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TIK WORKING PAPERS on Innovation Studies

No. 20111003

http://ideas.repec.org/s/tik/inowpp.html

Senter for teknologi, innovasjon og kultur
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Innovation: Exploring the knowledge base

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Version of October 2, 2011. For publication in Research Policy.

Abstract

New types of knowledge, and new ways of organising the production of it, may emerge as knowledge producers respond to the challenges posed by a changing society. This paper focuses on the core knowledge of one such emerging field, namely, innovation studies. To explore the knowledge base of the field, a database of references in scholarly surveys of various aspects of innovation, published in "handbooks", is assembled and a new methodology for analysing the knowledge base of a field with the help of such data is developed. The paper identifies the core contributions to the literature in this area, the most central scholars and important research environments, and analyses - with the help of citations in scholarly journals - how the core literature is used by researchers in different scientific disciplines and cross-disciplinary fields. Based on this information a cluster analysis is used to draw inferences about the structure of the knowledge base on innovation. Finally, the changing character of the field over time is analysed, and possible challenges for its continuing development are discussed. The paper updates and extends the analysis on an earlier working paper in this series (Fagerberg and Sapprasert 2010).

Acknowledgments

Work on this paper started during the academic year 2007-2008 when two of the authors worked together in the "Understanding Innovation" Group at The Centre for Advanced Study (CAS) at the Norwegian Academy of Science and Letters in Oslo, Norway. It was continued as part of the EXPLORE project within the DIME Network of Excellence financed by the European Commission. Economic support from CAS and DIME (European Commission) is gratefully acknowledged. Thanks must also be given to Cristina Chaminade, Faiz Gallouj, Bronwyn Hall, Charlie Karlsson, Marshall Scott Poole, Larissa Shavinina and Paul Stoneman for help in supplying the data used in the paper. We are indebted to participants at seminars at CIRCLE in Lund University, the University of Torino, the Sant' Anna School of Advanced Studies in Pisa, Bocconi University, SPRU at the University of Sussex, and the EXPLORE/DIME workshops and final conference for valuable comments and suggestions. A special thank to Ben Martin who read the entire paper and provided numerous suggestions for improvements. The paper has also benefitted from comments and suggestions from the editors and referees of this journal. However, the authors are solely responsible for any remaining errors and omissions.

Keywords: Innovation studies, science studies, specialisms, bibliometrics

1. Introduction

A century ago the innovation theorist, Joseph Schumpeter, reflecting on the state of social science, pointed out that "individual social sciences ... did not arise through the logical division of some originally unified realm of knowledge; they arose by chance ... from some particular problem or method" (Schumpeter, 1910/2003, as cited in Andersen, 2009, p.312). From this perspective, social science should be seen as an evolving structure, constantly challenged by new problems and the need for new knowledge. New types of knowledge, and new ways of organising the production of it, may emerge as knowledge producers respond to the challenges posed by a changing society. Arguably, the existing disciplines within social sciences are themselves (comparatively recent) examples of how new knowledge fields emerge and gradually establish themselves with appropriate organisations and institutions (Merton, 1973). There is no reason to believe that the existing pattern of organisation in the social sciences represents 'the end of history' in this respect. On the contrary, new scientific fields continue to emerge, within and across existing disciplines (Becher and Trowler, 2001; Whitley, 2000). It is important, not the least for the design of research policy, to improve our understanding about such processes.

This paper explores the knowledge base of one such field, namely "innovation studies", which may be defined as the scholarly study of how innovation takes place and what the important explanatory factors and economic and social consequences are.[1] As shown by Fagerberg and Verspagen (2009) this field has grown rapidly in recent years (see also Figure 1), and several thousand academics worldwide are currently researching such issues. However, their study was based on a survey of the practitioners in the field, i.e. scholars who identify with the term "innovation studies", and did not examine the characteristics of the knowledge base that these scholars share. In contrast this paper seeks to identify the core contributions to the literature on innovation, as well as the users of this literature (as reflected in citations in scholarly journals), and analyze the structure of the knowledgebase in this area. The changing character

[1] The term "innovation studies" has become quite widely used. For example, of the 1115 respondents to the survey reported in Fagerberg and Verspagen (2009), 80% answered that they did research in "innovation studies". But the term is of fairly recent origin and to the best of our knowledge no commonly accepted definition exists. The term innovation - the phenomenon under study in "innovation studies" - is much older and may take on different meanings. However, as pointed out by Freeman (1985), Schumpeter (1928, 1934, 1942) had a relatively precise definition of innovation, and it is this definition that has become standard in "innovation studies". See section 2 of this paper for more on Schumpeter's approach.

of the field over time is also analysed, and possible challenges for its continuing development are discussed.

Although innovation is a fashionable topic today, this has not always been the case. In fact, back in the early part of the previous century, when the present social sciences were emerging, little attention was paid to the subject. An exception was the Austrian-American economist Joseph Schumpeter (1912/1934, 1942), who advanced a theory in which innovations, and the social agents underpinning them, were seen as the driving force of economic development (see e.g. Andersen, 2009; Fagerberg, 2003; McCraw, 2007). He also provided us with the definition of innovation that is used within innovation studies today (see the next section). The topic received somewhat more attention around the time of the Second World War, when policy makers, first in the US and then elsewhere, became interested in R&D and innovation as an important impetus to progress in the military and (to a lesser extent) the civil sector (Godin, 2006; Hounshell, 2000). Still, as Figure 1 suggests, in the early 1960s the literature was still in its infancy. Things were about to change, however, because in the course of a few years, several important contributions emerged within different disciplines – in particular, economics (Nelson, 1959; Schmookler, 1966), management (Burns and Stalker, 1961) and sociology (Rogers, 1962; Coleman et al., 1966). The first cross-disciplinary research centres on the topic were established in the mid-1960s, of which SPRU at the University of Sussex came to be the most prominent.[2] Since then, research in this area has flourished, with particularly strong growth in the 1990s (Figure 1). Several specialised journals and professional societies[3] of interest for this field have also emerged.

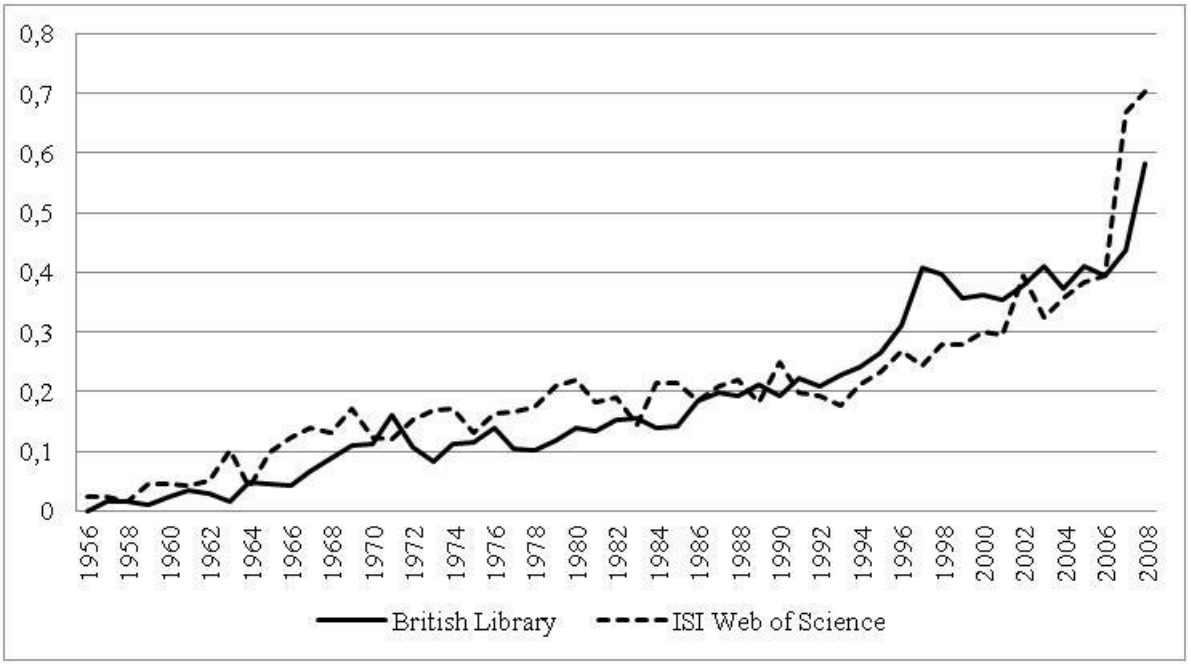
As pointed out above, one important way in which social science renews itself is by responding to the emergence of new "problems", pointing to the scarcity or lack of relevance of the received knowledge. Such challenges, especially when accompanied by new resources, may attract researchers from a variety of backgrounds and lead to the creation of new research communities, with institutions and organisations designed to promote scientific progress in the area. Such institutional and organisational features may be of great help when exploring the cognitive characteristics of a field, because they make it easier to identify the most

[2] SPRU (Science Policy Research Unit) was established in 1966. Later, many others followed, increasingly with an explicit focus on innovation. Through a web-search, Fagerberg and Verspagen (2009) identified more than a hundred such research centres or departments worldwide within the social sciences, more than eighty percent of which were located in universities.

[3] The most important are the International Joseph Schumpeter Society, founded in 1986, and the Technology and Innovation Management Division (TIM) of the (American) Academy of Management, established in 1987.

important contributions and contributors. For example, in their study of the field of Strategic Management, Hambrick and Chen (2008) were able to identify the central contributions/ contributors to that field because it was organised around a society (the Strategic Management Society) and a journal (Strategic Management Journal). However, the degree of institutionalisation and organisation may vary widely across fields. Although, as mentioned, some professional meeting places have emerged for Innovation Studies, there is no society that covers the entire field (Fagerberg and Verspagen, 2009). Furthermore, while the journal Research Policy[4] is generally acknowledged to be an important publishing outlet for this type of work, there is also a range of other publication channels which are drawn upon by researchers in this area. Hence, it may be necessary to look elsewhere for ways in which to identify the central scholarly contributions and the cognitive characteristics of this field.[5]

Figure 1. Growth of the literature on innovation



Note: Publications with 'Innovation' in the title, as a per cent of annual additions.

A different way of studying the cognitive characteristics of a field, which may be more applicable in the present case, consists of identifying the core contributions by means of

[4] In 1971, Christopher Freeman, the first director of SPRU, also founded Research Policy, one of the first specialised journals focusing on R&D and innovation.

[5] This is also why Fagerberg and Verspagen (2009) felt compelled to collect their own data by means of a self-selecting "snowball" survey. Their study identified a large number of relatively small research groups bound together by a smaller number of what they called "cognitive communities", that is, networks of (groups of) scholars bound together by a common appreciation of central scholars in the field (sources of inspiration), common meeting places, and journals. However, it is possible that, by only including scholars who identified themselves with the term "innovation studies", the study overlooked researchers who work on innovation in contexts where the term is less common.

expert assessments (Crane, 1969 & 1972). Thus the analysis presented in this paper exploits the fact that a number of authoritative contributions surveying the field or important parts of it already exist, published in the form of so-called "handbooks". It seems reasonable to assume that the authors of such surveys include references to the most important scholarly contributions of relevance to their topics. Although the topics of these surveys will differ somewhat, as may the references, some contributions are likely to be referred to many times simply because they are considered to be particularly central – in other words, they represent the core knowledge of the field. It will be assumed, therefore, that the subset of references which are referred to many times by different experts constitutes the core contributions in this area.

The next section provides a description of the process that led to the identification of the core literature in this area. The characteristics of this literature, including the core contributors and research environments, are also analysed. Then, in section three, the focus shifts to the users of the core literature as evidenced by citations to the core literature in scholarly journals. Particular emphasis is placed on the disciplinary orientation of these users as reflected by the journals in which they publish. Based on information on the core literature and its users section four explores, with the help of cluster analysis, the underlying structure of the field. Section 5 investigates how the field has changed over time. The final section summarises the lessons emerging from the study and discusses possible challenges for the field's continuing development.

2. Innovation: Identifying the "core" literature

The first step in the research was to identify a number of important reference works (authoritative handbooks and the like) that could be used to explore the core literature of the field. Reference lists in central contributions to the field were scrutinized and various web-searches were conducted to identify relevant sources. Eventually, eleven handbooks were identified comprised of 277 chapters surveying different aspects of innovation. The possibility of including other works that are not called handbooks, but nevertheless make an attempt to survey the field or parts of it, such as textbooks, was also considered. However, the conclusion was that references are not necessarily used in the same way (and for the same purpose) in different types of texts, so that as long as a sufficiently large number of "handbooks" could be identified, it would be preferable to stick to these.

Data and methods

The eleven handbooks are listed in Table 1. Three (Dodgson and Rothwell, 1994; Shavinina, 2003; Fagerberg et al., 2004) have a fairly general orientation, aiming to cover as much relevant literature as possible. Another three focus on aspects of relevance for organization and management (Cozijnsen and Vrakking, 1993; Poole and van de Ven, 2004; Shane, 2008). Two (Stoneman, 1995; Hall and Rosenberg, 2010) have an explicit focus on the economics of innovation. The remaining three handbooks are concerned with more specialized topics such as innovation in services (Gallouj and Djellal, 2010), innovation and development (Lundvall et al., 2009) and spatial aspects of innovation (Karlsson, 2008). Together, these eleven handbooks should give a broad and reasonably balanced representation of the literature in this area.

Next, all the references in these books, chapter by chapter, were collected and entered into a database. However, since the style of referring to published works differs, and there may be errors of various kinds that need to be corrected, the references were "cleaned" so that the same reference appeared in exactly the same way each time. A special problem was present for books published in several editions such as, for example, Schumpeter's "Capitalism, Socialism and Democracy" or Marshall's "Principles of Economics". For the purpose of this research it was chosen to treat references to different editions of the same book as references to one publication (the first edition). The assumption, then, was that references to different editions of the same book essentially refer to the same intellectual message. Another reason for this choice was that it appears that many authors refer to the first edition independently of which edition they have had access to. For example, it is quite common to refer to Schumpeter's first German edition of "Theory of Economic Development" from 1912, although we can probably safely assume that very few of those citers have ever seen it.

