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A Citation/Co-citation of Research Policy

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ABSTRACT   *In this paper bibliometric (co-citation analysis) and social network analysis techniques are used to investigate the intellectual pillars of the literature in Research Policy. We apply a cross-level type of analysis to provide a comprehensive picture of deeper disciplinary roots, long-term subjects and time-varying discourses. In practice, we map the research concerns at the journal, author and publication level which represent disciplines, subjects and themes. By applying this multi-dimensional view we provide insights into hierarchical and interlinked patterns of the evolving scientific discourse. We position dominant subjects around a shared common core of literature and discuss recent changes in themes in relation to possible future work. Last but not least we significantly find evidence for the discipline-spanning as well as integrating effects of the scientific discourse within research policy which justifies its characterization as a discipline of its own.*

KEYWORDS: Research Policy, bibliometric techniques, school of thought, research themes, factor analysis, co-citation, citation analysis, social network analysis.

Introduction

Over the last two decades *Research Policy* (RP) has established itself as the leading journal in the field. However, defining the scope and coverage of that field is problematic as it encompasses many sub-fields from a variety of different disciplines. These range from public and science policy, micro- and macro-economics, and the applied disciplines of technology management, R&D, product innovation and management strategy.

This paper empirically investigates the research-space occupied by *Research Policy* through an examination of the citation patterns present in the journal itself. This analysis allows both a clear un-subjective picture of the span and concerns of *Research Policy* to be drawn, but also identifies the issues arising from the interrelationships of its source fields, journals and the plotting of the works of leading authors. The paper starts with a brief review of bibliometric studies to introduce the approach which is followed by a description of the data. The principal investigation involves factor analysis performed to determine the latent structure underlying the *Research Policy* literature at the journal and author level to explore the integration of fields, and also at the individual cited article level to explore the evolution of research themes. These three

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levels of analyses are finally brought into relation to each other in order to provide an integral view on the development of our discipline.

Studies of the Academic Literature

There are a number of techniques that can be used to examine a body of literature. Most frequent is the simple literature review where a highly subjective approach is used to structure the earlier work (Drejer, 1996; 1997). More objective, quantitative techniques are also available and use an analysis of author citations, co-citations, or a combination of the two. Citation analysis is based on the premise that authors cite papers they consider to be important to the development of their research. As a result, heavily cited articles are likely to have exerted a greater influence on the subject than those less frequently cited (Sharplin and Mabry, 1985; Culnan, 1986). As such these analyses represent "the field's view of itself" (White and Griffith, 1980). There are well defined concerns surrounding citation analysis, including the problem that a study may be heavily referred to due to its poor quality. However, with adequate screening and a sufficiently large sample, citation analysis provides a useful insight into which papers and authors are considered influential. Similarly, co-citation analysis involves analysing the frequency with which two citations appear together in the literature (Small, 1973). The approach is instrumental in identifying groupings of authors, topics, or methods and can help us understand the way in which these clusters relate to each other.

A number of bibliometric analyses have been performed on single levels of analysis and on the literatures of fields adjacent to *Research Policy*. At the highest level of aggregation, Linton and Thongpapanl (2004) provide a journal citation analysis of 10 technology and innovation management journals to gain insights into their relative ranking and their positioning. Analogeously, Karki (1996) examined the sociology of science literature on the journal level and found that information scientists and sociologists exchange ideas only when they are discussing 'scholarly communication' as a subject. Cottrill *et al's* (1989) investigate the links between 'diffusion theory' and 'technology transfer' in more detail. Again, they found the use of distinct approaches within each sub-field but that they rarely interacted with each other. Culnan (1986) used co-citation analysis at the author level to investigate the founding pillars of management information systems and found the subject to have more affinity with information science than organisation studies. Similarly, Pilkington and Liston-Heyes (1998) identified the sub-fields in operations management and in particular the problems scholars from different geographic traditions have in agreeing common themes. To the best of our knowledge no such study has dealt with an integral view of the multi-layer developments within the field of RP.

Methodology

The data used in this study included the contents (article titles, authors, publication dates, and citations) of *RP* from 1985 to the end of 2003. Access to the data was by the on-line version of the Social Science Citation Index (SSCI) which is offered through the Web of Science system.

The reliance on *RP* alone may be viewed as providing a biased record of the area's literature which might also include the contents or partial contents of other journals such as *Int. J. Innovation Management, R & D Management, Technovation,* and numerous others. However, the authors feel

that there is no other journal which covers the same breadth and depth of innovation and technology management in as highly regarded a manner and so believe its selection provides as comprehensive a picture as needed. Indeed one of the aims of the research resulting in this paper was to investigate to what extent *RP* was able to bridge the multiple disciplines in which research on innovation and technology management is occurring. This was a primary interest of the authors as they themselves come from divergent disciplinary backgrounds - operations management and marketing.

The initial extraction of the data from the SSCI resulted in 1,147 articles by 759 different main authors. The discrepancy is due to multiple articles by the same author and because many authors also feature as co-authors with others. Table I shows the authors with the most articles published in the sample.

A certain amount of manipulation was required to standardise entries and correct inconsistencies in the SSCI particularly the spelling of author names, affiliations, and journals. For example at least three different abbreviations were used for the *International Journal of Operations and Production Management* journal: *IJOPM, IJOpProdMan* and *IntJOPM*; and author's names seemed to arbitrarily include one or two initials. The 1,147 source articles produced a total of 18,838 citations.

