J (17 citations)
- Mansfield E (16 citations)
- Vernon R (16 citations)

In Pavitt's 1972–1987 publications
- Pavitt K (43 citations)
- OECD (27 citations)
- Nelson R (25 citations)
- Freeman C. (21 citations)
- Scherer F (18 citations)

In Pavitt's 1988–2002 publications
- Pavitt K (47 citations)
- Patel P (39 citations)
- Rosenberg N (22 citations)
- Freeman C. (21 citations)
- Nelson R (21 citations)

Journals cited by Keith Pavitt
- Research Policy (178 citations)
- Economic Journal (25 citations)
- Scientometrics (15 citations)
- American Economic Review (13 citations)
- Industrial and Corporate Change (13 citations)
- Harvard Business Review (12 citations)
- Omega (12 citations)
- Science (11 citations)
- Journal of Political Economy (10 citations)
- Science and Public Policy (10 citations)
- Quarterly Journal of Economics (9 citations)
- World Patent Information (8 citations)
- International Technology Transactions (8 citations)

In Pavitt's 1972–1987 publications
- Research Policy (62 citations)
- Economic Journal (8 citations)
- Omega (7 citations)
- Futures (6 citations)
- Science (6 citations)

In Pavitt's 1988–2002 publications
- Research Policy (116 citations)
- Economic Journal (17 citations)
- Industrial and Corporate Change (17 citations)
- Scientometrics (10 citations)
- Harvard Business Review (9 citations)

3.3. Keith Pavitt's most cited research papers

Keith Pavitt's work has been well received over the decades. We identified a total of 863 citations to all his indexed articles. The median paper has received 6.5 citations while the mean citation rate is 22.7 citations per paper. Pavitt's share of uncited or less frequently cited articles is low whereas the share of highly cited papers is considerable. More than 26% of his indexed papers have been cited more than 30 times. Sixteen of his papers were cited 10 or more times. The share of papers that have remained uncited so far is below 8%. Fig. 2 presents a citation profile of his œuvre. Pavitt's most cited paper accounts for about a third of all the citations he has received so far.

Table 4 presents a list of Keith Pavitt's most cited papers. Pavitt's most cited journal article is his *Research Policy* paper on "Sectoral patterns of technical change"

Table 4
Most cited papers written by Keith Pavitt in the SSCI

Title	Journal	Year	Times cited
Sectoral patterns of technical change—towards a taxonomy and a theory	Research Policy	1984	266
The size distribution of innovating firms in the UK, 1945–1983	Journal of Industrial Economics	1987	79
Large firms in the production of the world's technology—an important case of non-globalization	Journal of International Business Studies	1991	76
Patent statistics as indicators of innovative activities—possibilities and problems	Scientometrics	1985	66
What makes basic research economically useful	Research Policy	1991	56
R-and-D, patenting, and innovative activities—a statistical exploration	Research Policy	1982	42
The technological competencies of the world's largest firms: complex and path-dependent but not much variety	Research Policy	1997	37
What we know about the strategic management of technology	California Management Review	1990	36
Government policies towards industrial innovation—review	Research Policy	1976	33
Multi-technology corporations: why they have "distributed" rather than "distinctive core" competencies	California Management Review	1997	32
Technological accumulation, diversification and organization in UK companies, 1945–1983	Management Science	1989	28
Is western-Europe losing the technological race	Research Policy	1987	25
Sectoral patterns of production and use of innovations in the UK, 1945–1983	Research Policy	1988	24
The continuing widespread (and neglected) importance of improvements in mechanical technologies	Research Policy	1994	17
Comment on a dynamic model of process and product innovation	Omega-International Journal of Management Science	1976	12
Technology policy in the 1990s—old trends and new realities	Journal of Common Market Studies	1993	10

with more than 266 contributions, which is currently the third most cited article published in *Research Policy*. His next highly cited papers were in the *International Journal of Industrial Economics*, *Journal of International Business Studies*, and *Scientometrics*. This points to the broad, interdisciplinary relevance of his contributions from management to economics and indicators, rather than contributions to a highly specific audience.