Table 1. Reference works

Name of author/(year)	Title	Thematic Orientation	Publisher	Chapters (references)
Cozijnsen & Vrakking (1993)	Handbook of Innovation Management	Management/ Organization	Blackwell	9 (280)
Dodgson & Rothwell (1994)	Handbook of Industrial Innovation	General/ Industrial	Elgar	35(1247)
Stoneman (1995)	Handbook of the Economics of Innovation and Technological Change	Economics of Innovation	Blackwell	13 (1630)
Shavinina (2003)	International Handbook on Innovation	General/ Industrial	Elsevier	71 (4303)
Fagerberg, Mowery & Nelson (2004)	The Oxford Handbook of Innovation	General/ Industrial	Oxford	22 (1688)
Poole & Van de Ven (2004)	Handbook of Organizational Change and Innovation	Management/ Organization	Oxford	13 (1958)
Karlsson (2008)	Handbook of Research on Innovation And Clusters	Geography & Development	Elgar	24 (1465)
Shane (2008)	Handbook of Technology and Innovation Management	Management/ Organization	Wiley	16 (1494)
Lundvall, Joseph & Chaminade (2009)	Handbook of Innovation Systems and Developing Countries	Geography & Development	Elgar	13 (974)
Hall & Rosenberg (2010)	Handbook of the Economics of Innovation	Economics of Innovation	Elsevier	29 (4518)
Gallouj & Djellal (2010)	The Handbook of Innovation and Services	General/ Industrial	Elgar	32 (1756)

Of the 21,313 references in the eleven handbooks 14,857 references were to different publications. But most of these were cited only occasionally. Since the focus of the analysis was on the more commonly cited references, as indications of the knowledge base shared by practitioners in the field, it was chosen to limit the analysis to publications cited in at least three different handbooks. 562 references satisfied this criterion and are hence candidates for being included in "the core literature". However, in ranking these according the number of times they are cited, one encounters the problem that older titles have a greater chance of being cited than those published more recently. Hence, in order to provide a fairer comparison of how many times a set of publications is referred to, an indicator that corrects for this was calculated (the J-index). Define the maximum citations (M) for any publication as one citation

per chapter in any handbook published at least one year after the publication we are looking at.[6] If the actual number of citations is A, then this indicator, the J-index, is:

$$J = (A * 100)/M,$$

A final choice regards where to put the threshold for inclusion in "the core literature". A high threshold would lead to small sample of highly cited publications. A low threshold would give a much larger sample and more variety in all respects (including, perhaps, relevance). In the present case it was chosen to define the core literature on innovation as the subset of references that satisfied a threshold level of the J-index of 3.25. Thus, any publication cited less than once per thirty chapters (of those chapters that could potentially have cited it) would not be included in the core literature. This gave a set of 130 core publications (see Appendix A for details).

The J-index reflects how important a publication is perceived to be within the field of innovation studies (as judged by experts in the area). However, its influence may not be limited to this specific field, but may extend to other specialties and disciplines. In order to ascertain to what extent this is the case, citations to the core literature in journals included in the Web of Science (ISI – Thomson) were identified, with a very large number coming to light (around 160,000 citations in total). These citations are analysed in more detail in the next section.

Sensitivity analysis

The sensitivity of the results to the selection of sources was also investigated. In most cases the editors of the handbooks are academics of very high standing, so one might assume that they will tend to exercise rigorous quality control of the handbook chapters. However, although many handbook editors are highly cited in the Web of Science, this does not apply to all of them. So – for this or other reasons – the possibility cannot be excluded that the quality of the editorial work may vary. Moreover, since the orientations of the handbooks differ, it may be that some publications are referred to many times by a specialized handbook for

[6] For example, for Nelson and Winter (1982) the maximum number of possible citations is 277, as there are 277 chapters in the 11 handbooks, and all are published after 1982. However, for Christensen (1997) the maximum number of possible citations is only 220, since three of the handbooks, with altogether 57 chapters, were published before 1997.

reasons that have as much to do with its orientation (geography or development, for example) as innovation. The requirement that publications included in the core knowledge should be cited by at least three different handbooks may be assumed to minimize this potential bias. However, one cannot exclude the possibility that the problem remains to a certain degree.

Three robustness tests were conducted. In the first, for each individual publication in the core literature, the handbook with the highest number of citations to that specific publication was identified. Then the citations from that handbook to the publication in question were eliminated, the J-statistics recalculated and the resulting ranking compared to the one reported in Appendix A. The result was that 95% of the top twenty were the same and the correlation coefficient between the two rankings was 0.93. In a second test, the handbooks were removed one by one, the J-indexes recalculated and the (eleven different) rankings obtained through this procedure (each based on ten handbooks) compared to the ranking in the Appendix. The results from these eleven additional tests are broadly similar to those of the test mentioned above (on average 93% of the top twenty were the same and the correlation coefficient between the two rankings was 0.92).[7] Finally, in the third test, a more radical approach was adopted. All three handbooks published during the 1990s were removed, the J-indexes and the ranking based on it recalculated, and the usual comparison performed. However, 90% of the top twenty were still the same and the correlation coefficient between the two rankings was 0.78. These results indicate that the picture presented here is reasonably robust with respect to the selection of handbook sources.

The core literature

Table 2 lists the twenty most important contributions to innovation studies based on the 277 assessments (contained in handbook chapters) included in this study. The name and location of authors, title, publication type, year, J-index and the average number of citations per year in the Web of Science are reported for each of these top twenty contributions.

Taken together, the twenty top ranked contributions cover a wide range of topics of relevance for innovation. Some are **theoretical** in nature, such as Schumpeter's classic texts "The Theory of Economic Development", originally published in 1912 in German and in a revised

[7] For these eleven tests, the top twenty shares were in the 85%-100% range, while the correlation coefficients with the original ranking varied from 0.79-0.99.

English edition in 1934 (number 4 on the list), and "Capitalism, Socialism and Democracy" from 1942 (number 19). Here, Schumpeter portrays innovation as a dynamic force that causes continuous transformation of social, institutional and economic structures (Andersen, 2009; McCraw, 2007). Many ideas that are central in the innovation literature today can be found already in these works (Fagerberg, 2003 & 2004) such as, for example, the definition of innovation as "new combinations" of existing knowledge and resources; the distinction between invention (new ideas) and innovation (implementing these in practice); the classification of innovations into product, process and organisational innovation, and the keen interest in how radical their social and economic impacts are (revolutionary, radical etc.). Schumpeter, particularly in his early work, also emphasized the important role that committed entrepreneurs capable of overcoming an inert or resisting environment may play for innovation and, largely for this reason, Schumpeter is also acknowledged as an important source of inspiration in the entrepreneurship literature (Landström et al., 2011).

Other top-ranked contributions focus on **new concepts or frameworks of analysis** and/or their application. For instance, this is true of Nelson's, Lundvall's and Freeman's work on "National Systems of Innovation" that appeared around 1990 (number 2, 6 and 12 on the list). In this line of work, a new, holistic perspective on the roles of policy, governance and institutions for innovation was presented that became very influential both inside and outside academia (among other things through the involvement of the OECD). The framework particularly emphasises the need to study the interactions between the various factors, including policy, governance and institutions, that influence a country's innovation and growth performance. Another widely diffused framework of analysis, especially among analysts and policy makers dealing with regional issues, which also focuses on the interaction between domestic factors in fostering innovation and growth, is Porter (1990), number 3 on the list. Like Nelson and Winter's work, Porter's book is very highly cited in the Web of Science, indicating the wide applicability of the approach. Other examples of novel concepts or frameworks that have inspired new work are Pavitt's (1984) empirically based "taxonomy" of innovation activities in different sectors and industries, and Henderson's and Clark's concept of "architectural innovation" (number 9 and 17 on the list, respectively).

Table 2. Innovation: Top 20 contributions

No	Author	Country	Title	Type	Year	J-index	Citations (ISI/Year)
1	Nelson R & Winter S	USA	An Evolutionary Theory of Economic Change	Book	1982	18.8	165.0
2	Nelson RR	USA	National Innovation Systems	Book	1993	15.7	61.0
3	Porter ME	USA	The Competitive Advantage of Nations	Book	1990	14.4	166.9
4	Schumpeter JA	Austria/ USA	The Theory of Economic Development	Book	1912/ 1934	14.1	39.5
5	Rogers EM	USA	Diffusion of Innovations	Book	1962	14.1	204.3
6	Lundvall B-Å	Denmark	National Innovation Systems – Towards a Theory of Innovation and Interactive Learning	Book	1992	13.4	59.3
7	Freeman C	UK	The Economics of Industrial Innovation	Book	1974	12.6	30.4
8	Cohen W& Levinthal D	USA	Absorptive Capacity	Article	1990	11.9	124.3
9	Pavitt K	UK	Sectoral Patterns of Technical Change	Article	1984	11.6	23.2
10	Arrow K	USA	Economic Welfare and Allocation of Resources for Invention	Book Chapter	1962	10.5	26.0
11	Saxenian A	USA	Regional Advantage:	Book	1994	9.9	87.3
12	Freeman C	UK	Technology Policy and Economic Performance: Lessons from Japan	Book	1987	9.7	20.2
13	von Hippel E	USA	The Sources of Innovation	Book	1988	9.7	52.6
14	Christensen C	USA	The Innovator's Dilemma	Book	1997	9.5	88.4
15	Teece DJ	USA	Profiting From Technological Innovation	Article	1986	9.4	46.5
16	Kline S & Rosenberg N	USA	An Overview of Innovation	Book Chapter	1986	9.4	15.0
17	Henderson R & Clark K	USA	Architectural Innovation	Article	1990	9.4	49.2
18	Rosenberg N	USA	Inside the Black Box	Book	1982	9.0	37.1
19	Schumpeter JA	USA	Capitalism, Socialism and Democracy	Book	1942	7.9	64.0
20	Tidd J; Bessant J; Pavitt K	UK	Managing Innovation	Book	1997	7.7	40.3

Note: Since the SSCI starts in 1956, ISI/year for the publications prior to this year (Schumpeter 1934, 1942) was calculated as total ISI citations over the number of years from 1956 to 2008.

Finally, a number of highly rated contributions consist of **synthetic overviews and interpretations** of the current knowledge of innovation or aspects of it. The prime example here is Freeman's "The Economics of Industrial Innovation" from 1974, which for a long time had a virtual monopoly in presenting the 'state of the art' of knowledge in the field and came in several editions (number 7). The latter comment also applies to Rogers' overview of work on the diffusion of innovations (Rogers 1962, no. 5 on the list), which – among other things because of its exceptionally broad coverage of a large number of cases – has continued to attract interest in a wide range of disciplines and scientific fields. Hence, it is the most highly cited in the Web of Science of the top twenty contributions. In contrast to most of the other contributions, it is written from a sociological perspective, focusing on the conditions that affect the adoption by users of products or technologies new to them. Other contributions with an "overview" character include Christensen (1997) and Tidd et al. (1997) (number 14 and 20 on the list respectively), both focusing on issues of relevance for the management of innovation, and Kline and Rosenberg (1986) which covers the field more broadly and also proposes a "chain-linked" model of innovation that foreshadows much of the later work on systems of innovation (no. 16).

Characteristics of the core

On a general level, what clearly emerges from this table is the strong American presence. About three quarters of the top twenty contributions are American, and this is also true for the larger sample of 130 core contributions. However, what is perhaps even more striking is that eighty percent of these top ranked publications take the form of books. If the analysis is extended to include the whole sample of publications, although the share of journal articles rises somewhat, the majority are still books (see Appendix A). This may have to do with the emerging nature of the field (it clearly takes time to develop a proper set of organisations and institutions, including professional societies and journals), and books therefore may play a more important role in the early phase than later. Here, it may be worth noting that many new journals have emerged in this area in recent years. However, it may also be that the book format, with its scope for a more holistic analysis, is more suitable for (a large part of) the academic discourse in this field than articles in journals. In fact, this holds for many disciplines and fields within the social sciences and the humanities (Hicks, 1999). Therefore it is not necessarily surprising that it also applies to a broad, interdisciplinary field of the type under study here.

The final column to the right in Table 2 reports the average annual number of citations in journals to these contributions (Web of Science). Although many of the entries are highly cited, there is not a particularly high correlation between the assessments by the experts, as reflected in the J-index, and the number of citations from the Web of Science. This is neither surprising nor worrying. The J-index reflects the importance of the various contributions to the field of innovation studies as assessed by experts in this particular field. In contrast, the number of citations in the Web of Science reflects the impact or popularity of the work in question in the world of science more generally. There is no reason to expect these to be correlated. A good example is Thomas Kuhn's outstanding work "The Structure of Scientific Revolutions" (1962), which has earned nearly four hundred citations per year since publication, a truly staggering number (see Appendix A). However, this primarily reflects its importance for a wide range of disciplines/fields, extending far beyond social science, and has little to do with its role within innovation studies. In fact, its influence is rather modest in the latter field (no. 43 on the list with a J-index of 5.4).

Influential contributors typically publish several important works, often in cooperation with others. For example, while most authors in the sample have one publication which fits the threshold for inclusion in the core literature, three of them have contributed between seven and eight publications each, either alone or in cooperation with others. Table 3 ranks the top twenty scholars in this area on the basis of their total contributions, how those contributions were assessed by the experts, and adjusting for co-authorship. The "Total J-index" is the (co-author adjusted) sum of the J-indices of an author's works (a similar calculation is used for "Total ISI/Year", which refers to citations in the Web of Science).

Four contributors stand out as being particularly influential, namely, Nelson, Freeman, Rosenberg and Schumpeter. However, ranking scholars is a risky business. It is reassuring, therefore, that the results reported here are broadly similar to the list of scholars identified as important "sources of inspiration" by Fagerberg and Verspagen (2009) on the basis of an international survey of more than one thousand researchers in innovation studies.[8] The list is

[8] Fagerberg and Verspagen (2009) reported names of nine scholars that served as important "sources of inspiration" for the respondents of their web-based survey. Comparing these to the nine highest ranked scholars here, the two rankings have seven names in common. The two top contributors that are not on their list are Porter and von Hippel (ranked 5 and 7 in Table 3). The four top ranked contributors in Table 3 are all among the top five "sources of inspiration" identified by the respondents of their survey.

dominated by Americans: Only four of the top twenty (Schumpeter excluded) had a European affiliation at the time of publication (three of these from the UK).