Table I. Authors Contributing Articles to the Sample

Author	Number of Source Articles
Freeman C	18
Nelson R	18
Archibugi D	10
Hobday M	9
Mowery D	9
Radosevic S	8
Antonelli C	7
Hagedoorn J	7
Pavitt K	7
Tether B	7
Howells J	6
Mansfield E	6
Senker J	6
Tijssen R	6
Von Tunzelmann G	6
Etzkowitz H	5
Feller I	5
Granstrand O	5
Luukkonen T	5
Malerba F	5
Narin F	5
Odagiri H	5
Patel P	5

Table II. The Most Frequently Cited Journals

Journal Title	Number of Citations
Res Policy	680
Am Econ Rev	260
Econ J	201
Adm Sci Q	169
Manage Sci	158
R D Manage	157
Strategic Manage J	157
J Polit Econ	152
Harvard Bus Rev	149
J Econ Lit	143
Q J Econ	138
J Ind Econ	133
Rev Econ Stat	123
Ind Corp Change	119
Calif Manage Rev	117
Scientometrics	115
Science	108
Sci Publ Policy	108
Technovation	104

Results

Citation Analysis

Preliminary analyses of the data produced interesting background statistics, for example the frequency of journal citations, listed in Table II. Not unsurprisingly given the discussion about *RP* as the cornerstone of an emerging discipline above, general management and strategy specific journals featured prominently alongside the technology management and economics specific journals.

A standard approach often used in bibliographic analysis is to concentrate on cited authors as a proxy for their ideas, amalgamating all their publications together (Culnan, 1986). This is normal practice as studies start with a few key authors as a seed which is then expanded by searches of citations in the SSCI. In these cases, author name searches offer a massive time advantage over looking at individual publications in data retrieval and are far more accurate. In our case, given the census type approach following the adoption of *Research Policy* as our source, we are able to use the more detailed and robust measure of individual papers and texts. Table 3 gives the frequencies with which a particular individual document has been cited.

Although it does not eliminate the bias against younger authors, an article-based ranking places more emphasis on the quality (as opposed to the quantity) of the documents produced by a given author than a ranking of the frequencies with which a particular author has been cited.

Table III. Publication Citation Frequency

Cited Publication	Number of Citations
Pavitt K, Res Policy (1984)	90
Teece D, Res Policy (1986)	75
Cohen W, Econ J (1989)	66
Dosi G, Res Policy (1982)	65
Nelson R, Res Policy (1977)	58
Cohen W, Adm Sci Q (1990)	51
Dosi G, J Econ Lit (1988)	47
Tushman M, Adm Sci Q (1986)	43
Griliches Z, J Econ Lit (1990)	38
Henderson R, Adm Sci Q (1990)	38
Levin R, Brookings Papers Ec (1987)	37
Nelson R, J Polit Econ (1959)	36
Abernathy W, Technol Rev (1978)	33
Jaffe A, Q J Econ (1993)	31
Dasgupta P, Res Policy (1994)	28
Utterback J, Omega-Int J Manage S (1975)	26
Mansfield E, Res Policy (1991)	26
Arthur W, Econ J (1989)	26
Patel P, J Int Bus Stud (1991)	26
Vonhippel E, Res Policy (1976)	25
Lundvall B, Technical Change Ec (1988)	25
Rosenberg N, Res Policy (1990)	24
Jaffe A, Am Econ Rev (1989)	24
Pavitt K, J Ind Econ (1987)	24
Rosenberg N, Res Policy (1994)	24
Freeman C, Res Policy (1991)	24
David P, Am Econ Rev (1985)	24
Martin B, Res Policy (1983)	23
Gibbons M, Res Policy (1974)	23
Vernon R, Q J Econ (1966)	23
Abernathy W, Res Policy (1985)	23
Romer P, J Polit Econ (1990)	22
Pavitt K, Scientometrics (1985)	21
Mowery D, Res Policy (1979)	21
Scherer F, Am Econ Rev (1965)	21
Arrow K, Rev Econ Stud (1962)	21
Mansfield E, Rev Econ Stat (1995)	20
Clark K, Res Policy (1985)	20
Narin F, Res Policy (1997)	19
Vonhippel E, Res Policy (1987)	18
Griliches Z, Bell J Econ (1979)	18
Cohen W, Hdb Ind Org (1989)	18
Pavitt K, Res Policy (1991)	18
Teece D, Ind Corp Change (1994)	18
Rothwell R, Res Policy (1974)	18
Wernerfelt B, Strategic Manage J (1984)	18

In addition, Table III represents the focus of the field and gives us an indication of the popularity of certain topics. Examining the list, one notices the high frequency of articles from *Research Policy* itself which supports our decision to concentrate on this as the source for the data. Clearly *Research Policy* has exerted a significant influence as it provides the majority of the central literature. It is also interesting to note the predominance of economics titles over the showing for general management titles as the most influential publications. It is surprising to find few management titles in the list in Table 3, with only *ASQ* featuring strongly and limited contributions from *SMJ* and *Int. J. Business Studies*. The absence of any articles from such titles as *Harvard Business Review* and the like, or those published by the Academy of Management may suggest that the theoretical roots of *Research Policy* lie in the economic discipline rather than the more applied management field. This is an observation we return to later in the paper.

Whilst the tables above give us some insight into the field and represent a fairly standard citation analysis, the method does not give a clear account of the concentration of interests within the field. We address such issues by performing various analyses on the co-citation matrix. Co-citations are counts of the frequency with which two existing documents are cited *together* in a new document and their analysis enables us to say something about the way ideas support and interact with each other and also to plot the structure of intellectual disciplines (Small, 1973; White and Griffith, 1981).

Co-citation Analysis

Co-citation analysis can be applied to different levels of aggregation: On the level of single publications, it can be used to study relationships among specific conceptual ideas or empirical findings (Small, 1973). At a highly aggregated level, an analysis of co-cited journal titles can investigate patterns in the generation of scientific knowledge (Rost, Teichert, 2004). At an intermediary level of aggregation, author co-citation analysis (ACA) provides insights about underlying schools of thought in scientific discourse (White, Griffith, 1981). Joint citation occurrences of author pairs are used as raw data, no matter what piece of their works is being cited. Thus, ACA shows how actors are positioned relatively to each other in a research field.