The interdisciplinary reach of his work is also illustrated in the pattern in which his most cited paper was received. Apart from *Research Policy*, the taxonomy paper was more cited in *Small Business Economics*, *Technology Analysis and Strategic Management*, the *International Journal of Technology Management*, *Technovation* and *Regional Studies*. *Technological Forecasting and Social Change* also belongs among the top journals in which the 'Sectoral patterns of technical change' paper was cited. Articles in which the influence of this work can be found are varied, including some 90 different SSCI journals, such as *Journal of Evolutionary Economics*, *Organization Science*, *Policy Sciences* or *World Development*. However, *Research Policy* has remained the journal in which the paper was cited the most. As illustrated in Fig. 3, the wide reach across a substantial spectrum of journals has evolved over the past 20 years but really set in about 10 years after the article was published. While the paper was already cited at a certain level in the first 10 years after publication, the paper experienced its

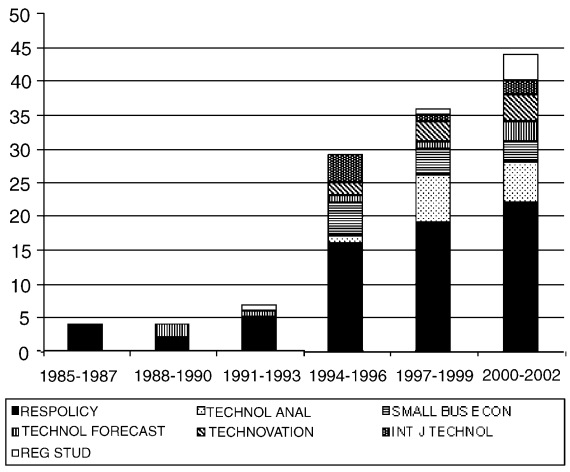

Fig. 3. Reception of the 'Pavitt Taxonomy'.

breakthrough in the mid and late 1990s. This trend has persisted until today.

Two mechanisms of increasing returns (i.e. positive feedbacks) can be hypothesized to be operating in tandem behind these dynamics, as identified by studies in the sociology of science. First, there are increasing returns at article level—in this case regarding his top-cited article—implying that the more cited (widespread) an article is at a point in time, the more likely it is going to be cited ahead of time (i.e. temporary increasing returns). Second, there are increasing returns at author level, implying that the more an author has become cited and well known, the more his/her new articles will become cited per post-publication year, at least for some time to come. These two mechanisms interact. The case of Keith Pavitt might then be typical as his breakthrough article from 1984 helped build his reputation as a scholar, which in turn *increased* the propensity among his colleagues to cite his later works. Other factors also come into play, of course, such as an increase in an author's skills (through "learning by publishing") and growth of a relevant epistemic community (i.e. through doctoral students—Keith Pavitt's students feature prominently among the citing authors in the last 10 years).

An increase in the frequency of publication of *Research Policy*, coinciding with this surge, also confirms such growth, and has certainly contributed in increasing the impact of this paper. While during the period 1980–1993 an average of 25 articles were published in *Research Policy* annually, for the period ranging from 1994 to 2003 this figure increased to 63.

One may speculate about other reasons for the greater impact in the more recent period, but the increased interest in sectoral innovation systems in the 1990s could be another possible reason. The impact factor of the journal *Research Policy* has also been changing positively, which may also reflect such greater impact of the field.

Taking a closer look at the diffusion of the 1984 (Pavitt, 1984) article reveals that after a gestation period an S-shaped diffusion pattern sets in terms of both total number of citations and number of journals with citations (see Fig. 3). This suggests increasing returns (such as in an epidemic diffusion model of a logistic type) at both intra- and interdisciplinary levels for this article.[8] One may also observe that the set of journals in which Keith Pavitt frequently published differs from the set of journals frequently citing his 1984 article, apart from *Research Policy*. These sets are also fairly scattered around in the journal co-citation map (Fig. 5). Such scattering could perhaps be interpreted as reducing spill-overs across journals, thereby possibly strengthening the interdisciplinary nature of Keith Pavitt's publishing in general as well as the reception of his 1984 article, but that must be left as a hypothesis at this point. It should also be borne in mind that Keith Pavitt's interdisciplinarity was more a consequence of his extra-disciplinary problem and method orientation than of a conscious strategy to build bridges across certain disciplines.

3.4. Co-citation maps

Drawing on data from the 1419 papers citing Keith Pavitt, we produced two co-citation maps covering the period from 1972. As the methodology centres on his work, he appears quite naturally in the middle of the author-map. The first map is based on cited authors (Fig. 4), while the other one presents a map of journals co-cited with Keith Pavitt's works (Fig. 5). Both maps illustrate the wide intellectual environment in which his work was received.