Table 3. Innovation: Top 20 contributors

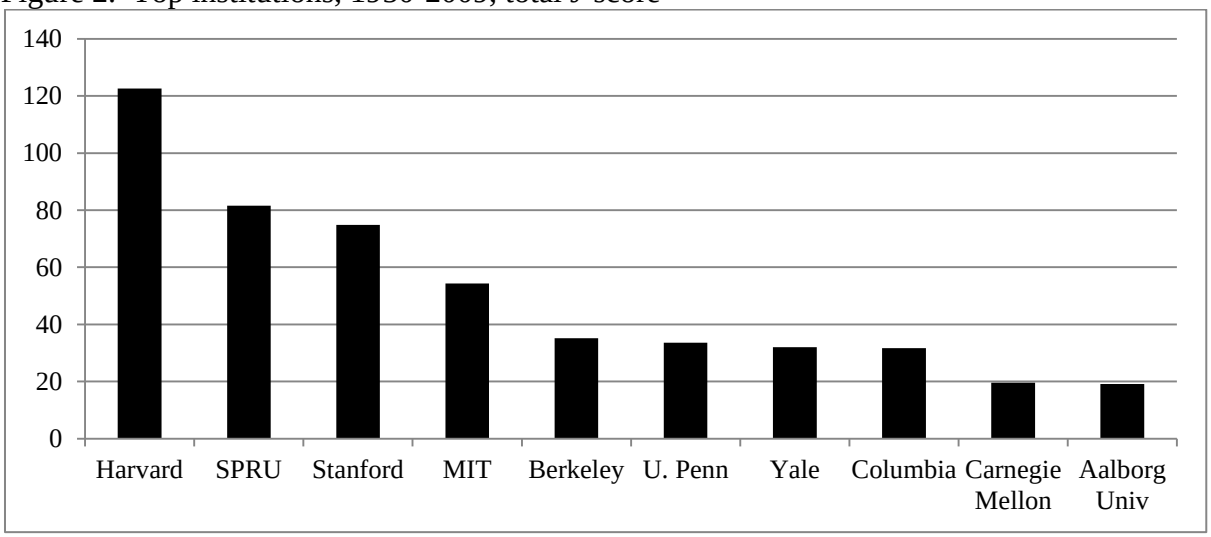
Rank	Authors	Affiliation(s)	No of works in core	Country	Total J-index	Total ISI/year
1	Nelson R	Columbia/ Yale/RAND	7	USA	37.6	175
2	Freeman C	SPRU	8	UK	35.5	88
3	Rosenberg N	Stanford	8	USA	33.4	95.9
4	Schumpeter JA	Harvard/ Graz	3	USA/ Austria	27.4	160
5	Porter M	Harvard	3	USA	24.9	353
6	Griliches Z	Harvard	5	USA	24.2	93.7
7	Von Hippel E	MIT	3	USA	20.2	54.3
8	Lundvall B-Å	Aalborg/ OECD	2	Denmark/ France	19.1	76.9
9	Pavitt K	SPRU	3	UK	15.5	44.5
10	Chandler AD	Harvard	3	USA	14.8	182
11	Rogers EM	Ohio State Univ.	1	USA	14.1	175
12	Teece DJ	Berkeley	3	USA	12.8	88
13	Winter S	Yale	3	USA	12.5	95.9
14	Cohen W	Carnegie Mellon	4	USA	12.4	160
15	Romer P	Yale	2	USA	12.3	353
16	Dosi G	SPRU	4	UK	11.9	93.7
17	Arrow K	Stanford	1	USA	10.5	54.3
18	Jaffe A	Harvard	3	USA	10.3	76.9
19	Saxenian A	Berkeley	1	USA	9.9	44.5
20	Mansfield E	Pennsylvania	3	USA	9.9	182

Note: Since the SSCI starts in 1956, ISI/year for the publications prior to this year (Schumpeter 1934, 1942) was calculated as total ISI citations over the number of years from 1956 to 2008.

Figure 2 ranks the ten top research institutions in this area based the scientific contributions of their employees and the importance of these contributions as assessed by experts (the J-index). The calculation shows that the most productive and influential institutions tend be top American universities such as Harvard University, Stanford University, MIT and University

of California, Berkeley. However, one European institution - SPRU (Science Policy Research Unit, University of Sussex, UK) - home to influential scholars such as Freeman and Pavitt, rivals many of its much larger and better funded American counterparts for a place among the top institutions in this area. But one has to move down to the tenth place to find the next European institution on the list, Aalborg University, home to the scholar Bengt Åke Lundvall, who among other things has done much to propagate the "national system of innovation" approach (Lundvall, 1992).

Figure 2. Top institutions, 1950-2009, total J-score



3. Innovation: Knowledge users

This section will move from the knowledge producers, and the experts assessing their work, to the users of this knowledge. The use of scientific knowledge leaves trails, for instance in the form of citations, and these will be exploited here. As mentioned previously, a search was made for citations to the full sample of 130 contributions in the scholarly journals included in the Web of Science (ISI Thomson), and a note was made of the scientific fields of these journals, as reflected in the so-called subject-areas.[9] In this way, it was possible to make a connection between each citation and one or more scientific fields (a journal may cover several subject-areas). By taking all citations to a particular contribution into account, a quantitative assessment may be obtained of how this contribution is used by scholars in different scientific fields or disciplines.

[9] ISI categorises journals, and hence articles, based on subject-area(s), which may be disciplines or "specialisms" within or across disciplines.

A total of more than six thousand journals (in all areas of science) cited the innovation core literature. However, most of them cited it very little, i.e. one citation per year or less. 10% of the journals accounted for more than three quarters of the citations. Table 4 below lists the 20 most important citing journals, which collectively account for slightly less than one quarter of all citations. As is evident from the table, authors in Research Policy are especially frequent users of this literature, with the leading management journal, Strategic Management Journal, in second place. In fact, most of the top citing journals belong to the fields of management and business, which indicates that scholars in management and business studies are very important users of the innovation core literature. Nonetheless, the list of top journals also includes a journal focusing on regional issues and, toward the bottom of the list, a (heterodox) economics journal.

Although examining the top journals is quite illustrative, we may obtain a more precise description of the disciplinary orientation of the knowledge users in this area by adopting the approach described above, i.e. taking account of the information about the subject-area categories of citing journals. However, it should be noted that these categories, of which there are several hundred, have been developed by ISI over the years, and they do not always cover disciplines or scientific fields in a way that is appropriate for research. For example, the extent to which specialities within, or cutting across, disciplines are covered varies considerably, and relatively recent, although vibrant, fields may not be covered at all. Thus, journals focusing on a novel area such as innovation studies, to the extent that such journals are included at all, tend to be found in other categories. For example, the rather ill-defined "planning and development" category is home to Research Policy,[10] the most important journal in this area.

[10] Research Policy is also classified under 'Management'.

Table 4. Knowledge users: Top twenty Journals

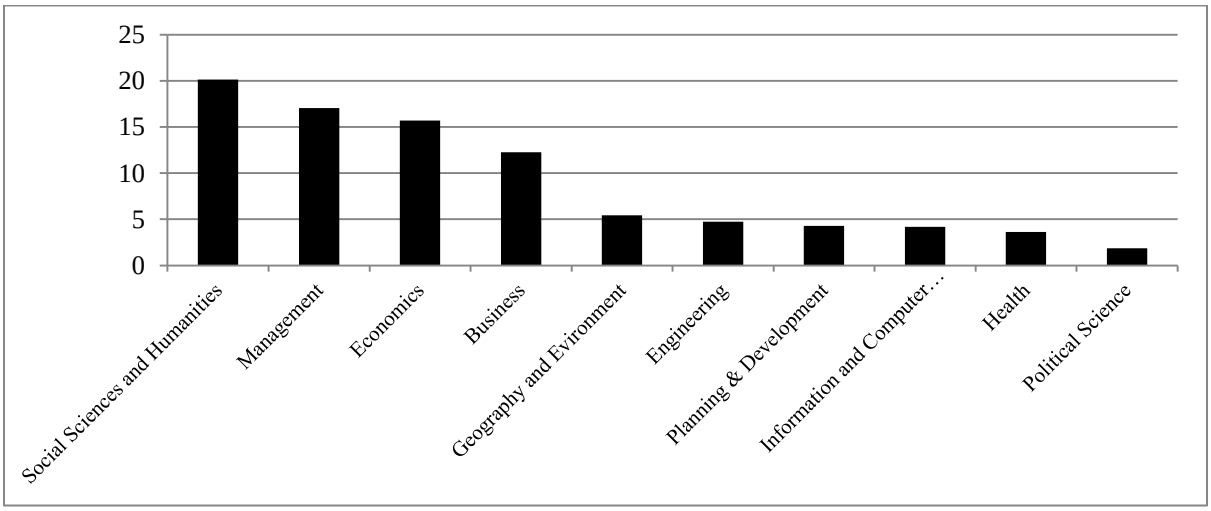
Rank	Journal	Per cent	Cumulative	Subject-area(s)
1	RESEARCH POLICY	3.4	3.4	Management; Planning & Development
2	STRATEGIC MANAGEMENT JOURNAL	2.4	5.8	Business; Management
3	INTERNATIONAL JOURNAL OF TECHNOLOGY MANAGEMENT	1.3	7.1	Engineering, Multidisciplinary; Management; Operations Research & Management Science
4	ACADEMY OF MANAGEMENT REVIEW	1.3	8.4	Business; Management
5	JOURNAL OF MANAGEMENT STUDIES	1.2	9.6	Business; Management
6	ORGANIZATION SCIENCE	1.2	10.7	Management
7	ACADEMY OF MANAGEMENT JOURNAL	1.1	11.9	Business; Management
8	TECHNOVATION	1.1	13.0	Engineering, Industrial; Management; Operations Research & Management Science
9	ADMINISTRATIVE SCIENCE QUARTERLY	1.1	14.0	Business; Management
10	ORGANIZATION STUDIES	1.0	15.0	Management
11	REGIONAL STUDIES	0.9	16.0	Environmental Studies; Geography
12	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	0.9	16.9	Business; Planning & Development
13	MANAGEMENT SCIENCE	0.9	17.7	Management; Operations Research & Management Science
14	R & D MANAGEMENT	0.8	18.5	Business; Management
15	INDUSTRIAL AND CORPORATE CHANGE	0.7	19.2	Business; Economics; Management
16	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	0.7	19.9	Management; Multidisciplinary Sciences
17	HUMAN RELATIONS	0.6	20.5	Management; Social Sciences, Interdisciplinary
18	SMALL BUSINESS ECONOMICS	0.6	21.2	Business; Economics
19	JOURNAL OF INTERNATIONAL BUSINESS STUDIES	0.6	21.8	Business; Management
20	CAMBRIDGE JOURNAL OF ECONOMICS	0.6	22.4	Economics

In some cases the subject-areas are fairly aggregated (economics, for instance), while in other cases a discipline may be divided into several different categories (psychology may serve as example of this). For the purpose of this research, it would be useful if the subject-areas could be aggregated into a smaller number of groups of like-minded scholars. To approach this objective, the most obvious adjustments were made first (such as merging all the different subgroups within psychology into one group). In a second step the citation patterns of the 35 biggest subject-areas (those with 500 citations or more each), which together accounted for more than 90% of the total citations to the core literature, were analysed to determine whether or not some of these could be meaningfully aggregated. Particular attention was paid to how scholars in the different subject-areas used the core literature in innovation studies, and if the citation patterns (preferences) of two subject-areas were strongly correlated, this was taken as an argument for merging the two. Similarly, if the patterns turned out to be rather different, this was seen as a reason for keeping them apart. In this way, it was possible to identify a large group of like-minded users in disciplines such as education, psychology, philosophy and sociology, which were aggregated into a common "Social sciences and humanities" group. Similarly, this grouping exercise identified a cluster of (strongly related) scientific fields focusing on health, and another which incorporated information and computer science, as well as a third which emphasised spatial issues (urban studies, geography and environmental studies).[11]

Figure 3 provides an illustration of how the users are divided across the ten largest groups, which collectively account for 89% of the total citations to the core literature in the Web of Science. The Figure confirms that the core literature is used in a broad array of disciplines and scientific fields. The composite "Social sciences and humanities" group is the largest with 20% of the users, followed by "Management" (17%), "Economics" (16%) and "Business" (12%). Together the latter three areas, which all focus on economic activities in one way or another, account for nearly one half of the total number of users. There are also many users in other areas of social science (not included in the larger composite), the largest of which are the "Geography and Environment" and "Planning and Development" fields. Although the overwhelming number of users is within social sciences (broadly defined), there is also a significant number in areas such as engineering and natural science.

[11] Readers interested in more details may consult Appendix B to this paper.

Figure 3. Knowledge users: Disciplinary orientation (Top 10 subject-areas), percentage

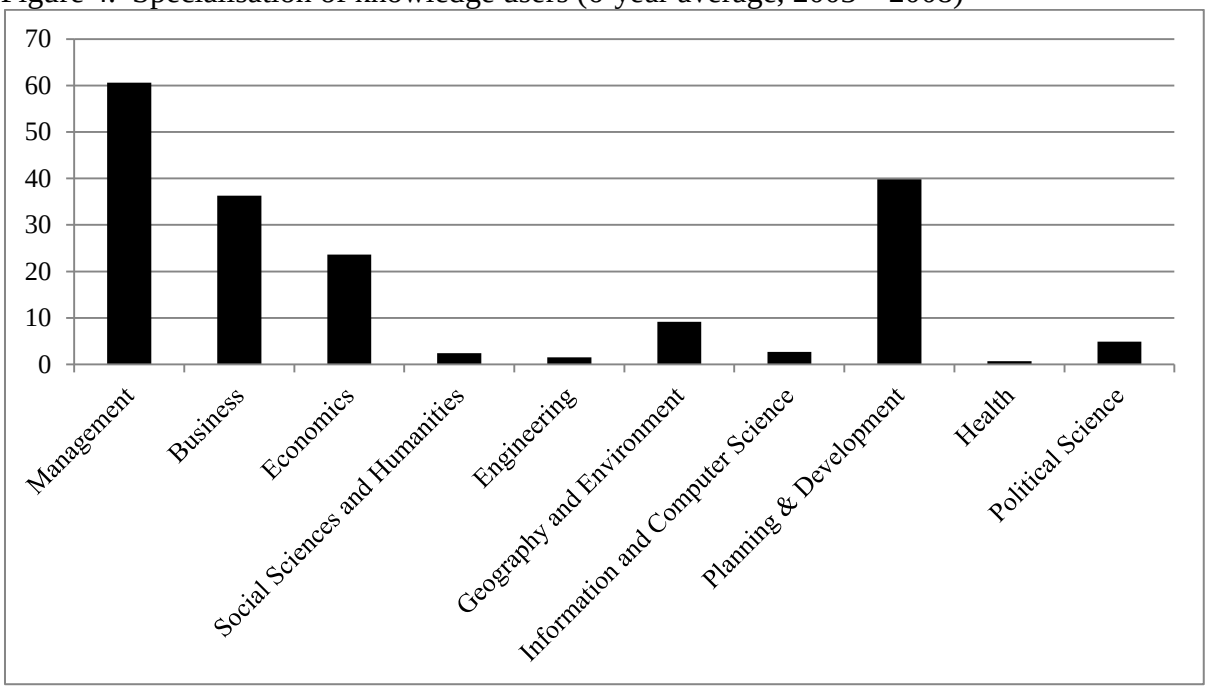


Source: Own calculations based on statistics from ISI Web of Science

A better impression of the interest shown by researchers from different fields for the innovation core literature may be obtained by adjusting the shares reported in Figure 3 for differences in the size of subject areas. This may be done by dividing these shares with the shares of the same subject areas in all citations in the Web of Science.[12] Hence, if the users within a specific subject area show an above average interest in the literature on innovation, the adjusted figure (Specialization) will be greater than one and vice versa. The results (Figure 4) indicate that the reason why the composite "Social sciences and humanities" group has the largest share is not that users in this area are particularly strongly influenced by the innovation core literature but that there are many scholars and hence citations in this area. For "Management" it is the other way around; it is a relatively small area in terms of citations, but users within this area are 60 times more likely than the "average scholar" to cite the core literature. Also users within the "Planning and Development" and "Business" fields are eager users of this literature and the same holds, although to a lesser extent, for "Economics", "Geography and Environment" and "Political Science".