All these aggregated levels of information rely on the co-citation matrix – a cross referenced grid of co-appearance frequencies for the citations in the sampled documents – an extract of the publication level data for *Research Policy* is shown in Table IV.

Journal Co-citation: Discipline Span

One of the primary aims of the authors in performing this research was to establish the coverage and academic antecedents of *Research Policy* itself. In establishing the remit of the journal we can offer advice on publication opportunities and also discuss the way that research policy as a subject has developed and also whether it is emerging as a distinct discipline in its own right. In order to examine these features, we first studied the co-citations at the publication title level of detail.

A similar matrix to that shown in Table 4 was constructed but which only recorded journal titles, and included the top 78 titles which each gained 22 or more citations in the data set.

Table IV. Co-citation Matrix (extract): The most cited papers

	Cohen (1989)	Pavitt (1984)	Teece (1986)	Cohen (1990)	Dosi (1982)
Cohen (1989)	-	14	16	14	6
Pavitt (1984)	14	-	11	10	13
Teece (1986)	16	11	-	11	9
Cohen (1990)	14	10	11	-	3
Dosi (1982)	6	13	9	3	-
Tushman (1986)	2	5	10	5	16
Dosi (1988)	13	15	6	10	6
Nelson (1977)	2	16	11	2	25
Henderson (1990)	4	3	9	5	12
Jaffe (1993)	5	1	1	4	0
Griliches (1990)	9	5	0	4	2
Nelson (1959)	9	4	5	5	3

This was then subjected to a factor analysis to extract latent structures from the pattern of journal citations. This statistically driven analysis effectively groups the journal titles together based on their repeated co-citation by the source articles and shows the constituent disciplines of *Research Policy* and says much about the span and integration of the subject it reports. The names of each factor were given by the authors after investigating the titles themselves.

The results of the factor analysis are summarised in Table V which shows the factor loadings for the journals in the first four factors. These four factors are labelled as economics, management, technometrics and regional studies and these results have been confirmed by repeating the examination on a split sample and by expanding the citation frequency selection hurdle to greater than seven citations. Repeating the exercise on this much larger data set produced the same results as Table 5, but with other appropriate journals added to the groups. Thus, the roots of RP can be allocated to four statistically orthogonal, i.e. distinctly different and non-overlapping disciplines. There are only few journals which relate to more than one disciplinary discourse: In respect to those few exceptions, we note one the one hand truly overarching, often method-oriented journals as Econometrica, Journal of Management or Science, on the other hand we observe other RP-related journals as RD-Management and Technovation. Note however that none of the listed journals adheres to all four major discourses simultaneously, thus Research Policy truly stands out in respect to integrating the discourses to which it relates.

Other statistically significant factors were extracted from this expanded data, but a lack of depth in the data prevents these results from being confirmed by split sample techniques. However, these results are still informative and were interpreted as representing other disciplines which *Research Policy* spans and included: human geography, technology policy, national innovation systems (a group of books and chapters from books mostly from SPRU), entrepreneurship, journalism (news papers etc), historical perspectives, agricultural and public policy, and medical advances.

The results below show that *Research Policy* acts as a bridging journal between what have traditionally been different disciplines. However, further analysis is required to explore whether this is just in terms of span or whether the ideas are being integrated and synthesised into a new discipline.

Table V. Factor Analysis Results: The Antecedent Journals of Research Policy

	Count of Citations	Factor 1*: Economics	Factor 2*: Management	Factor 3*: Technometrics	Factor 4*: Regions
Bell J Econ	52	0.8620			
J Econ Perspect	43	0.8305			
Oxford Rev Econ Pol	20	0.8267			
Econ Lett	24	0.8178			
Econometrica	89	0.7940	0.4081		
Int J Ind Organ	64	0.7933			
Rate Direction Inven	23	0.7850			
Hdb Ind Org	29	0.7826	0.5414		
Rev Econ Stat	123	0.7799			
Hdb Ec Innovation Te	22	0.7687			
R D Patents Producti	19	0.7642		0.4062	
J Polit Econ	152	0.7594	0.4065	0.4181	
Oxford Econ Pap	26	0.7554			
Nber Working Paper	37	0.7496			
Rand J Econ	90	0.7424	0.5291		
Brookings Papers Ec	61	0.7321	0.4757		
J Econ Hist	42	0.7240		0.4056	
Ec Innovation New Te	62	0.7160		0.5326	
Rev Econ Stud	48	0.7141			
J Ind Econ	133	0.7051	0.5271		
Positive Sum Strateg	21	0.6608		0.4378	
Q J Econ	138	0.6574		0.4385	0.4071
J Evol Econ	56	0.6129		0.5904	
Explor Econ Hist	14	0.6091	0.4865		
Technical Change Ec	55	0.6052	0.4055	0.5532	
Futures	42	0.5955		0.4850	
Rev Ind Organ	21	0.5854	0.4465		
Technol Forecast	63	0.5793	0.4529	0.4107	
Sti Rev	43	0.5748		0.5315	
Sci Publ Policy	108	0.5709		0.5524	
Policy Sci	15	0.5455		0.5157	
Science	108	0.5355	0.4203	0.4889	
Acad Manage Rev	68		0.9200		
Acad Manage J	62		0.8688		
Org Sci	74		0.8596		
J Prod Innovat Manag	40		0.8413		
Res Org Behav	27		0.8307		
Sloan Manage Rev	53		0.7853		0.4821
J Manage	29	0.4603	0.7573		
Am Sociol Rev	57		0.7518		
Res Technological In	22		0.7453		
Calif Manage Rev	117	0.4035	0.7433		
Brit J Manage	20		0.7251		
Res Technol Manage	46		0.7096		0.5240