Author co-citation maps are a way of illustrating the intellectual relatedness of researchers on the basis of their co-occurrences in the reference list of papers. In this particular case the source papers are those citing any work of Pavitt. In order to make the map we have selected the authors most co-cited with him, and we have also counted the number of times all of them have been co-cited. Then, the matrix of co-citations was submitted to a multi-dimensional scaling software that tried to find a two-dimensional representation of that matrix. Such a representation, even if not directly proportional, indicates a relationship with the distance between two authors in the map and the number of co-citations received, that is, the number co-occurrences in the reference lists of papers citing Pavitt. The circle areas have been made proportional to the citation frequency of each author.

[8] The data and scope of this research note do not allow for a more rigorous test of this hypothesis.

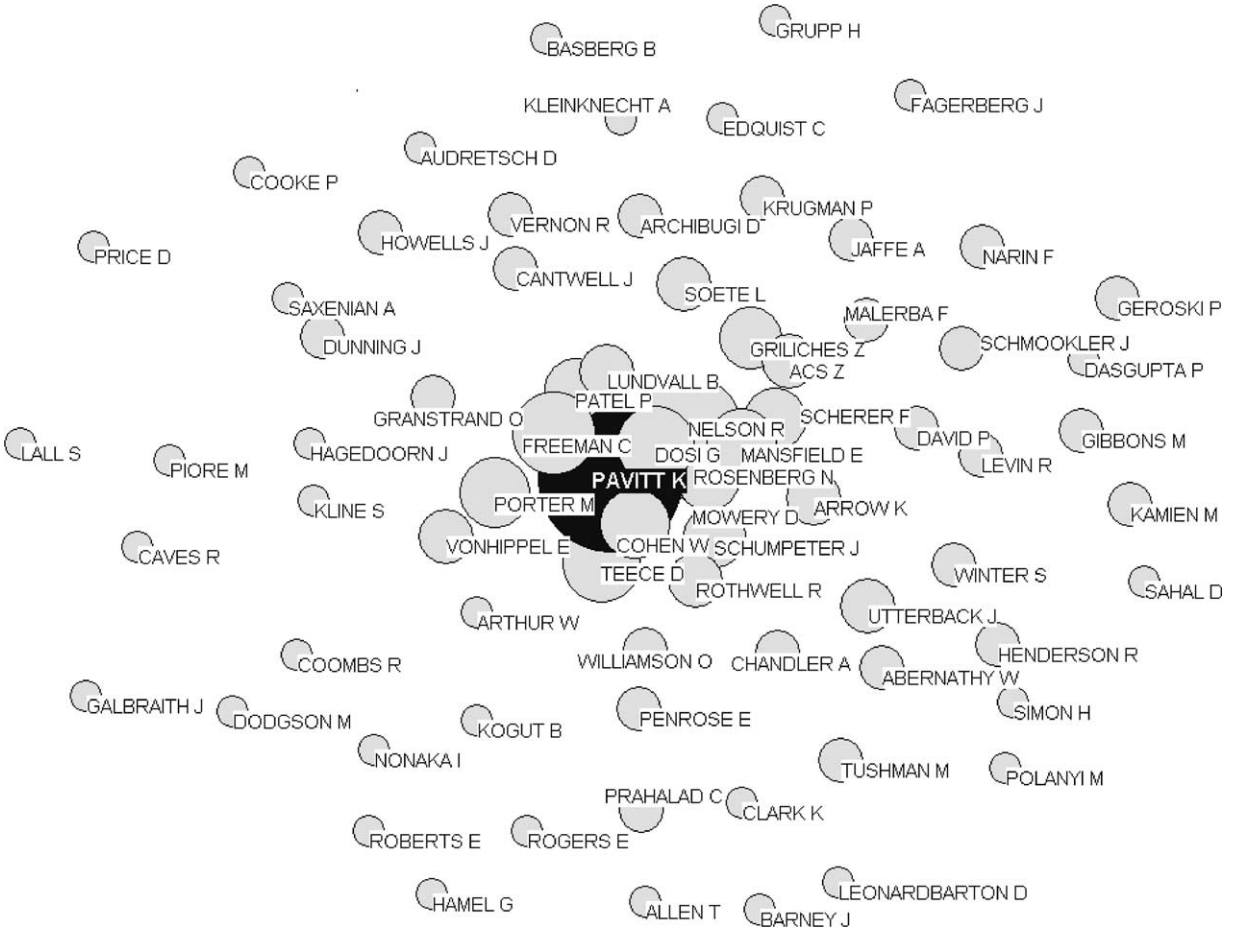

Fig. 4. Author co-citation map.