[12] For reasons that had to do with data availability this calculation was made for the period 2003-2008 only.

Figure 4. Specialisation of knowledge users (6-year average, 2003 – 2008)

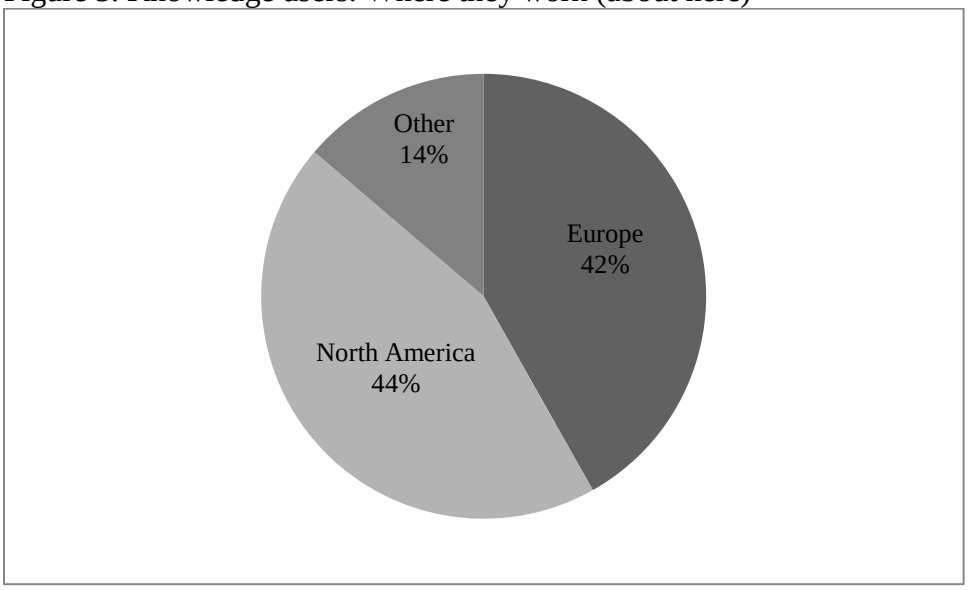


Source: Own calculations based on statistics from ISI web of science.

Figure 5 attempts to shed light on the geographical composition of the knowledge users. Unfortunately, the data do not allow for a complete analysis of authors and their locations, since much of this information is missing, especially for the years prior to 1998.[13] Therefore, the figure is based on a subset of 89,099 papers published after 1997. The largest group of users is to be found in North America, closely followed by Europe, with the rest of the world some way behind. These findings differ from those reported by Fagerberg and Verspagen (2009) who, based on a web-based survey of scholars in the field, concluded that "innovation studies" appears to be a predominantly European phenomenon. However, the sample in Fagerberg and Verspagen (2009) consists of researchers that consider themselves to be part of "innovation studies". If this notion is more widely used in Europe than elsewhere, as perhaps is the case, this may explain the difference in results between the two studies.

[13] The lack of information of earlier years means that it is not possible to explore changes which may have occurred in the geographic spread of the knowledge users during the period covered by this study.

Figure 5. Knowledge users: Where they work (about here)



Source: Own calculations based on statistics from ISI web of science.

4. Exploring the structure of the knowledge base

Having identified the core literature, analysed its characteristics and mapped the users of this literature, this section exploits this information to explore the structure of the knowledge base on innovation. The method that will be applied is cluster analysis, an exploratory tool that sorts similar objects into groups (clusters), so that the degree of association between objects is maximal if they belong to the same group, and minimal otherwise.[14] Hence, literature that share the same type of characteristics, and have similar users, will tend to be sorted into the same cluster.

As for the *characteristics of the literature*, a number of different variables are used. Firstly, the analysis includes a set of variables reflecting the orientation of the handbooks that, by referring to a particular contribution, contribute to its inclusion in the core literature (see Table 1). Moreover, based on the institutional affiliation of the authors of the handbook chapters, the roles of central research environments in promoting specific contributions are taken into consideration. The analysis also includes a variable to measure the impact of the research environment with which the author(s) of the various contributions to the core literature were affiliated at the time of publication (Excellence).[15] Finally, an attempt was

[14] For a full listing of the variables used in the cluster analysis, see appendix C.
[15] This variable is measured as the sum of the J-indices of all publications in the core literature emanating from that particular research environment (adjusted for co-authorship).

made to establish what the literature is about, i.e., mapping its thematic priorities, by allocating keywords to the core literature. It would clearly have been preferable to identify these by means of an analysis of abstracts or full texts. But the core literature mainly consists of books which do not have abstracts and are not accessible in machine-readable format. Therefore, the titles of the publications were analysed, with a focus on commonly used terms. [16] In a next step we searched for keywords and/or similar characterizations in international bibliographical databases, such as the Web of Science, the US Library of Congress and the British Library, and added these to our data set. In the case of articles in journals, the thematic priorities identified through this procedure were checked against abstracts (where these existed). Books, although lacking abstracts, were often found to have short, synthetic descriptions on the cover, which could be used for the same purpose.[17] This led to the identification of 14 different "keywords.[18]

Regarding *user characteristics* the most important dimension to take into account is their disciplinary orientation as reflected by the shares of the ten most important subject-areas or groups in the total citations in scholarly journals to the various contributions (see Figure 3). In addition, a variable which reflects the popularity of the contribution in the scientific world in general relative to innovation studies proper was also included (Outsider).[19] Moreover, the analysis takes into account the fact that some journals, such as Research Policy and Strategic Management Journal, are much more prestigious, and that citations from users that publish in such journals may signal particular importance or relevance (RP and SMJ).[20]

Various clustering methods are available, but not all of these allow for a mix of continuous and categorical variables in the analysis. The two-step cluster method in SPSS (version 11.5 and later) fulfils this requirement, and was, therefore, chosen for the analysis. In the first step, the objects are aggregated into a large number of small clusters, while in the second step,

[16] The titles were divided into words, and the number of times a specific word appeared was counted. Commonly used but uninteresting words such as "and" were excluded. Similar words, such as "economic" and "economy" were grouped together. Likewise, different terms with the same meaning, such as "new products" and "innovations", were also put in the same category.

[17] Only for a small number of older publications did this procedure not lead to a satisfactory result. In these cases the publications were consulted to see if there was additional information in the form of, say, a foreword, preface or first paragraph that could be used for these purposes.

[18] See Appendix D for a list of keywords.

[19] This variable is the ratio of the number of journal-citations per year (ISI/year) to the J-index. A small positive value (0.05) was added to the denominator to avoid problems caused by very low values for ISI/year for a few contributions (this implies a lower bound of 2.3 for the average number of citations in ISI per year).

[20] These variables are calculated as the number of citations from articles published in Research Policy and Strategic Management Journal, respectively, as a proportion of all citations to the contribution.

these clusters are merged into a limited number of larger clusters by means of agglomerative hierarchical clustering. According to statistical criteria the two best solutions are those with two and three clusters (see Appendix D for details).[21]

The structure of the knowledge base

The analysis demonstrates that there are two main "poles" in the innovation literature, one of which focuses on innovation in firms, and is popular with scholars in business and management, while the other emphasises the role played by technology and innovation in economic and social change more generally. The latter is particularly influential among scholars with a background in economics and other social sciences. However, a more detailed analysis suggests one can distinguish a third branch of research, positioned between the two main poles, and which contributes significantly to keeping the other two parts of the knowledge base connected. For this reason, the main focus here is on this three-cluster solution.[22] Table 5 summarises the main characteristics of these three clusters.

The largest cluster, consisting of 66 contributions, is characterized by a thematic preference for the economic aspects of R&D, technology and innovation, hence the label "Economics of R&D". Not only is "Economic" the dominant thematic focus, the largest citing field is also "Economics", followed by "Social Sciences & Humanities". The contributors to this literature are mainly Americans, working in top US universities, while the users of this knowledge are much more evenly distributed geographically (close to the sample average). The most central work, as assessed by the experts (the J-index), is Porter's 1990 book "The Competitive Advantage of Nations", followed by Schumpeter's "Theory of Economic Development" (1934), and Freeman's "The Economics of Industrial Innovation" from 1974. Hence, the term "economic(s)" does not necessarily imply that the literature in this cluster is predominantly mainstream economics. There are three economics journals among the ten most important journals citing this cluster, of which only one is clearly mainstream (American Economic Review), while one is more heterodox (Cambridge Journal of Economics)[23] and the remaining

[21] Various criteria are available. This study uses the BIC (Schwarz Bayesian Information Criterion) and Ratio of Distance Measures (see Appendix C for details). However, as Hair et al. (2010) point out, the purpose of a cluster analysis is primarily to explore structures in the data, and the informed judgement of the researcher is therefore crucial when deciding the number of clusters.

[22] It may be noted that, due to the hierarchical clustering method, the three-cluster solution is a mere aggregation of the solution with four clusters, and so on. For details of the two and four-cluster solutions, see Appendix C.

[23] This also holds for the next journal on the list (no 11); Journal of Evolutionary Economics.

one, Small Business Economics, is an entrepreneurship journal. Moreover, the most important citing journals are not in economics proper, but in bordering fields such as business, management, planning and development, economic geography and environmental studies. This is a notably broad church.

Table 5. Clustering the literature (3-cluster solution)

Cluster	Organizing Innovation	Economics of R&D	Innovation Systems
Works (authors)	50 (83)	66 (102)	14 (18)
Thematic focus	Innovation (62%) Organization (50%) Sector/Industry (48%) Firm (42%)	Economics (63%) R&D (36%) Innovation (32%) Technology (32%)	Innovation (100%) System (56%) Technology (38%) Macro (31%)
Most central works (J-index)	Nelson and Winter 1982 (18.8) Rogers 1962 (14.1) Cohen & Levinthal 1990 (11.9)	Porter 1990 (14.4) Schumpeter 1934 (14.1) Freeman 1974 (12.6)	Nelson 1993 (15.7) Lundvall 1992 (13.4) Freeman 1987 (9.7)
Most important affiliation	Harvard (16%) MIT (12%)	Harvard (16%) Stanford (11%)	SPRU (28%) Stanford (17%)
Location of authors	North America (75%) Europe (20%)	North America (77%) Europe (20%)	Europe (67%) North America (33%)
Most important citing journal	Strategic Management Journal	Research Policy	Research Policy
Largest citing field	Business (30%) Management (21%)	Economics (34%) Social Sciences & Humanities (28%)	Management (22%) Economics (22%)
Specialisation	Management (1.5) Business (1.5) Information & Computer Science (1.4)	Economics (1.5) Geography & Environment (1.4) Political Science (1.3)	Planning & Development (5.1) Geography & Environment (2.9) Engineering (2.3)
Location of citers	North America (49%) Europe (38%)	Europe (44%) North America (42%)	Europe (67%) North America (17%)

The second largest cluster, named “Organizing Innovation”, consists of 50 works united by a strong focus on innovation, organization, sector/industry and firms. As in the previous case, the knowledge producers are predominately Americans, while the users are more geographically widespread, though with Americans in a clear majority. The largest citing field

is "Business" (followed by "Management"), and the most central work is Nelson and Winter's "An Evolutionary Theory of Economic Change", which – although written by two economists – has found a much larger audience among Business and Management scholars (Meyer, 2001).[24] Another characteristic feature of this literature is that all of the most important journals that cite it – of which the Strategic Management Journal is the most prominent – have "Business" or "Management" among their subject-areas.