Am J Sociol	56	0.5298	0.6888		
Technol Rev	56	0.4265	0.6880		
Ieee T Eng Manage	96		0.6849		0.4666
Harvard Bus Rev	149		0.6797		0.5181
J Econ Behav Organ	80	0.5806	0.6712		
Small Bus Econ	49	0.5871	0.6542		
Omega-Int J Manage S	55	0.5072	0.6522		
J Law Econ	43	0.6183	0.6268		
R D Manage	157		0.5803		0.5800
Technovation	104	0.5491	0.5529	0.4494	
J Ind Studies	14	0.4328	0.5311		
World Dev	50		0.4840	0.4243	
Res Evaluat	22			0.7540	
Sci Technol Hum Val	20	0.4593		0.7011	
Sci Technol	34			0.6921	
Scientometrics	115	0.5984		0.6447	
Hdb Quantitative Stu	14	0.4938		0.6232	
Int J Technol Manage	56		0.5556	0.6088	
Technol Soc	23			0.5984	
Technol Anal Strateg	65		0.4169	0.5524	
Natl Innovation Syst	22	0.5175		0.5505	
Natl I Ec Rev	16	0.5221		0.5457	
Rev Ec Ind	22	0.4431	0.4319	0.5332	
Res Manage	51	0.4186	0.4731	0.5165	
Geografiska Ann B	12				0.9488
Technology Managemen	11				0.9331
Int Studies Manageme	15				0.9119
Oxford B Econ Stat	36				0.9073
Kyklos	25				0.8545
Transnational Corpor	12				0.8323
Economica	44				0.7840
J Int Bus Stud	62				0.7751
Reg Stud	47			0.4080	0.7045
Cambridge J Econ	81	0.4826			0.5977
J Common Mark Stud	22	0.4349		0.4219	0.5441

* Factor Loadings <0.4 omitted.

Author Co-citation Analysis: Subjects

In order to investigate the subjects of interest to *Research Policy* and whether the ideas from different disciplines are being integrated to synthesise new subjects or approaches we performed an analysis at the slightly lower level of aggregation of author. Such author co-citation analysis (ACA) as pioneered by White and Griffith (1981) is a fairly well established technique in which citations are attributed to the first cited author and as such the authors stand as a proxy for the ideas of their publications. The co-citation frequencies for the authors can be analysed in a number of ways and the resulting groups explored in terms of the subjects they represent and also the way in which they relate. On analysing the co-citation matrix, it was found

that there was a centralisation towards a common highly interlinked set of literature which dominated attempts to identify the different subjects using standard statistical analysis – i.e. a factor analysis of the correlations of the co-citation matrix to extract the latent dimensions and so describe the structure of the relationships. Whilst the factor analysis produced interesting results, there was considerable overlap in the areas which made interpretation difficult as many citations loaded onto several factors. Accordingly, the factors which were extracted mostly appeared to have a persistent dimension and were not associated with particularly high eigen-values, indicating that the dimensions were not particularly distinct. Similar issues were found when normal cluster analysis techniques were used, as multicollinearity in the frequency measure became an issue.

In view of these difficulties, alternative approaches based on social network analysis (SNA) were adopted. SNA represents a number of tools which have been developed to study the players, their centrality, roles and topology of social networks (Scott, 1991). One such method involves core and periphery models which use extracts central players - those who are highly connected to all others in the network - from those who have only limited connections (Borgatti, et al., 1999). For this study, the identification of the central themes is valuable in itself, and their removal leaves the more subtle patterns in the connection of the remainder easier to study.

The core-periphery model was produced using the CORR algorithm in UCINET 6.0, a social network analysis software package. Whilst the term periphery is used here, the periphery authors are still part of the main traditions of *Research Policy* but lie outside of its insipient primary focus. Specifically, the CORR procedure maximizes the correlation between the observed co-citation data and an idealized structure matrix consisting of ones in the core block interactions and zeros in the peripheral block interactions (Borgatti et al.,2002). By applying this procedure, a set of 26 authors is identified as core. Pavitt receives by far the most citations; he is also connected to all other authors in the data set. Being editor of *Research Policy*, he is thus as well the most centrally cited author. Summarizing, findings indicate that core authors can and ought to be differentiated from authors in a periphery.
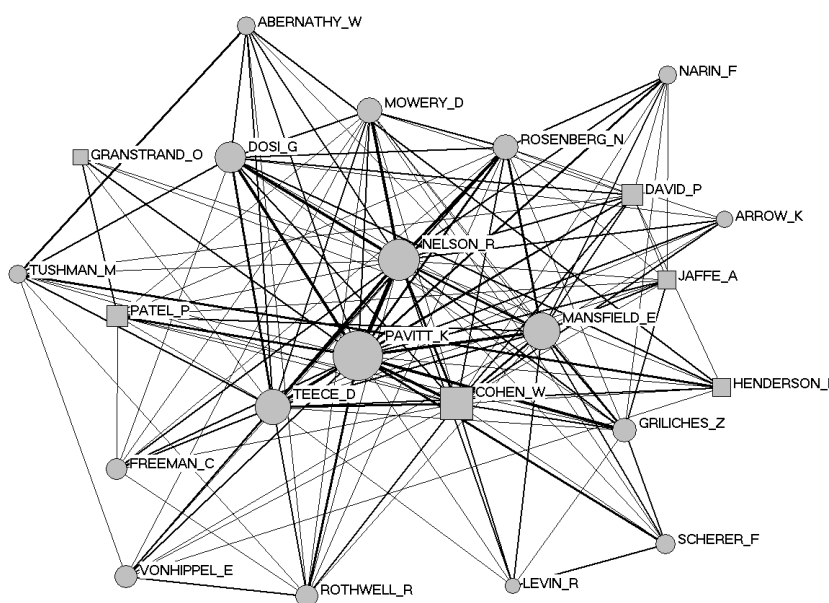

Figure 1. The Core Authors and their Interrelationships

Figure 1 summarizes the intellectual structure within the core. Authors are co-located according to a multidimensional scaling of their interconnectedness in a two-dimensional space. The relative amount of co-citations of two authors is indicated by the thickness of connecting lines and only a minimum of ten received co-citations is shown. Nodes are either displayed as circles if the authors' average cited publication stems from before 1990 or as rectangles if, on average, newer publications than 1990 were cited. The size of the nodes indicates the relative amount of authors' received citations in total.