Co-cited authors include economists, economic historians, and sociologists of science and technology as well as management scholars. An earlier bibliometric effort to map the economics literature (Granstrand, 1994) placed Keith Pavitt close to the area of economics of technology/innovation, being part of a field with Chris Freeman as the central figure. Other authors included G. Dosi, C. Perez, R. Rothwell and L. Soete. This type of economic works was more qualitative in nature, often historic at both macro and micro-levels and tended to be outside mainstream economics. Much of this is associated with evolutionary economics and with R. Nelson as key author.[9] These associations are also visible in this co-citation map.

The author co-citation map also reveals that Pavitt's work was co-cited with authors on both sides of the Atlantic. While some colleagues from, or previously from, SPRU are central, several US authors are often co-cited with Pavitt's work, and some who are less directly related to the innovation studies field, such as Michael Porter.

A more recent development illustrated in our maps may be the integration of economics, management and policy fields in which Keith Pavitt's work had a bridging function. The co-citations reveal that his work found relevance alongside the work of central authors in the management and economics literature. This also reflects a current convergence, indicated by

[9] It should be noted here that the co-citation maps use first authors only, which does not always fully reflect all existing links.

Fig. 5. Journal co-citation map.

a growing number of books and professorial chairs with the title 'economics and management of innovation or technology'. The journal co-citation map also allows us to see a correspondingly wide reception of Keith Pavitt's ideas and increasingly wider relevance of the journal of which he was an editor. *Research Policy* is at the centre, surrounded by a variety of journals covering fields such as management, economics, econometrics, sociology, policy analysis and bibliometrics. In particular, the journal co-citation map indicates that his work was relevant beyond a strict disciplinary approach. Looking at the different journals and various disciplines that are related in this map, one could say that he pursued a problem-oriented approach. Keith Pavitt did not consider himself an economist. For him, mono-disciplinary belonging was less important. Rather, he took pride in communicating with several disciplinary communities, especially economists, management scholars and policy analysts. Such communication patterns are clearly reflected here.

This finding is reinforced by a comparison of the most prominent authors co-cited with Keith Pavitt for science and technology (ST), business and economics (BE) as well as other journals (OT). Many of the highly cited authors are prominent in more than one of the fields. As Table 5 illustrates, 35 of the authors cited more than 30 times in the data set have published in journals in two or more fields. A total of 25 authors publish across the three fields. This illustrates that Keith Pavitt was associated intellectually with other interdisciplinary scholars.[10]

[10] Following a suggestion from a referee, we also carried out an analysis of most frequent key words. Also here we could establish little difference between the fields.

Table 5
Prominent authors and fields citing them

Twenty five authors co-cited in three fields	
	Acs Z.J., Archibugi D., Cantwell J., Cohen W.M., Dosi G., Freeman C., Griliches Z., Jaffe A.B., Lundvall B.A., Mansfield E., Mowery D.C., Nelson R., Patel P., Pavitt K., Porter M.E., Rosenberg N., Rothwell R., Scherer F.M., Schmookler J., Schumpeter J.A., Soete L., Teece D.J., Utterback J.M., Von Hippel E.
Ten authors co-cited in two fields	
BE, ST	
	Arrow K.J., David P.A., Malerba F., Williamson O.E.
ST, OT	
	Gibbons M., Howells J., Mowery D., Narin F.
BE, OT	
	Abernathy W.J., Vernon R.
Twenty four authors co-cited in one field	
BE	
	Caves R.E., Chandler A.D., Geroski P.A., Henderson R.M., Kamien M.I., Kogut B., Krugman P., Levin R.C., Tushman M.L., Winter S.G.
ST	
	Callon M., Dasgupta P., Field E., Granstrand O., Grupp H., Hagedoorn J.
OT	
	Cooke P., Dodgson M., Leonard Barton D., Malecki E.J., Nonaka I., Prahalad C.K., Scott A.J., Storper M.

Note: BE (business and economics), ST (science and technology), OT (other).