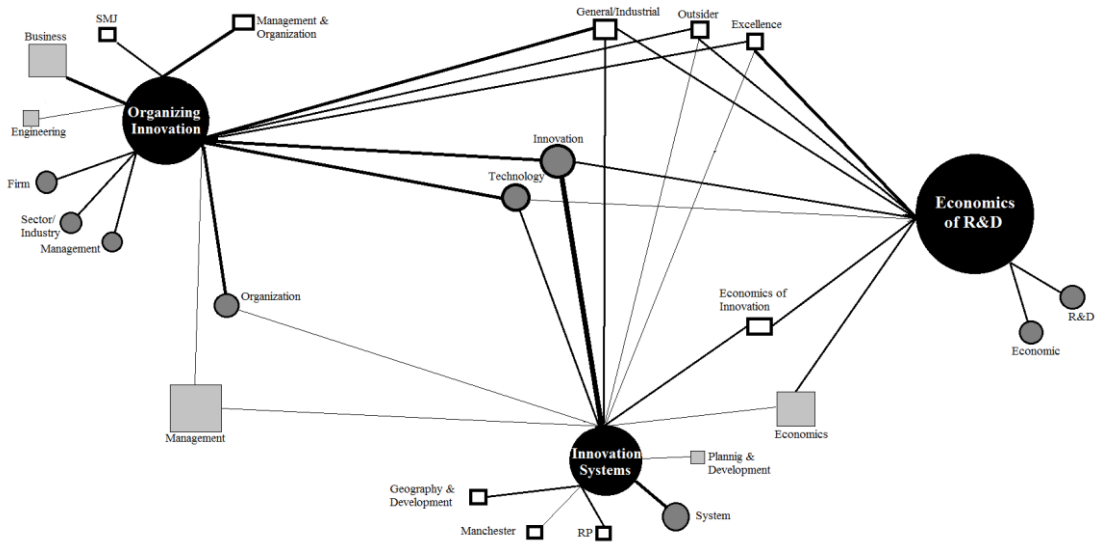
Finally, there is a small cluster of 14 contributions focusing on "Innovation" and "System" in particular, hence the term "Innovation Systems" for this cluster. In contrast to the two other clusters, this is a predominantly European cluster with respect to producers as well as users of its knowledge. While in the two previous cases the most important affiliation was Harvard, for this cluster it is SPRU (followed by Stanford). The most important works are the three best known contributions to the literature on National Systems of Innovation (Nelson, 1993; Lundvall, 1992; and Freeman, 1987). As in the "Economics of R&D" cluster, the most important citing journal is Research Policy (in which SPRU plays a central role). Journals focusing on spatial topics, such as economic geography, regional studies and urban studies, also play a very important role. Indeed, more than one in three of the twenty top citing journals focus on such issues. In spite of this, the most important citing field is "Management", followed by "Economics". However, when one adjusts for differences in size of fields, a different picture emerges. Those most likely to cite this literature are to be found in "Planning and Development", "Geography and Environment" and "Engineering". Hence this literature clearly has a very strong cross-disciplinary appeal.

Figure 6 summarises the above information in the form of a network graph. The literature clusters are shown as circles of various sizes, depending on the number of works in the cluster, and the variables taken into account in the cluster analysis are treated as being possible links between clusters. For example, if two literature clusters share a thematic focus (keyword), this constitutes a link between the two. In the analysis, the numerical value of these variables was normalised to a range between zero and unity, with unity indicating a very strong connection, and zero no connection at all. Since there will always be a certain amount of variety in the characteristics within a cluster, there will normally be many weak links (close

[24] According to Meyer (2001), Nelson and Winter's book has many more citations in management and organizational science journals than in economics journals. The likelihood of a citation was six times higher in the Strategic Management Journal than in the American Economic Review.

to zero) and a smaller number of stronger links indicating the existence of more robust relationships between the cluster and the variables. If all links are taken into account, independent of their strength, all clusters will appear to be closely connected. However, when the weaker, less important, links are removed, a clearer structure emerges, which is why these weaker, less typical links, have been eliminated in Figure 6.

Figure 6. Relationships between literature clusters and variables (cut off = 0.25)



Note: The network map is based on the three dimensions from the cluster analysis (see Appendix C). Literature clusters are denoted by black circles of different sizes, based on the number of works in the cluster. *Generation and selection* (HB orientation, affiliation, most citing journal, Outsider and Excellence) variables are represented by empty squares. HB orientation squares are sized based on the number of HBs which are part of a given category of orientation. *Thematic Orientation* variables (keywords) are represented by dark grey circles of different sizes, based on the share of the 130 core innovation literature that have the keyword concerned in the title or abstract. *Disciplinary Orientation* variables (citing fields) are represented by light grey squares of different sizes, based on the amount of citations to the 130 core innovation literature from the (composite) subject-area concerned. The strength of the relationships between the clusters and the variables is indicated by line thickness, the thicker the line, the stronger the relation.

As is evident from the Figure, variables may either differentiate between clusters or constitute bridges that connect them. In the case of the "Organizing Innovation" cluster (to the far left), this appears as a fairly well-defined cluster with a series of variables, reflecting specific thematic priorities, links to various communities and a publication channel, that differentiate it from the two other clusters. This holds also to a large extent for the "Innovation Systems" cluster but not to the same degree for the cluster on "Economics of R&D". The variables that contribute most strongly to network integration are to be found in the middle of the figure.

First, the network is bound together by a common thematic focus (reflected in key-words such as "innovation" and "technology"). A second form of network integration, reflected in the "General/industrial" (handbook) variable, comes from sustained efforts by leading academics (handbook editors) to take stock of – and synthesise – the knowledge common to all three clusters. Third, a contribution to network integration comes from shared appreciation of works by academics from top-rated research environments ("excellence") whose influence extends far beyond innovation studies proper ("outsider"). Finally, the highly cross-disciplinary "Innovation Systems" cluster also contributes to integrating the network, since this cluster is linked with "Economics of R&D" through a shared focus on the economic aspects of technology and innovation, and with the "Organizing Innovation" cluster by a common interest in Organization and Management.

5. The evolution of the field

This section traces the evolution of the core literature and its users, from the early Post-War period to the present time, focusing on the emergence of new core contributions, the academics behind them and the (changing) roles of the institutions (with which they are affiliated) and the disciplinary and cross-disciplinary fields they belong to. In order to do so, the entire period has been divided into three periods of equal duration, the years 1950-1969, 1970-1989 and 1990-2009. Table 6 gives some main statistics for these three periods.

Table 6: The evolution of the field

Period	Total J	J per Work	No of Scholars	No of Institutions	No of Countries
1950-1969	98.9	5.5	25	13	2
1970-1989	261.0	5.7	51	17	4
1990-2010	316.9	5.4	82	44	11

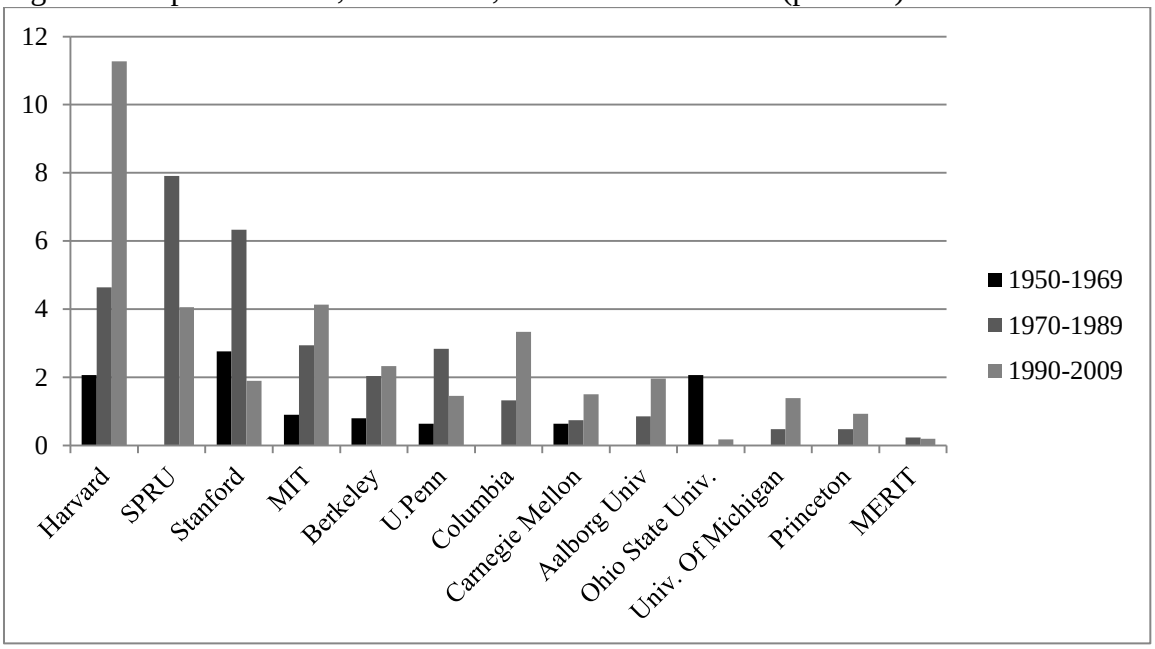
Note: Since the SSCI starts in 1956, ISI/year for the publications prior to this year was calculated as total ISI citations over the number of years from 1956 to 2008.

According to assessments of the experts, the contribution from works published between 1950 and 1969 to the core knowledge in the field was relatively modest (85 % of the core knowledge was produced after 1970), and so were the number of scholars and institutions

involved in producing these works.[25] The activity was concentrated in two countries only, the USA and the UK. However, in the 1970s and 1980 production of new knowledge gained pace, the number of scholars taking part doubled, and the number of institutions and countries involved also increased. During the two last decades the production of new knowledge continued to grow at rapid speed, as did the number of scholars in this area. What is particularly striking, however, is the sharp increase in the number of institutions and countries taking part. From a relatively small activity in a few universities in the USA and UK, scholarly work on innovation has now developed into a much broader and more international community.

Figure 7 ranks the top research institutions in this area based on the scientific contributions of their employees to the core literature and the importance of these contributions as assessed by experts (the J-index). For each institution the sum of the contributions in the three time periods equals the share of that institution in the core literature over the entire period (as assessed by the experts). Thus the figure reflects both the share of each institution and the growth of the field over time. Only institutions that contributed to the core knowledge in at least two of the three periods are included.

Figure 7. Top institutions, 1950-2009, share of total J-score (per cent)



[25] It should be noted that this is an ex post assessment. There may have been studies published during the 1950s and 1960s that were influential at the time, but are no longer recognized as being important , and therefore not cited by the authors of the handbook chapters. However, the data presented in Figure 1 above are consistent with the view that there were few contributions in this area before the latter half of the 1960s.

The figure reveals substantial changes in the contribution of different institutions over time. In the early days the most important institution was Stanford, followed by Harvard and Ohio State (with which Rogers was affiliated at the time). However, in the 1970s and 1980s the leading role was taken over by a newcomer, namely SPRU, followed by Stanford and Harvard.[26] Although SPRU continued to be an important institution after 1990, the leading role was now taken over by Harvard (by a considerable margin), followed by MIT and with SPRU now in third place. The important role played by SPRU in the 1970s and '80s, and the subsequent emergence of new European players such as the IKE group at Aalborg University in Denmark and MERIT at Maastricht University in the Netherlands, was in no small part related to the entrepreneurial role played by Christopher Freeman, SPRU's first Director, who at different times had affiliations with all three of these research environments (see Fagerberg et al., 2011).[27]

The evolution of the core literature

Table 7 reports the five top contributions to the core literature in each time period: before 1970 (including also Pre-War contributions), the 1970s and 1980s, and from 1990 onwards.

What characterises the contributions from the first period is above all that they appear to be quite unrelated, except for the fact that two of them are written by Schumpeter. Although the remaining three all appeared in the course of a few years in the early 1960s, their themes and approaches, as well as the research environments from which these contributions emerged, have little in common. One stems from American "rural sociology" (Rogers, 1962), another is an early British attempt to write a textbook in the management of innovation (Burns and Stalker, 1961) while the third lays out a mainstream economics perspective on how resources to R&D may be allocated (Arrow, 1962).[28] In fact, even the most basic concepts differ.

[26] Yale, home to both Nelson and Winter at the time, actually rivals Harvard for the third place during this period, but since Yale was not present in lists for the other two periods, it is not included in the figure.
[27] Freeman stepped down as Director of SPRU in 1982 (after 16 years of service) and retired from the University of Sussex in 1986. He continued to be active several years after his formal retirement, and held part-time visiting professorships at Aalborg and MERIT. See Fagerberg et al. (2011) for a more extensive analysis of Freeman's contribution to innovation studies.
[28] It is noteworthy that the contribution by Arrow was the result of a NBER conference in 1960 on "The Rate and Direction of Inventive Activity" to which most of the prominent US economists interested in the topic contributed (Nelson, 1962). This clearly signals an increased interest in the topic among American economists at the time. However, this initiative did not extend to sociologists working on similar issues, albeit from different perspectives, or connect to research on these topics in other parts of the world.

Rogers (1962), for example, attributes a different meaning to the term innovation than Schumpeter and the later "innovation studies" literature (Freeman, 1985; Fagerberg, 2004).

Table 7. The Core Literature, three time periods

No	Author	Country	Title	Type	Year	J-index	Citations (ISI/Year)
	Before 1970						
1	Rogers EM	USA	Diffusion of Innovations	Book	1962	14.1	204.3
2	Schumpeter JA	Austria/ USA	The Theory of Economic Development	Book	1934	14.1	56.3
3	Arrow K	USA	Economic welfare and the allocation of resources for invention	Book Chapter	1962	10.5	26.0
4	Schumpeter JA	USA	Capitalism, Socialism, and Democracy	Book	1942	7.9	81.3
5	Burns T & Stalker GM	UK	The management of innovation	Book	1961	7.6	55.7
	1970-1989						
1	Nelson R & Winter S	USA	An Evolutionary Theory of Economic Change	Book	1982	18.8	165.0
2	Freeman C	UK	The Economics of Industrial Innovation	Book	1974	12.6	30.4
3	Pavitt K	UK	Sectoral patterns of technical change	Article	1984	11.6	23.2
4	Freeman C	UK	Technology Policy and Economic Performance	Book	1987	9.7	20.2
5	Von Hippel E	USA	The Sources of Innovation	Book	1988	9.7	52.6
	1990-2009						
1	Nelson R	USA	National Innovation Systems: A Comparative Study	Book	1993	15.7	61.0
2	Porter M	USA	The Competitive Advantage of Nations	Book	1990	14.4	166.9
3	Lundvall B-Å	Denmark	National Systems of Innovation	Book	1992	13.4	59.3
4	Cohen W & D Levinthal	USA	Absorptive capacity: A new perspective on learning and innovation	Article	1990	11.9	124.3
5	Saxenian A	USA	Regional Advantage	Book	1994	9.9	87.3

Note: Since the SSCI starts in 1956, ISI/year for the publications prior to this year was calculated as total ISI citations over the number of years from 1956 to 2008.