Overall, the graph visualizes the relative positioning of authors within the core. The very core consists of the authors Cohen, Mansfield, Nelson, Pavitt and Teece, with Dosi, Patel, Rosenberg towards the outer edge of the graph. Their location stems from the fact that the graph reflects only interrelations within the core with the latter three authors highly connected to authors outside of the core.

Assessment of the Periphery Subjects

Analysing the periphery identified in the same CORR procedure above enables the differentiation of the literature into major subjects or sub-fields of *Research Policy*. With the core authors removed from the data, we were able to employ the standard technique of a factor analysis of the correlations in the co-citation network to group the periphery into sub-fields. The factors were extracted based on the calculated Pearson's R by principal components analysis with varimax rotation. Our preferred solution (Table VI) contains seven factors with a minimum initial eigenvalue of 3.4 and explains 74.4 per cent of the total variance. Of these factors, the first three contribute 59 percent of the explained variance, with the remaining four 15.4 per cent. This indicates large differences in the prominence of specific discourses in the investigated journal, and the relative dominance of the first three. Table VI displays the result of the factor analysis which reveals seven research subjects along with their relative locations in the network in Figure 2. Here, the relative positioning of subjects around the core was retrieved from their overlappings and from the calculated factor values of core authors within the subjects.

The factors (subjects) were labelled based on inspection by the authors. The first two factors were most significant and covered discourses on *Technology Strategy for Single Companies* and *Research Policy for National Systems of Innovation* and complement each other well as fundamental perspectives. The first assumes a single company perspective, while the second relates to entire economic systems. Their dominance in the discipline as a whole is reflected in the way both research streams closely connect to the core, and they can be classified as the classical perspectives of *Research Policy*. The business-related discourse is also closely related to the fourth field, the *Application of Theories of the Firm* while the economic interpretation is similarly linked to methodological approaches present in the sixth dominant stream *Econometric Applications and Technometrics*. In contrast, the third major discourse identified is the field *Globalization and International R&D Networks*, which is unusual in being relatively autonomous and has few overlaps with the other research streams and the core.

Table VI. Relationships of Periphery Authors to Research Streams[*]

FACTOR_1	Factor Loading	FACTOR_2	Factor Loading	FACTOR_3	Factor Loading
ALLEN_T	0.81	ABRAMOVITZ M (5,6)	0.64	ARCHIBUGI D (2,5)	0.71
ANDERSON_P	0.69	ADAMS_J (4,6)	0.63	BARTLETT_C	0.95
BURGELMAN_R	0.76	CALLON_M (7)	0.75	BASBERG_B (2,6)	0.51
CHRISTENSEN C. (7)	0.67	DASGUPTA_P (4)	0.76	CANTWELL_J	0.91
CLARK_K	0.86	FAGERBERG_J (5)	0.76	CHENG_J	0.91
COOPER_A	0.79	FELDMAN_M	0.69	CHIESA_V	0.85
COOPER_R (7)	0.68	FELLER_I (4)	0.69	DEMEYER_A	0.91
CUSUMANO_M	0.82	GIBBONS_M (1)	0.78	DUNNING_J	0.93
EISENHARDT K (7)	0.62	GRANOVETTER M (4,7)	0.44	FLORIDA R	0.80
ETTLIE_J	0.87	GRUPP_H	0.79	HAKANSON_L	0.93
HANNAN_M	0.75	HICKS_D	0.90	HEDLUND_G	0.94
IANSITI M (4)	0.74	KATZ J	0.84	HEWITT G	0.91
KLEPPER_S (5,7)	0.66	KLEVORICK_A (4)	0.78	HIRSCHEY_R	0.83
LEONARDBARTON_D	0.78	KLINE_S (4,5)	0.65	HOWELLS_J	0.88
LEVINTHAL_D	0.69	LUNDVALL_B (5)	0.59	KOGUT_B (4)	0.66
MARCH_J	0.67	LUUKKONEN_T	0.77	KUEMMERLE_W	0.93
MARPLES_D	0.82	MARTIN_B	0.78	LALL_S	0.72
REINGANUM_J (4,7)	0.58	MEYERKRAHMER_F	0.79	MILLER_R (1,5)	0.55
ROBERTS_E	0.79	PRICE_D	0.89	NIOSI_J	0.86
ROSENBLOOM_R	0.72	ROMER_P (5)	0.68	ODAGIRI_H	0.79
SAHAL_D (5)	0.67	SAVIOTTI P (5,7)	0.47	PEARCE_R	0.90
SIMON_H	0.79	SCHMOCH_U	0.82	RONSTADT_R	0.93
TEUBAL_M (2,5)	0.51	SOLOW_R (6)	0.59	SCHMOOKLER_J (5)	0.64
UTTERBACK_J (5)	0.76	STONEMAN_P (6)	0.54	VERNON_R	0.85
VANDEVEN_A	0.83	STORPER_M (5)	0.54		
WINTER_S (5,6,7)	0.55	TUSSEN_R	0.77		