3.5. Citation links between Scientometrics and Research Policy

Keith Pavitt always had an interest in science and technology indicators; his contributions played an important role in both the research policy and the bibliometric communities. A recent review of journal references in *Scientometrics*, a core journal of the bibliometrics and informetrics community, indicates that *Scientometrics* authors cite articles from *Research Policy* frequently over a sustained period of time (Persson, 2003).[11] This raises the question of the extent to which one may be able to detect Pavitt as a driving force behind the close link between the quantitative and policy-oriented fields of science and technology studies.[12]

Table 6
Most frequently cited authors in *Research Policy* and *Scientometrics*

	Cited first author	Grand total
1	Schubert A.	285
2	Braun T.	278
3	Pavitt K.	190
4	Narin F.	180
5	Moed H.F.	160
6	Leydesdorff L.	157
7	Martin B.R.	130
8	Vinkler P.	124
9	Small H.	111
10	Haitun S.D.	101
11	Glänzel W.	100
12	Beaver D.D.	94
13	Nederhof A.J.	93
14	Nelson R.R.	79
15	Von Hippel E.	78

Note: based on journal self-citations and citations in the other journal only.

Looking at the combined sets of *Scientometrics* and *Research Policy* citations in both journals, one can clearly see his important role. He was a bridge between the world of scientometrics and the sphere of research policy (Table 6).

One can distinguish between different sets of citations involving the two journals: journal self-citations and citations from one journal to the other. We traced all of them and calculated rankings of the most cited first authors for each of the possible categories. As the following results illustrate, Pavitt was the most influential first author as measured by citations not only for within-journal self-citations of *Research Policy* but also the most frequently cited first author of *Scientometrics* papers in *Research Policy*. However, the journal co-citation map presented above shows that the link between *Research Policy* and *Scientometrics* is not generally strong among the authors drawing on Keith Pavitt, even if he cited *Scientometrics* relatively highly. Following Granovetter (1973), one may thus see Pavitt as the central 'weak tie' between *Scientometrics* and *Research Policy*.

Keith Pavitt was one among 37 authors with citations across the 4 directions and one among only 10 authors who had more than 5 citations in each of the 4

[11] Especially in more recent years, *Research Policy*was among the most frequently cited journals, second only to *JASIST*.

[12] This strong link needs to be considered also in the context of the declining (citation) relationship between the quantitative/bibliometric aspects of STS and the sociologically and qualitatively focused communities (see e.g. Van den Besselaar, 2000).

Table 7
Most cited authors by citing direction

Research Policy Citing Research Policy		Research Policy Citing Scientometrics		Scientometrics Citing Research Policy		Scientometrics Citing Scientometrics	
Cited first author	Times cited	Cited first author	Times cited	Cited first author	Times cited	Cited first author	Times cited
Pavitt K.	142	Pavitt K.	24	Martin B.R.	70	Schubert A.	272
Von Hippel E.	77	Narin F.	21	Narin F.	51	Braun T.	268
Nelson R.R.	73	Leydesdorff L.	15	Moed H.F.	46	Leydesdorff L.	121
Teece D.J.	72	Schubert A.	13	Healey P.	25	Vinkler P.	117
Dosi G.	69	Small H.	11	Peters H.P.F.	25	Small H.	100
Rosenberg N.	59	Braun T.	10	Katz J.S.	17	Glänzel W.	100
Mansfield E.	55	Nederhof A.J.	10	Moravcsik M.J.	17	Haitun S.D.	98
Narin F.	47	Martin B.R.	8	Leydesdorff L.	15	Moed H.F.	92
Mowery D.C.	42	Moed H.F.	8	Mansfield E.	12	Beaver D.D.	89
Granstrand O.	34	Schmoch U.	8	Van Vianen B.G.	12	Nederhof A.J.	74
Martin B.R.	31	Luukkonen T.	7	Collins P.	11	...	
Patel P.	31	Van Raan A.F.J.	7	Pavitt K.	11	Pavitt K.	11

directions.[13] Among these 37 authors he was the most cited author in *Research Policy*, both to his papers in *Research Policy* and in *Scientometrics*. It is clear from this data that among the authors more clearly linking the two journals he is the most influential author in *Research Policy*. Table 7 lists 10 authors with more than 5 citations in each of the 4 directions.