This state affair changed during the 1970s and 1980s (Table 7). Three of the top five publications during this period originated from SPRU, with Freeman's early synthesis of the state of the art in "The Economics of Industrial Innovation" (Freeman, 1974) being the most popular among the experts. Hence, there is a strong European presence among the top contributions emerging during these years, related to the rise of SPRU as a leading research environment in this area, with Freeman and Pavitt as the most prominent academic figures. But the most highly rated publication overall from this period is Nelson and Winter's "An Evolutionary Theory of Economic Change" (Nelson and Winter, 1982). However, some of the central ideas of Nelson and Winter's work may also be found in Freeman's 1974 book, though in a more rudimentary form.[29] Without making claims about who inspired whom, it is clear that this is no mere coincidence. Arguably, what it shows is that the small evolutionary community in the US, represented above all by Nelson and Winter, and the neo-Schumpeterians in SPRU, led by Freeman and Pavitt, were already quite closely connected at that time. In fact, in 1973 Nelson had spent a sabbatical in SPRU. In the preface to his 1974 book, Freeman thanks, apart from his administrative support staff, just one person, Nelson.[30]

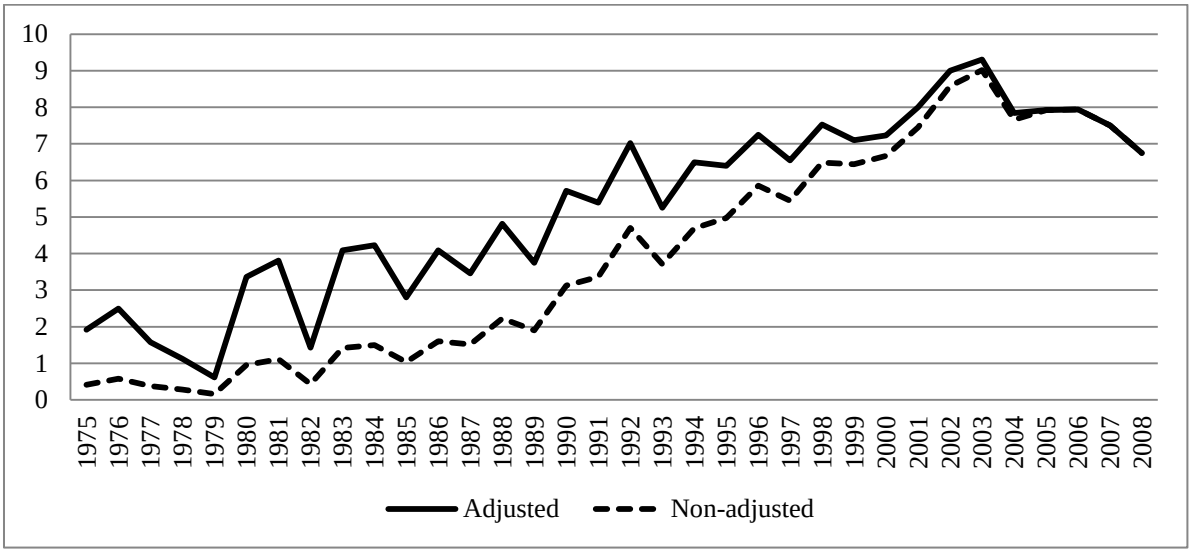
After 1990, the development of research in this area takes a new twist. While much of the previous work had focused on innovation in firms and industries, some of the attention now shifted towards the role of innovation in the entire economy, and how institutions and policies might be adjusted so that society could enjoy the full benefits of innovation and its diffusion. Four of the five top contributions between 1990 and 2009 focus on such "macro" issues, related to the regional, national or international level. Two of these, Lundvall (1992) and Nelson (1993), champion a "systems" approach to the study of these phenomena, which as mentioned earlier has attracted a lot of interest from policy makers and inspired a host of new work, focusing not only on the national level but also on regions (Braczyk et al., 1998). Arguably, the development of this new approach owes a lot to the influence of Freeman, who from the very start of SPRU had insisted on seeing innovation and diffusion in a system perspective (Fagerberg et al., 2011), and who was the first to use the notion of a "national innovation system" in print (Freeman, 1987).

[29] See, in particular the chapter on "Innovation and the Strategy of the Firm", pp. 255-282 in Freeman (1974).
[30] In contrast, Nelson and Winter in their 1982 book thank a large number of people, two of whom are Freeman and Pavitt (Nelson and Winter, 1982, p. x)

The evolution of the user community

One way to illustrate the evolution of the field is by mapping the tendency of users to cite not only one but a number of contributions to the core literature. Over the period as a whole, the overwhelming majority (83 %) of the users cite at most one or two of the core publications. Only 5% of the users - what will be termed "frequent users" - cite five or more contributions to the core literature. Frequent users, however, collectively stand for nearly one third of the total number of citations to the core, so they are clearly a very important part of the total user community. Figure 8 plots the number of frequent users as a share of the total from the mid 1970s onwards. As the Figure shows, there were very few frequent users back in the 1970s. This holds even if one adjusts for the fact that a large part of the core literature is more recent (and hence could not be cited at that time). However, the share of frequent users grew steadily during the 1980s and 1990s until it reached a level of 7-9% (with some fluctuation in recent years).[31] Arguably, the emergence of a substantial group of frequent users may be seen as a clear indication of the field's increasing maturity.

Figure 8. Share of frequent users by year, 1975 -2008



Note: The adjusted share corrects for the change in number of publications in the core literature over time.

To back up this interpretation a comparison will be made between the citation pattern of the frequent users (in scholarly journals) and the assessments of the handbook authors (the

[31] The fallback in the share of frequent users recent years from 9 to 7 % is interesting, but it cannot be excluded that this have to do with problems with the data for the most recent years, caused by, for example, delays in reporting.

experts). This is done in Table 8 which plots frequent citers' top twenty in terms of citations between 1990 and 2008 (of the 130 contributions in the core literature) on the vertical axis against the ranking suggested by the experts (J-index) on the horizontal axis. In this way four quadrants emerge. The top left quadrant contains publications that are assessed as being among the top twenty by both groups of assessors. In contrast, the publications in the bottom left are less popular among the frequent citers than among the experts, while the opposite holds for the publications in the top right quadrant.[32] The numbers refers to the rank suggested by the experts (see Appendix A).

Table 8. The core literature: Frequent users in the most recent period versus the expert

		Experts' assessment	
		Top 20	Rest of literature
Frequnt citers	Top 20	1 Nelson & Winter 1982 2 Nelson1993 3 Porter 1990 4 Schumpeter 1934 6 Lundvall 1992 8 Cohen & Levinthal 1990 11 Saxenian 1994 13 von Hippel 1988 15 Teece 1986 17 Henderson & Clark 1990 19 Schumpeter 1942	24 Tushman & Anderson 1987 26 Marshall 1920 27 Romer 1990 40 Nonaka & Takeuchi 1995 64 Teece, Pisano & Shuen 1997 69 Penrose 1959 72 Williamson 1975 109 Porter 1980 112 Granovetter 1985
	Rest of literature	5 Rogers 1962 7 Freeman 1974 9 Pavitt 1984 10 Arrow 1962 12 Freeman 1987 14 Christensen 1997 16 Kline & Rosenberg 1986 20 Tidd, Bessant & Pavitt 1997	Rest of core literature (101 works)

[32] It is noteworthy that Rogers (1962), which is one of the most highly cited publications in the core literature in the ISI Web of Science (see Appendix A), is not highly cited by the frequent citers. The same goes, incidentally, for the most highly cited core publication in the ISI Web of Science, Kuhn (1959). This confirms our earlier interpretation that these authors are "outsiders", i.e. scholars that are much more appreciated in the world of science more generally, than in the specific field under study here.

The most important thing to note is that that the two rankings have a lot in common. Eleven of the top twenty contributions to the core literature are also among the frequent citers' favourites.[33] This includes central theoretical works such as those by Schumpeter (1934, 1942) and Nelson and Winter (1982), the most important books on national innovation systems (Lundvall, 1992; Nelson, 1993) as well as the to some extent related publications by Porter (1990) and Saxenian (1994), and important contributions to the literature on innovations in firms such as Cohen & Levinthal (1990), Henderson & Clark (1990) and von Hippel (1988). Among the entries on the experts' top twenty that do not make it to the frequent user's favourites, five are in section 2 classified as having an overview/synthesis character, e.g., intended (or used) for teaching purposes. Some of these are also quite old. Hence, although these works may in fact have been quite influential, it is perhaps more natural to cite them in handbooks, which to some extent target research students, than in contributions to the research frontier. As for the nine works that are more highly rated by the frequent users than the experts, most of these focus on firms in one way or another, indicating, probably, that innovation in firms is a central topic on the frequent citers' research agenda. This may also have to do with how the user community has developed in recent years. To explore this, Figure 9 traces the evolution of the user community, as evidenced by the shares of the ten largest user groups in the total citations to the core literature, from the early 1950s onwards.[34]

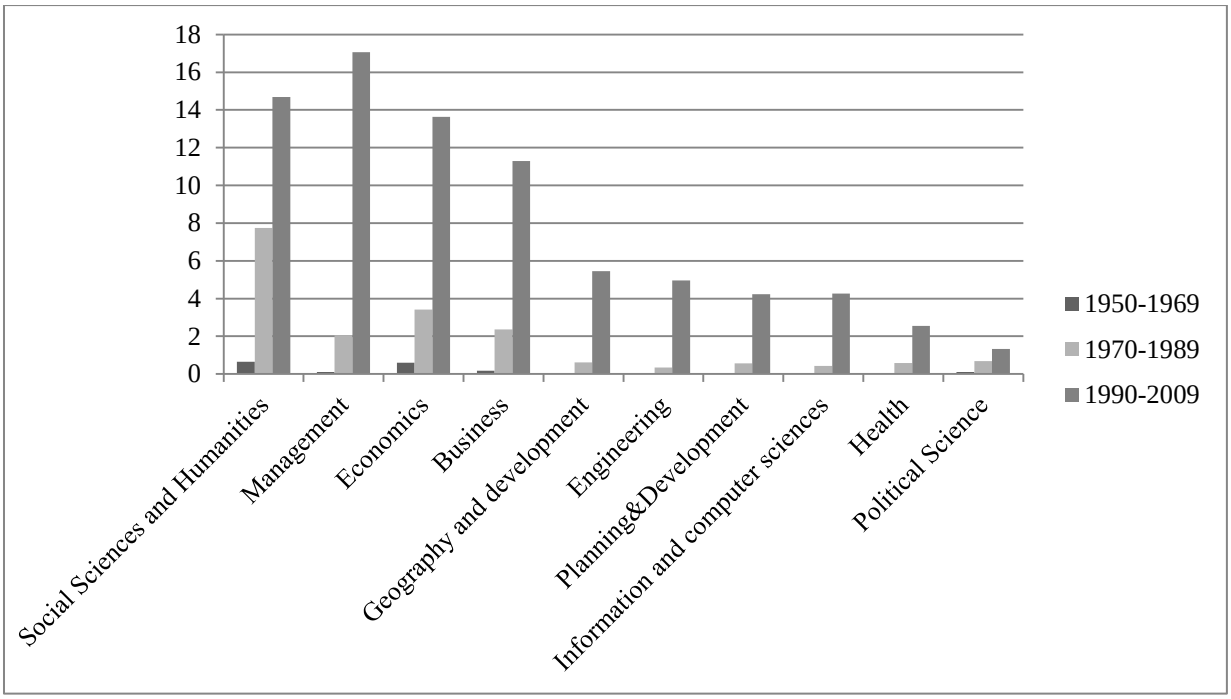
As shown in the Figure 9, before 1970 citations to the core literature were few and far between, and tended to come from "Social Sciences and Humanities" and Economics. In the decades that followed citation activity increased steadily and spread out to many different user groups extending beyond social science proper. A number of smaller fields, often with a distinct cross-disciplinary bent, increased their presence within the user community during these years. However, what particularly strikes the eye is the rapidly growing role of management, from a very low share before 1970 to a leading role more recently. In fact, the important role played by management scholars in recent years is even more pronounced among the frequent users, for which the share of management in the most recent period is

[33] This correspondence is even higher for authors. 16 of the top twenty core contributors (Table 3) are also among the frequent users' top twenty authors in terms of citations (summed up over an author's contributions and adjusted for co-authorship). Five of the top six are the same on the two rankings (Freeman, Nelson, Porter, Rosenberg and Schumpeter).

[34] For each user group the sum of the contributions in the three time periods equals the share of the group in the total number of citations over the whole period. Hence, the figure reflects both the roles of the various user groups and the growth in citation activity over time.

close to one third (compared to around one fifth for the user community as a whole).[35] It is understandable, therefore, that topics of relevance for management also get a high place on the agenda within innovation studies.

Figure 9. The evolution of the user community 1950-2009



Source: Own calculations based on statistics from ISI web of science.