FACTOR_4	Factor Loading	FACTOR_5	Factor Loading	FACTOR_6	Loading
ARORA_A (1)	0.65	BELL_M (1,2)	0.66	ACS_Z (2,4)	0.55
BARNEY_J (1)	0.55	CARLSSON_B (1,2)	0.61	AUDRETSCH_D (2,4)	0.42
BROCKHOFF K (3)	0.58	DEBRESSON C	0.61	EVENSON R (2,4)	0.56
COASE_R (1)	0.44	LEE_J (1)	0.57	GEROSKI P (4)	0.60
GULATI_R	0.84	MALERBA_F (2,6)	0.64	HALL_B (2)	0.77
HAGEDOORN_J	0.80	PEREZ_C	0.69	LERNER_J (2,4)	0.63
HAMEL_G (1)	0.83	RICHARDSON_G (1,4)	0.57	PAKES_A (2)	0.75
KAMIEN_M	0.74	SOETE L (2,6)	0.48	TRAJTENBERG M (2,	0.57
KATZ_M (7)	0.69				
KLEINKNECHT_A	0.78				
LINK_A (2)	0.72				
OUCHI_W (1)	0.71				
PISANO_G (1)	0.67				
PORTER_M (1,5)	0.55			FACTOR_7	Factor loading
POWELL_W	0.67			ANTONELLI_C (2,6)	0.52
PRAHALAD_C (1)	0.59			ARTHUR_W (1,2,5)	0.65
SAKAKIBARA_M	0.83			COWAN R (1,2,5)	0.55
SPENCE A (6)	0.77			EISENBERG_R (4,6)	0.44
VEUGELERS_R	0.67			FARRELL_J (1)	0.70
WERNERFELT_B (1)	0.55			FORAY_D (1,2,5)	0.60
WILLIAMSON_O (1)	0.69				

[*] Authors are assigned to factors according to their highest factor loading. Secondary associations are indicated by their additional factor numbers listed in parantheses.
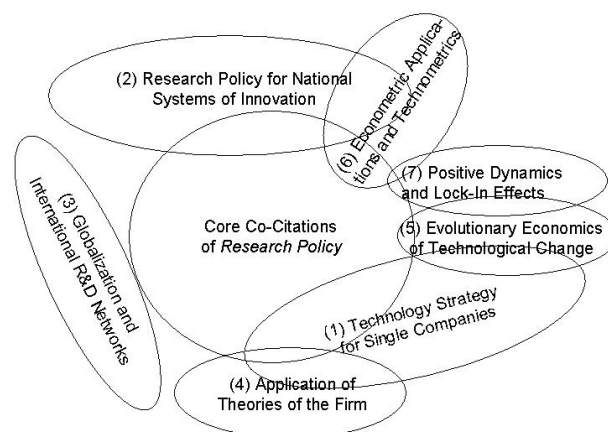
Figure 2. Interrelationship between the Core and Periphery Citations

Certain, more recent, developments also emerge in the analysis, in particular the discourse on *Positive Evolutionary Dynamics and Lock-In Effects* which represents a relatively new perspective but is interestingly built on works in *Evolutionary Economics of Technological Change*, the fifth factor extracted. In addition, the former can be distinguished from its predecessor by several newer methodological approaches which also appear in the sixth factor *Econometric Applications and Technometrics*. These tools and methods are also becoming more prominent and increasingly feature in the more central discourse on *Research Policy for National Systems of Innovation*.

Table VI and Figure 2 are very telling in their coverage of the subjects or sub-fields and concern the interdisciplinary nature of *Research Policy*. This adds weight to the notion that we are seeing the synthesizing effects of RP as a discipline. The sub-fields of *Research Policy* not only span different disciplines as suggested by the journals analysis above, but here we can see that they actively integrate these diverse perspectives into joint research approaches and subjects.

A final interest was to explore the citation data to try and establish the trajectories of research themes in *Research Policy*. Such information can be valuable in outlining areas of future work and also in defining the specific differences between *Research Policy* and its antecedents. The next section presents the results of analysing the co-citation data at the individual publication level.

Article Co-citation Analysis: Themes and Trajectories

The author co-citation analysis (ACA) described above represents a trade-off in detail versus reliability. The high volume of author only data employed above to establish the core subjects, sub-fields and their relationships, means that we have been able to examine the reliability of the results above and they prove statistically very robust. In this section, the normal ACA method, with its proxy of author for idea, has been refined to the individual publication level giving a more detailed representation of topics discussed. Also as our data is the entire contents of *Research Policy* itself, we can be fairly confident that the data is not subject to sampling bias. The adoption of the publication level of analysis enables us to examine changes in ideas or research themes, but with less certainty than above.

In order to identify trends and changes in themes, the source documents were divided in to two groups - early and late – based on the publication date. The division was made to label up to and including 1998 as "early" (and after 1998 as "late") as this gave two approximately equal samples in terms of volume of citations (9,481 and 9,357 respectively) which ought to maximise the reliability of the results. Co-citations were tabulated for both source groups of documents, with a cut off selection point of six and more citations used for the early data - giving 126x126 co-citation matrix - and greater than or equal to seven used for the late data - giving 116 references. These co-citation matrices were then subjected to factor analysis, as above. The groupings of literature produced were statistically reliable, but could not be subjected to the same degree of confirmation to those above and so should not be viewed as definitive.

All the articles in the groups were examined and the group named by the authors, with the resulting labels and the best fitting articles summarised in Table 7.

Table 7. Comparison of Early and Late Research Policy Themes, with leading References