In accordance with expectations, Pavitt's taxonomy article was his most cited paper in *Research Policy*, being cited 91 times, followed by his paper on 'What Makes Basic Research Economically Useful' (Pavitt, 1991) which was cited 18 times in other *Research Policy* articles, and his exploration of R&D, patenting and innovative activities which has been cited 42 times since 1982. Pavitt's *Scientometrics* paper most frequently cited in *Research Policy* is his 1985 paper on possibilities and problems of patent statistics as indicators of innovative activities which was cited 24 times in *Research Policy*. This paper was also his *Scientometrics* article most cited in *Scientometrics*.

4. Conclusions

This paper aimed at exploring the impact Keith Pavitt has had on research in science, technology and innovation. Naturally, this study honored his multifaceted contributions to the field. Our analysis has shown that Keith Pavitt contributed a considerable number of highly cited research papers. Irrespective of the type of analysis, *Research Policy* is the journal at the heart of Keith Pavitt's work. Our study also highlighted his role as a bridge between policy and bibliometric communities. An analysis of citations between *Research Policy* and *Scientometrics* identified Keith Pavitt as a critical link between the two fields. This should be seen as a particular achievement since these areas have tended to drift apart in recent years.

This integrating function went beyond the bibliometrics/policy context and also encompassed areas of management and economics. Our co-citation analysis has demonstrated the wide and interdisciplinary reception of Pavitt's ideas. One could say that this indicates a role as a 'converger' stimulating interaction between the management, economics and policy communities.

The scope of this study was limited. We looked only at journal articles indexed in the *SSCI* and, therefore, missed a number of important publications. Our case study of the *Research Policy–Scientometrics* connection could have been extended to explore the interrelation between the research policy and management and economics communities further. Also, one could have viewed Keith Pavitt's work in the context of other eminent contributors in these areas, such as D. Price, C. Freeman, R. Nelson, F. Narin and others. However, our main objective was to characterize rather than compare his research work and impact and in this way pay

[13] Citations in *Research Policy* to papers by the author in *Research Policy*, citations in *Research Policy* to papers by the author in *Scientometrics*; citations in *Scientometrics* to papers by the author in *Research Policy*; citations in *Scientometrics* to papers by the author in *Scientometrics*.

homage to what we consider a central and bridging contribution to the innovation studies literature.

Finally we should be aware that our study is no more than a snapshot of the current appreciation of Keith Pavitt's work in the STI community. Since we completed our research for this study, many more citations have been made to Keith Pavitt. This just illustrates his continuing impact on our field.

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References

de Solla Price, D., 1965a. Little Science, Big Science. Columbia University Press, New York.

de Solla Price, D., 1965b. Is technology historically independent of science? A study in statistical historiography. Technology and Culture 6, 553–568.

Godin, B., 2003. The emergence of science and technology indicators: why did governments supplement statistics with indicators? Research Policy 32, 679–691.

Granovetter, M., 1973. The strength of weak ties. American Journal of Sociology 78, 1360–1380.

Granstrand, O. (Ed.), 1994. Economics of Technology. North-Holland/Elsevier, Amsterdam, pp. 1–37.

Granstrand, O. (Ed.), 2003. Economics, Law and Intellectual Property. Kluwer Academic Publishers, Dordrecht, pp. 9–40.

Griliches, Z., 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature 28, 1661–1707.

Hall, B., Jaffe, A., Trajtenberg, M., 2001. The NBER patent citation data file: lessons, insights and methodological tools. NBER Working Paper No. W8498.

Jaffe, A., Trajtenberg, M., 2002. Patents, Citations, and Innovations: A Window on the Knowledge Economy. MIT Press, Cambridge, MA.

Pavitt, K., 1963. Research, innovation and economic growth. Nature 200, 206–210.

Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy 13, 343–373.

Pavitt, K., 1991. What makes basic research economically useful? Research Policy 20, 109–119.

Pavitt, K., 1998a. Technologies, products and organisation in the innovating firm: what Adam Smith tells us and Joseph Schumpeter doesn't. Industrial and Corporate Change 7, 433–452.

Pavitt, K., 1998b. The inevitable limits of EU R&D funding. Research Policy 27, 559–568.

Persson, O., 2003. 25 years of scientometrics—mapping its structure and dynamics. Paper Presented at the Eighth Annual Nordic Workshop on Bibliometrics, Informetrics and Research Policy, Aalborg, October 2–3, 2003.

Van den Besselaar, P., 2000. Communication between science and technology studies journals: a case study in differentiation and integration in scientific fields. Scientometrics 47, 169–193.