6. Conclusion

New scientific fields or specialties, within or across disciplines, emerge from time to time in response to challenging problems and the resulting need for new knowledge. In fact, many of the several hundred "subject-areas" listed in the Web of Science are related to the rise of such fields or specialties within, but increasingly also across, established disciplines. However, since such emerging areas of knowledge usually lack most of the institutions and organisations that characterise established disciplines, they may be difficult to study, as with the field under scrutiny here. Confronted by this challenge, this paper chose to study the characteristics of the field "through the eyes of experts", i.e. the authors of chapters in

[35] The other subject area that is clearly overrepresented among the frequent users is the cross-disciplinary (and policy-oriented) Planning and Development area, This is, however, a much smaller area than Management (among the frequent users there are three Management users for every Planning and Development user). The high shares of these two subject areas come at the expense of the composite Social Science and the Humanities group, which plays a much smaller role among the frequent users than in the user community as a whole.

handbooks surveying the field. Having identified the core contributions to the field in this way, and analysed their characteristics, we also collected information about the users of this literature (as reflected in citations in scholarly journals) and their disciplinary orientation, as revealed by the subject-areas of journals in which their works are published. By combining information on the characteristics of the core literature, including its thematic priorities, with information on the disciplinary orientation of the users of this literature, it was thus possible to shed light on the nature of the relationship between the emerging field of innovation studies and other currents (including the established disciplines) within the world of science. The methodology developed here is not only applicable to innovation studies but may also be relevant for the study of other emerging fields or specialties that make use of handbooks to assemble the knowledge base underpinning its activities.[36]

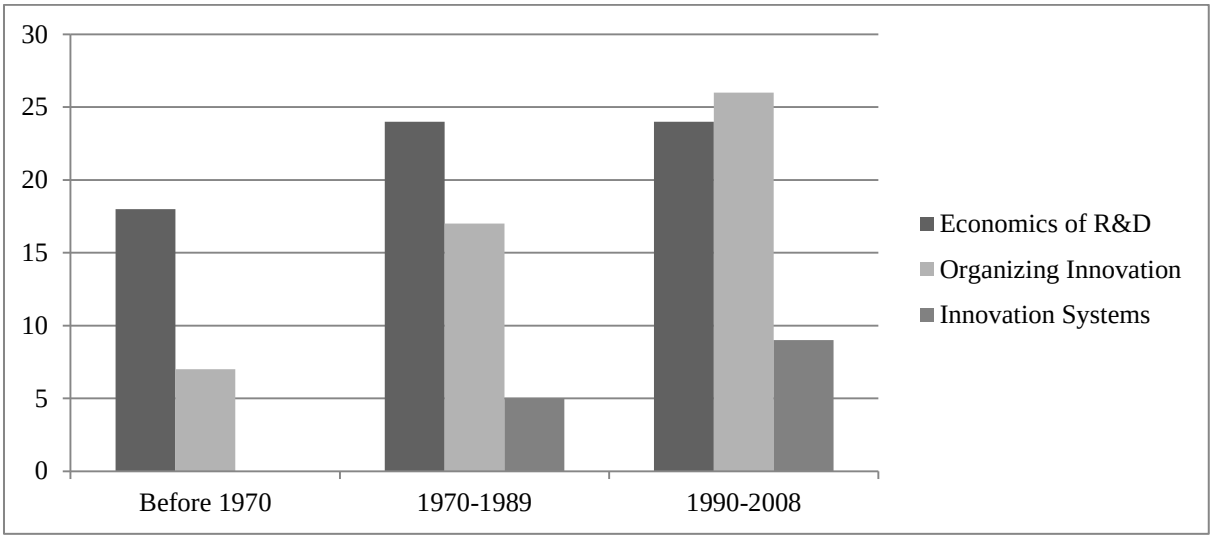
The analysis presented in this paper shows that a sizeable literature on innovation has developed, mostly from the 1950s onwards (although a few contributions, such as those by Schumpeter, are older), with a particularly strong growth in recent years. From a relatively small and disciplinary based activity in a few research environments in the US and the UK, a broad, international research community has developed, with – to a certain degree at least - its own institutions and organisations, such as centres/departments, journals and professional associations. In parallel with this a core literature, increasingly recognised as such by scholars in the field, has evolved, consisting of central theoretical contributions on innovation (such as those of Schumpeter and Nelson & Winter) and frameworks (and exemplars) for how to research innovation, its consequences and issues related to strategy, governance and policy at various levels of analysis.

Several different phases in the evolution of the field may be distinguished. In the **early phase** (until around 1970) the field was still in its infancy. The small amount of work that took place was mostly confined to two established disciplines within the social sciences, economics and sociology, with little if any interaction across the disciplinary borders. Hence, innovation research within economics and sociology followed different trajectories, and the two streams hardly took account of each other's work. However, in spite of the small size and lack of interaction across disciplinary borders, an important mobilization of societal support,

[36] Since the first version of this paper was written, two other studies have adopted the same methodology to study the emergence and characteristics of cross-disciplinary, problem-oriented fields of research (See Landström et al. (2011) and Nightingale et al. (2011) in this issue).

resources and scholarly interest took place during this phase. It is noteworthy that the support and resources that made the mobilization of scholarly activity possible mostly came from stakeholders outside the university system. For example, in the late 1950s Nelson researched the economics of R&D while working for the RAND corporation, a research arm of the US military, while at the same time Freeman, employed by a private research institute (NIER) supported by British industry, was busy surveying R&D in British industry. Policy-oriented research hubs, such as the NBER (National Bureau for Economic Research) in the US and the OECD in Europe, also played an important role in supporting the field's development during the early years. Most of the work emerging from these activities, some of which made it to the core literature, would be classified as "Economics of R&D", the dominant cluster at the time (Figure 10).[37]

Figure 10. Literature clusters, three periods, J-score.



Around 1970 the emerging field of innovation studies entered what may be termed its **growth phase**. The establishment of SPRU at the University of Sussex in 1966 was a turning point. From a modest start (with an academic staff of three persons) it quickly developed into a global hub for research in this area, attracting a large number of researchers, students and visiting scholars with a variety of educational backgrounds from all over the world.[38] Whether intended or not, an important effect was that leading American scholars within the "Economics of R&D" cluster, such as Nelson and Rosenberg, came to interact closely with

[37] Three quarters of the publications in the core literature published in 1969 or earlier belong to the "Economics of R&D" cluster.
[38] See Fagerberg et al. 2011 for further details.

Freeman and other European researchers, leading to the development of a - if not identical, so at least much more coherent - research agenda shared by a large number of researchers in the two continents.[39] As a result a number of important contributions to the core literature emerged during the 1970s and 1980s that contributed to shape the cognitive platforms of researchers in this area for years to come such as, for example, Freeman (1974) and Nelson and Winter (1982). Another characteristic feature of SPRU, in sharp contrast to the disciplinary narrow-mindedness that had characterized the early phase, was a strong emphasis on cross-disciplinarity, not only among the social sciences, but also in relation to other parts of the scientific world such as, for example, engineering science. This emphasis on cross-and inter-disciplinarity came to have lasting influence on the field, not the least through the many centres and departments that, often modelled on SPRU, were initiated in the years that followed, particularly in Europe. It also served to differentiate the emerging field from the existing disciplines within the social sciences. Arguably, the portrayal of the emerging field as a socially needed addition to existing disciplines and fields, rather than as a competitor for any one of them, made it somewhat easier (but definitely not easy!) to get acceptance for the new initiative by the (arguably rather inert) academic establishment.

Around 1990 the field enters what may be seen as a more **mature phase**, as indicated for example by the creation of specialized professional associations devoted to its progress, such as the International Joseph Schumpeter Society (ISS, founded in 1986) and the Technology and Innovation Management Division (TIM) of the (American) Academy of Management (started in 1987), and the emergence during these years of several specialized journals focusing on the field's development. Arguably, the creation of these associations reflects – and possibly cements - the division between the two main clusters in this area, "Economics of R&D" (ISS) and "Organizing Innovation" (TIM). From a modest start in the early phase, the "Organizing Innovation" cluster had grown rapidly during the growth phase so that, from around 1990 onwards, it rivalled the older and (at least previously) more established "Economics of R&D" cluster for the position as the largest part of the field (Figure 10). This tendency, it may be noted, is also evident among the users, as reflected by citations in scholarly journals. From being the fourth largest in the 1970s and 1989s, "Management" becomes the largest user group after 1990, relegating "Social Sciences and the Humanities" and "Economics" to the second and third place, respectively (Figure 9).

[39] This is what Dosi et al. (2006) dubbed the "Stanford–Yale–Sussex synthesis".

As shown above, the end of the 1980s[40] also witnesses the creation of a new literature cluster, "Innovation Systems", focusing on the role of innovation in national and regional development, how this may best be studied and the policy issues that arise. Thus what happens as the field matures, is not only that it grows larger in size and broadens geographically, but it also becomes more diverse thematically and perhaps also methodologically. Although this may be seen as a natural - and even beneficial (March 2004) – tendency in a growing field, since a certain degree of diversity is essential for progress in any area, it also points to new challenges. Arguably, for diversity to lead to progress in science, scholars and research groups advocating different methods and/or positions on central questions, need to be informed about – and seriously consider the merits of – central work emerging from the different streams. This is exactly what did not happen in innovation studies in the early years, and it is likely that the disciplinary insularity that characterized the field during these years hampered its progress. As pointed above, this state of affair changed during the growth phase, related to the increasing emphasis on cross-disciplinarity championed in particular by Freeman and practiced by SPRU, and the general acceptance of this stance in the growing community of innovation researchers world-wide. However, what accompanied this broadening of the field was an effort by leading academics throughout the 1970s and 1980s to take each others' positions on seriously and create sufficient room for interaction and debate.[41] Will such informal integration suffice in the much larger (and more diversified) community of scholars that has now developed? If not, as seems more likely, it is possible that the different parts that now constitute the field may drift further apart and, eventually, embark on altogether different trajectories, with possible negative consequences for scientific progress in this area (March 2004). For example, one might envisage a situation in which scholars in the "Organizing Innovation" cluster, fuelled by the increasing size and resources of the cluster, might become less inclined to interact with scholars from other areas. A relevant question, therefore, for scholars in this area is what new forms of integration that may be needed to ensure that the various parts of the field stay connected and the field as whole continue to thrive.

[40] Figure 10 may be a bit deceiving regarding the time profile of this cluster as all contributions are from 1986 or later.

[41] This took many forms and it is beyond the scope of this paper to discuss these in detail. However, one highly visible initiative of this sort was the so-called IFIAS project, in which a group of central researchers in this area met regularly and produced a joint book on "Technical Change and Economic Theory" (Dosi et al., 1988).

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Appendix A. Core innovation literature (ranked by J-index)

No.	Author	Country	Title	Type	Year	J-Index	ISI/ year	Cluster
1	Nelson, R. and Winter, S.	USA	An Evolutionary Theory of Economic Change	Book	1982	18.8	165.0	1
2	Nelson, R.	USA	National Innovation Systems: A Comparative Study	Book	1993	15.7	61.0	3
3	Porter, M.	USA	The Competitive Advantage of Nations	Book	1990	14.4	166.9	2
4	Schumpeter, J.A.	Austria/ USA	The Theory of Economic Development	Book	1934 1912	14.1	56.3	2
5	Rogers, E. M.	USA	Diffusion of Innovations	Book	1962	14.1	204.3	1
6	Lundvall, B.-Å.	Denmark	National Systems of Innovation - Toward a Theory of Innovation and Interactive Learning	Book	1992	13.4	59.3	3
7	Freeman, C.	UK	The Economics of Industrial Innovation	Book	1974	12.6	30.4	2
8	Cohen, W. and D. Levinthal	USA	Absorptive capacity: A new perspective on learning and innovation	Article	1990	11.9	124.3	1
9	Pavitt, K.	UK	Sectoral patterns of technical change: Towards a taxonomy and a theory	Article	1984	11.6	23.2	1
10	Arrow, K.	USA	Economic welfare and the allocation of resources for invention	Book Chapter	1962	10.5	26.0	2
11	Saxenian, A.	USA	Regional Advantage: Culture and Competition in Silicon Valley and Route 128	Book	1994	9.9	87.3	2
12	Freeman, C.	UK	Technology Policy and Economic Performance	Book	1987	9.7	20.2	3
13	Von Hippel, E.	USA	The Sources of Innovation	Book	1988	9.7	52.6	2
14	Christensen, C.	USA	The Innovator's Dilemma	Book	1997	9.5	88.4	1
15	Teece, D.J.	USA	Profiting from technological innovation: implications for integration, collaboration licensing and public policy	Article	1986	9.4	46.5	1
16	Kline, S.J. and N. Rosenberg	USA	An Overview of Innovation	Book Chapter	1986	9.4	15.0	3
17	Henderson, R. and Clark, K.	USA	Architectural Innovation	Article	1990	9.4	49.2	1
18	Rosenberg, N.	USA	Inside the Black Box	Book	1982	9.0	37.1	2
19	Schumpeter, J.A.	USA	Capitalism, Socialism, and Democracy	Book	1942	7.9	81.3	2
20	Tidd, J., Bessant, J. and Pavitt, K.	USA	Managing Innovation: Integrating Technological, Market and Organizational Change	Book	1997	7.7	40.3	1
21	Burns, T & Stalker, G.M.,	UK	The management of innovation	Book	1961	7.6	55.7	1

22	Chesbrough, H.	USA	Open Innovation: The new imperative for creating and profiting from technology	Article	2003	7.4	39.6	1
23	Nelson, R.	USA	The simple economics of basic scientific research	Article	1959	7.2	7.6	2
24	Tushman, M. and P. Anderson	USA	Technological discontinuities and organizational environments	Article	1987	6.9	44.6	1
25	Porter, M.	USA	Clusters and the new economics of competition	Book	1998	6.8	23.9	2
26	Marshall, A.	UK	Principles of Economics	Book	1920	6.5	76.9	2
27	Romer, P.	USA	Endogenous technological change	Article	1990	6.5	98.0	2
28	Von Hippel, E.	USA	Democratizing Innovation	Book	2004	6.1	1.3	1
29	Solow, R.	USA	Technical change and the aggregate production function	Article	1957	6.1	30.6	2
30	Griliches, Z.	USA	Issues in Assessing the Contribution of Research and Development to Productivity Growth	Article	1979	6.1	16.4	2
31	Cohen, W. and D.A. Levinthal	USA	Innovation and learning: The two faces of R&D - implications for the analysis of R&D investment	Article	1989	6.1	43.3	2
32	Chandler, Jr. A.D.	USA	Scale and Scope – The Dynamics of Industrial Capitalism	Book	1990	6.1	57.2	1
33	Leonard-Barton, D.	USA	Wellsprings of Knowledge: Building and sustaining the sources of innovation	Book	1995	5.9	51.2	1
34	Amabile, T. M.	USA	Creativity in Context: Update to the Social Psychology of Creativity	Book	1996	5.9	33.8	2
35	Edquist, C.	Sweden	Systems of Innovation	Book	1997	5.9	34.1	3
36	Abernathy, W. and Utterback, J.	USA	Patterns of industrial innovation	Article	1978	5.8	17.0	1
37	Barras, R.	USA	Towards a Theory of Innovation in Services: The Vanguard of the Services Revolution	Article	1986	5.8	3.1	3
38	Romer, P.	USA	Increasing Returns and Long-Run Growth	Article	1986	5.8	84.3	2
39	Lundvall, B.-Å.	Denmark	Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation	Book Chapter	1988	5.8	17.7	3
40	Nonaka, I. and Takeuchi, H.	Japan	The Knowledge-Creating Company: How Japanese Companies Create the Dynamic of Innovation	Book	1995	5.5	176.0	1
41	Arora, A., Fosfuri, A. and	USA, Spain,	Markets for Technology: The Economics of	Book	2001	5.5	17.4	1