Early 1	Trajectories and inertia: Schumpeterian *David (1985), Sahal (1985), Abernathy (1985), Abernathy (1978), Tushman (1986)*	Late 1	Globalisation of R&D *Hewitt (1980), Odagiri (1996), Florida (1997), Granstrand (1993), Ronstadt (1978), Cheng (1993)*
Early 2	Collaboration with rivals and know-how trading *Arrow (1962), Chesnais (1988), Mowery (1989), Katz (1986)*	Late 2	Spillover from public science and universities *Mansfield (1995), Mansfield (1996), Anselin (1997), Stephan (1996), Rosenberg (1994), Jaffe (1989)*
Early 3	Patents as measures of technology flow and R&D *Basberg (1983), Basberg (1987), Griliches (1990), Kodama (1986)*	Late 3	Cooperation, collaboration and external outsourcing *Teece (1992), Hamel (1991), Hagedoorn (2000), Hagedoorn (1993), Kleinknecht (1992)*
Early 4	Basic science and innovation, science push *Mowery (1983), Carpenter (1980), Pavitt (1987), Nelson (1990)*	Late 4	Longitudinal modeling of R&D as driver of economic growth *Coe (1995), Jaffe (1986), Romer (1986), Griliches (1992)*
Early 5	Demand pull – empirical *Vonhippel (1977), Scherer (1982), Walsh (1984), Vonhippel (1976), Vonhippel (1982), Mansfield (1986)*	Late 5	Discontinuity: re-Schumpeterian view *Anderson (1990), Abernathy (1978), David (1985), Arthur (1989), Utterback (1975)*
Early 6	Projects and problem solving *Vonhippel (1994), Allen (1966), Vonhippel (1990), Allen (1980), Marples (1961), Leonardbarton (1988)*	Late 6	RBV *Miller (1995), Iansiti (1994), Leonardbarton (1992), Hobday (1998), Teece (1994), Wernerfelt (1984)*
Early 7	Resource advantages from firm size *Teece (1982), Wernerfelt (1984), Prahalad (1990), Pavitt (1991)*	Late 7	Knowledge and learning *Ancori (2000), Cowan (1997), Lundvall (1994), Cowan (2000)*
Early 8	Cycles of diffusion and imitation *Metcalfe (1981), Mansfield (1980), Griliches (1957), Mansfield (1961), Pavitt (1982)*	Late 8	Linkage to science *Bell (1993), Hicks (1995), Rosenberg (1990), Pavitt (1991)*
Early 9	Spillover from competitors and location effects *Jaffe (1993), Ergas (1987), Jaffe (1989), Howells (1990)*	Late 9	Social dynamics and influence on innovation *Hughes (1987), Freeman (1988), Leydesdorff (1996)*
Early 10	Linkage to basic science networks *Klevorick (1995), Narin (1992), Rothwell (1992), Rothwell (1974)*		

Table 7 rightly shows many similarities to the results in earlier sections of this paper, with the central disciplines represented across many of the specific research themes, again adding evidence that *Research Policy* is spanning as well as integrating disciplines. Comparison across the early and late data provides valuable insights into how the discourse of *Research Policy* is evolving as we can identify and discuss the relative shifts in topics and their treatment. In particular the themes are shifting from narrow interpretations to richer, multi-dimensional stances of understanding and interpretation typified by addressing networks and linkages in the innovation process. These shifts are also characterised by a growing interest in the dynamics of change and issues surrounding periods of discontinuity.

One of the first observations is way that a focus on the globalisation of R&D has become the most easily observable theme in recent years and yet it does not feature in the early data in any form. This emerging, integral view on national systems of innovation should clearly be an area of future work and is perhaps one feature of the *Research Policy* discipline which distinguishes it from its more theoretical economic background and also from the management literature which tends to be more concerned with micro-level understanding of organizations and corporate strategy.

From the Table, the only theme which appears consistent across the study is the idea of collaboration with competitors, showing only slight change in emphasis from a language of know-how trading to one of outsourcing. This reflects the trend of many firms in the 1990s, and the formalisation of what may have been an observed phenomenon to a widespread managerial strategy. This has remained a central focus of *Research Policy* across the period of the data and so is clearly an important theme. It is interesting to note that this is one theme which shows the benefit of the multi-disciplinary approach. Economics view such relationships through the limited ideas of game theory or prisoners' dilemma, but managers have a more pragmatic focus as borne by the large strategy literature on the subject.

The Schumpeterian ideas of trajectories, inertia, and life-cycle remain as compelling in the later data as earlier and there is a refinement observable in the groups and their place on the list. Discontinuity has become a separate theme whilst theories of diffusion have been replaced as themes by knowledge management and learning. These are clearly the processes by which the diffusion happens. Another emerging theme is the way that spillover of technology has developed from an early focus on firm location to encompass the role that public science and universities in particular have in innovation. This is coupled with a refinement of views on science push which now encapsulate ideas of different stages or lifecycles in terms of basic science or commercial opportunities for universities.

It is interesting to see that we appear not to have managed to resolve the understanding of R&D and how it contributes to economic growth. This theme appears in both data sets but there is evidence of more elaborate measures of input and output developing, from patents to more complex measures in longitudinal studies. A similar evolution of a key theme appears with resources. The early literature is typified by arguments about firm size whereas the latter data shows we now appreciate that it is not the resources themselves, but their nature and how they are exploited which makes a substantial difference to success and innovation.

There are two themes which have slipped from view in the latter time frame: empirical studies of demand-pull, and an interest in projects and problem solving. This is probably as such topics have reached a formal level of understanding and are now securely located in the armament of managers, thus suggesting they are not areas of great future research potential. The contrary might be true of the emergence in the latter set of a group dealing with society's influence on both the innovation process and artefacts. This is typified by social theories of science and the social construction ideas and might be a reflection of future research streams.

Discussion: An Integrative Map of Research Policy

The results above present a selection of views on the theoretical frameworks which underpin *Research Policy*. Taking different levels of aggregation of citation adapt and analysing the results provides different insights depending on the level of data studied. But these different lenses of detail are related to one another and can be combined to show the relationship between the disciplines, subjects and themes. One critical finding is the presence of a core discourse which represents the emerging discipline of *Research Policy* and led by the likes of Pavitt, Nelson, Mansfield, Cohen, Teece, and others.

Taking the results above, we mapped the levels onto the one immediately above to show the relationships between the levels. The author groups identified were scored against the journals of their publications, and so we effectively mapped the subjects into the disciplines. Similarly, the article level groups of themes were ranked by identifying the authors which feature and so were mapped onto the subjects to which they belong. The results of this linkage between the levels are presented in Figure 3, and show the structure of the intellectual pillars of *Research Policy*.

There are some interesting features of the map, in particular the way some themes and subjects are mapped onto more than on discipline, with the strength of the line indicating the strength of the linkage. Only two themes are embedded in more than one concept: RBV (both Strategy as well as Theory), Linkage to Science (both Evoluationary view as well as Research Policy). The others are predominantly related to a single concept. (But we must stress that there are, however, sometimes only few authors as joint basis - thus the belonging of Patents and other themes is highly interpretative).

In Figure 3, we again see evidence of the integrative nature of *Research Policy* in establishing its own research space. Many of the subjects are found to spread across several disciplines indicating that our understanding of basic concepts is becoming deeper as we include theory and approaches drawn from traditionally separate disciplines. For example, we see the adoption of globalization as a managerial stance rather than as a regional dimension. In particular we can see an increase in managerial attention of themes which have their roots in the more economics or policy areas. This is perhaps important for establishing *Research Policy* as a discipline in its own right as it is developing a more practical and applied streak, but at the same time it relies on solid and established foundations.
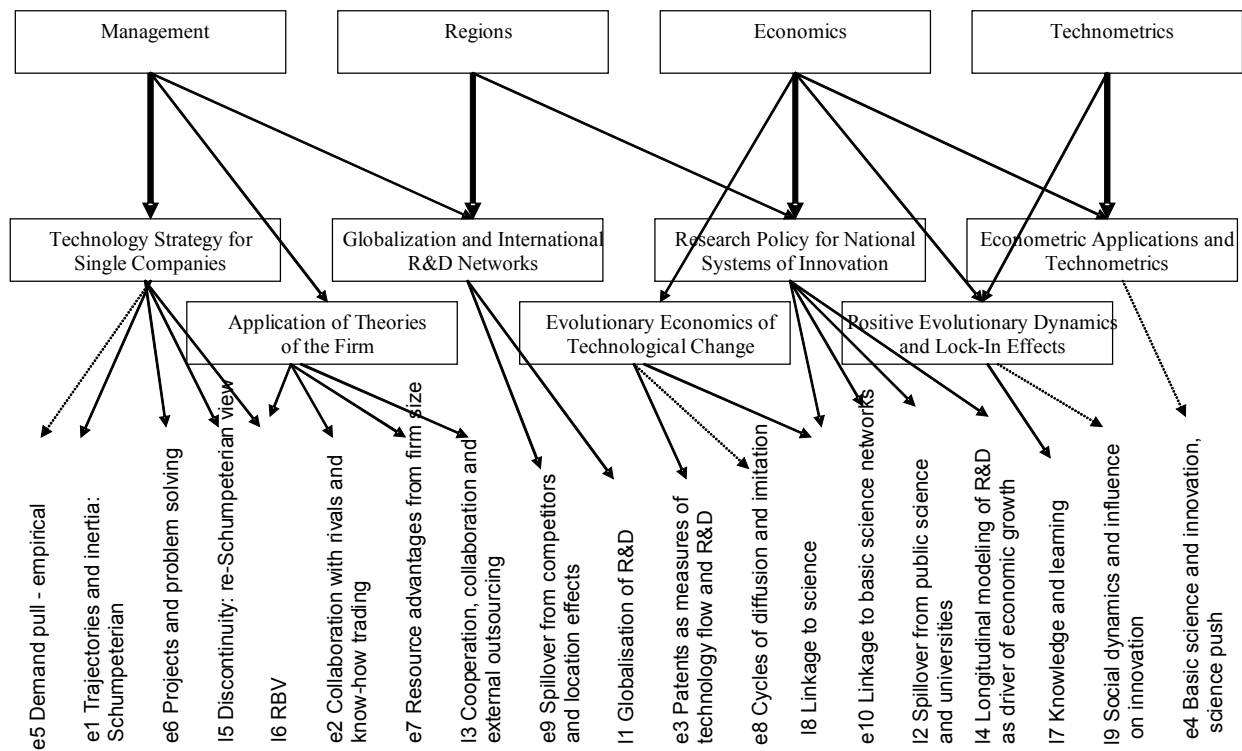
Figure 3. A Map of Research Policy Disciplines, Subjects and Theme Trajectories

Conclusion

Through the adoption of bibliometric (co-citation analysis) and social network analysis techniques we have investigated the intellectual pillars of the literature in *Research Policy*. In particular we have mapped the research concerns of the journal at three levels of aggregation which represent disciplines, subjects and themes. As well as an analysis and discussion of these three levels in isolation, we tie them together to present a multi-dimensional view of the topic identifying both the grounding of various themes and also allowing future avenues to be identified.

The study shows that the journal *Research Policy* acts as an interdisciplinary backbone to work from several different disciplines: economics, management, technometrics and regional studies. As such *Research Policy* serves its community in several ways, first by offering a common forum for the cross fertilisation of ideas from these disciplines. Further investigation at the author level shows that *Research Policy* acts not only as a common forum, but also as an integrator of the disciplines by publishing truly interdisciplinary work. By plotting the profiles of leading scholars we have shown the application of theories from one discipline into neighbouring areas and identified the core and most prominent subjects of research. The prominent subjects are public and science policy, micro- and macro-economics, and the applied disciplines of technology management, R&D, product innovation and management strategy. The core discourse itself, which represents the overarching and synthesizing nature of *Research Policy,* is represented by Pavitt, Nelson, Mansfield, Cohen, Teece, and others.

Alan Pilkington and Thorsten Teichert

By examining patterns of citation amongst individual articles, we have been able to identify the main themes and also plot how the treatment of the various issues has recently evolved. The changes in themes can be summarised as showing the cross discipline research of *Research Policy* in action as the emerging themes appear to draw on more than one subject or discipline. In particular the themes are shifting from narrow interpretations to richer, multi-dimensional stances of understanding and interpretation typified by networks of firms or players in the innovation process. These shifts are also characterised by a growing interest in the dynamics of change and issues surrounding periods of discontinuity. This aspect of integrating ideas to develop subtler theories is a powerful contribution and one which we believe will lead to distinct and valuable research policy discipline in its own right, further strengthening the position of the journal.

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