	Gambardella, A.,	Italy	Innovation and Corporate Strategy					
42	Schumpeter, J.A.	USA	Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process	Book	1939	5.4	22.9	2
43	Kuhn, T.	USA	The Structure of Scientific Revolution	Book	1959	5.4	377.9	2
44	Schmookler, J.	USA	Invention and Economic Growth	Book	1966	5.4	19.0	2
45	Rosenberg, N.	USA	Perspectives in Technology	Book	1976	5.4	19.1	2
46	Piore, M. and C. Sabel	USA	The Second Industrial Divide	Book	1982	5.4	99.8	2
47	Levin, R.C., A.K. Klevorick, R.R. Nelson and S.G. Winter	USA	Appropriating the returns from industrial research and development	Article	1987	5.4	30.6	2
48	Mowery, D.C. and Rosenberg, N.	USA	Technology and the Pursuit of Economic Growth	Book	1989	5.4	14.7	2
49	Jaffe, A.	USA	Real effects of academic research	Article	1989	5.4	19.5	2
50	Griliches, Z.	USA	Patent Statistics as Economic Indicators	Article	1990	5.4	32.1	2
51	Griliches, Z.	USA	The search for R&D spillovers	Article	1991	5.4	17.7	2
52	Dosi, G.	UK	Sources, procedures and microeconomic effects of innovation	Article	1988	5.1	31.3	2
53	Van de Ven, A., Polley, D., Garud, R. and Ventkataraman	USA	The Innovation Journey	Book	1999	5.0	15.0	1
54	Freeman, C. and Louçã, F.	UK	As time goes by. From the industrial revolution to the information revolution	Book	2001	5.0	10.7	2
55	Jaffe, A., M. Trajtenberg, and R. Henderson	USA	Geographic localization of knowledge spillovers as evidenced by patent citations	Article	1993	4.9	48.0	2
56	Rosenberg, N.	USA	Exploring the Black Box: Technology, Economics and History	Book	1994	4.7	15.3	2
57	Rothwell, R., Freeman, C., Jervis, P., Robertson, A. and Townsend, J.	UK	SAPPHO Updated - Project SAPPHO Phase II	Article	1975	4.7	9.1	1
58	Chandler, A.D. jr.	USA	The Visible Hand: the managerial Revolution in American Business	Book	1977	4.7	73.7	1
59	Mansfield, E., M. Schwartz and S. Wagner	USA	Imitation costs and patents: an empirical study	Article	1981	4.7	9.4	2
60	Dosi, G.	UK	Technological paradigms and technological trajectories: a suggested	Article	1982	4.7	29.7	1

			interpretation of the determinants and directions of technical change					
61	Arthur, W.B.	USA	Competing Technologies, Increasing Returns and Lock-in by Historical Events	Article	1989	4.7	39.3	2
62	Grossman, G.M. and Helpman, E.	USA, Israel	Innovation and Growth in the Global Economy	Book	1991	4.7	72.9	2
63	Rothwell, R.	USA	Successful Industrial Innovation: Critical Factors for the 1990s	Article	1992	4.7	9.5	1
64	Teece, D.J., Pisano, G., and Shuen, A.	USA	Dynamic capabilities and strategic management	Article	1997	4.5	125.3	1
65	Aghion, P. and Howitt, P.	USA	Endogenous Growth Theory	Book	1998	4.5	50.8	2
66	Sundbo, J. and Gallouj, F.	Denmark France	Innovation as a loosely coupled system in services	Article	2000	4.5	2.0	3
67	Owen-Smith, J., Powell, W.W.	USA	Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community	Article	2004	4.4	22.0	2
68	March J. G. and Simon, H.	USA	Organizations	Book	1958	4.3	79.6	1
69	Penrose, E.T.	UK	The Theory of the Growth of the Firm	Book	1959	4.3	43.8	1
70	Cyert R. M. and March, J. G.	USA	A Behavioral Theory of the Firm	Book	1963	4.3	4.6	1
71	Mansfield, E.	USA	Industrial Research and Technological Innovation	Book	1968	4.3	15.7	2
72	Williamson, O.E.	USA	Markets and Hierarchies: Analysis and Antitrust Implications	Book	1975	4.3	168.8	1
73	Lucas, R. E.	USA	On the Mechanisms of Economic Development	Article	1988	4.3	105.8	2
74	Clark, K. and Fujimoto, T.	USA, Japan	Product Development Performance	Book	1992	4.3	57.3	1
75	Dasgupta, P. and P. David	UK, USA	Towards a New Economics of Science	Article	1994	4.3	17.7	2
76	von Hippel, E.	USA	Sticky information and the locus of problem solving: Implications for innovation	Article	1994	4.3	0.5	1
77	Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M.	USA, UK, Canada, Brazil, Austria	The New Production of Knowledge, the Dynamics of Science and Research in Contemporary Societies	Book	1994	4.3	81.0	2
78	Audretcsh, D. B. and Feldman, M. P.	USA	R&D Spillovers and the Geography of Innovation and Production	Article	1996	4.1	37.8	2
79	Tushman, M. and C. O'Reilly	USA	Ambidextrous Organisations: Managing Evolutionary and Revolutionary Change	Article	1996	4.1	11.5	1

80	Aldrich, H.	USA	Organizations Evolving	Book	1999	4.1	50.8	1
81	Cohen, W. M., R. R. Nelson and J. P. Walsh	USA	Links and Impacts: The Influence of Public Research on Industrial R & D	Article	2002	4.1	12.8	2
82	Malerba, F.	Italy	Sectoral Systems of Innovation and Production	Article	2002	4.1	13.0	3
83	Smith, A.	UK	An Inquiry into the Nature and Causes of the Wealth of Nations	Book	1776	4.0	70.7	2
84	Abramovitz, M.	USA	Resources and output trends in the United States since 1870	Article	1956	4.0	2.8	2
85	Chandler, A.D.	USA	Strategy and Structure: Chapters in the History of the American Industrial Enterprise	Book	1962	4.0	51.5	1
86	Polanyi, M.	UK	The Tacit Dimension	Book	1966	4.0	49.5	2
87	Argyris, C. and D. Schon	USA/UK	Organizational Learning	Book	1970	4.0	49.8	1
88	Williamson, O.E.	USA	The Economic Institutions of Capitalism	Book	1985	4.0	2.1	2
89	Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L.	UK, USA, Nether-lands	Technical Change and Economic Theory	Book	1988	4.0	28.1	2
90	Freeman, C. and Perez, C.	UK	Structural crises of adjustment: business cycles and investment behaviour	Book Chapter	1988	4.0	7.3	3
91	Cohen, W. and R.C. Levin,	USA	Empirical studies of innovation and market structure	Book Chapter	1989	4.0	16.9	1
92	Dosi, G., Pavitt, K. and L. Soete	UK, Nether-lands	The Economics of Technological Change and International Trade	Book	1990	4.0	8.2	2
93	Womack, J.P., Jones, D.T. and Roos, D.	UK, USA	The Machine that Changed the World	Book	1990	4.0	100.4	1
94	Krugman, P.	USA	Geography and Trade	Book	1991	4.0	71.5	2
95	Mansfield, E.	USA	Academic research and industrial innovation	Article	1991	4.0	10.8	1
96	Teece, D.J. and Pisano, G.	USA	The Dynamic Capabilities of Firms	Article	1994	3.9	18.3	1
97	Utterback, J.	USA	Mastering the Dynamics of Innovation	Book	1994	3.9	42.1	1
98	Weick, K.E.	USA	Sensemaking in Organizations	Book	1995	3.6	114.0	1
99	Freeman, C.	UK	The National Innovation Systems in historical perspective	Article	1995	3.6	9.2	3
100	Storper, M.	UK	The Regional World: Territorial Development in a Global Economy	Book	1997	3.6	69.0	2
101	Zucker, L.G., Darby, M.R., and Brewer, M.B.	USA	Intellectual human capital and the birth of U.S. biotechnology enterprises	Article	1998	3.6	26.7	2

102	Heller, M.A., and R.S. Eisenberg.	USA	Can Patents Deter Innovation? The Anticommons in Biomedical Research.	Article	1998	3.6	42.1	2
103	Mowery, D.C. and Rosenberg, N.	USA	Paths of Innovation, Technological Change in 20th-Century America	Book	1998	3.6	8.5	3
104	Sundbo, J.	Denmark	The Organization of Innovation in Services	Book	1998	3.6	2.0	1
105	Bush, V.	USA	Science: The Endless Frontier	Report	1945	3.6	0.8	2
106	Griliches, Z.	USA	Hybrid Corn: An Exploration in the Economics of Technological Change	Article	1957	3.6	13.9	2
107	Nelson, R. and Winter, S.	USA	In search of a useful theory of innovation	Article	1977	3.6	13.4	1
108	Mowery, D.C. and Rosenberg, N.	USA	The influence of market demand upon innovation: A critical review of some recent empirical studies	Article	1979	3.6	6.4	1
109	Porter, M.	USA	Competitive Strategy: Techniques for analyzing a business, industry and competitors	Book	1980	3.6	161.9	1
110	DiMaggio, P.J. and Powell, W.W.	USA	The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields	Article	1983	3.6	114.7	1
111	Griliches, Z.	USA	R&D, Patents, and Productivity	Book	1984	3.6	13.6	2
112	Granovetter, M.	USA	Economic Action and Social Structure: The Problem of Embeddedness	Article	1985	3.6	158.3	2
113	Senge, P.	USA	The Fifth Discipline	Book	1990	3.6	194.2	1
114	Anderson, P. and Tushman, M.	USA	Technological Discontinuities and Dominant Design: A Cyclical Model of Technological Change	Article	1990	3.6	17.9	1
115	Edquist, C.	Sweden	Systems of innovation: perspectives and challenges	Book Chapter	2004	3.5	7.0	3
116	List, F.	Germany	The National System of Political Economy	Book	1841	3.2	2.6	2
117	Vernon, R.	USA	International investment and international trade in the product cycle	Article	1966	3.2	32.8	2
118	Thompson, J.	USA	Organizations in Action	Book	1967	3.2	111.4	1
119	Landes, D.	USA	The Unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present	Book	1969	3.2	21.7	2
120	Rosenberg, N.	USA	Science, innovation and economic growth	Article	1974	3.2	2.2	1
121	Weick, K.E.	USA	The Social Psychology of Organizing	Book	1979	3.2	100.6	1
122	Hughes, T.	USA	Networks of Power:	Book	1982	3.2	25.2	2

			Electrification in Western Society 1800-1930					
123	Scherer, F.M.	USA	Inter-industry technology flows in the United States	Article	1982	3.2	3.2	2
124	David, P.	USA	Clio and the Economics of QWERTY	Article	1985	3.2	33.5	2
125	Jaffe, A.	USA	Technological opportunity and spillovers of R&D: evidence from firm's patents, profits and market value	Article	1986	3.2	19.0	2
126	Katz, M.L. and C. Shapiro	USA	Technology adoption in the presence of network externalities	Article	1986	3.2	17.1	2
127	Nonaka, I.	Japan	The knowledge creating company	Article	1991	3.2	13.3	1
128	Freeman, C.	UK	Networks of Innovators: A Synthesis of Research Issues	Article	1991	3.2	11.7	3
129	Aghion, P. and Howitt, P.	USA	A Model of Growth through Creative Destruction	Article	1992	3.2	38.8	2
130	Acs, Z.J., D.B. Audretsch and Feldman, M.	USA	Real effects of academic research: comment	Article	1992	3.2	5.9	2

Note: Since the SSCI backfile starts from 1956, the ISI/year figure for the publications prior to this year (Schumpeter 1912, 1939, 1942, List 1841, Marshall 1920, Smith 1776, and Bush 1945) was calculated as the total ISI citations over the number of years from 1956 to 2008.

Appendix B. Subject-areas and sub-categories

Subject-areas	No. of citations	Sub-Categories (merged)
Social Sciences and Humanities	32 046	Multidisciplinary Sciences; Psychology (General, Applied, Biological, Clinical, Developmental, Educational, Experimental, Mathematical, Multidisciplinary, Psychoanalysis, Social); Humanities (Multidisciplinary); Anthropology; History & Philosophy of Science; Philosophy; History; Education (General & Educational Research, Scientific Disciplines, Special); Law; Sociology; International Relations; Social Issues; Social Sciences (Biomedical, Interdisciplinary, Mathematical Methods)
Management	27 158	-
Economics	24 994	-
Business	19 533	Business (general, finance)
Engineering	8 635	Engineering (Aerospace, Biomedical, Chemical, Civil, Electrical & Electronic, Environmental, Geological, Industrial, Manufacturing, Marine, Mechanical, Multidisciplinary, Ocean, Petroleum); Operations Research and Management Science
Information and Computer Science	7 544	Computer Science (Artificial Intelligence, Cybernetics, Hardware & Architecture, Information Systems, Interdisciplinary Applications, Software Engineering, Theory & Methods); Information Science and Library Science
Planning & Development	6 811	-
Geography and Environment	6 673	Geography (general, physical); Environmental Studies; Urban Studies
Health	5 780	Environmental Sciences; Healthcare Sciences & Services; Communication; Public, Environmental & Occupational Health; Medicine (General & Internal, Legal, Research & Experimental); Nursing
Political Science	2 982	-

Appendix C. TwoStep cluster analysis (solutions based on BIC and log-likelihood distance)

Number of clusters	*4*				*3*			*2*	
BIC (Ratio of distance measures)	*4079.75 (1.08)*				*3985.22 (1.13)*			*3915.98 (1.72)*	
Cluster	1	2*	3	4*	1	2*	3*	1	2
Number of members	50	42	14	24	50	66	14	50	80
Characteristics of the literature									
Management & Organization	0.31	0.09	0.13	0.15	0.31	0.13	0.13	0.31	0.10
General/industrial	0.52	0.35	0.40	0.29	0.52	0.40	0.40	0.52	0.37
Economics of Innovation	0.21	0.44	0.42	0.41	0.21	0.43	0.42	0.21	0.43
Geography & Development	0.06	0.24	0.25	0.11	0.06	0.16	0.25	0.06	0.21
SPRU	0.21	0.20	0.19	0.09	0.21	0.15	0.19	0.21	0.16
Harvard	0.19	0.20	0.11	0.09	0.19	0.14	0.11	0.19	0.17
Berkeley	0.14	0.13	0.10	0.18	0.14	0.15	0.10	0.14	0.14
Stanford	0.18	0.18	0.06	0.10	0.18	0.14	0.06	0.18	0.14
Manchester Univ.	0.10	0.20	0.28	0.11	0.10	0.15	0.28	0.10	0.18
Excellence	0.42	0.47	0.30	0.35	0.42	0.41	0.30	0.42	0.40
Innovation	0.62	0.40	1.00	0.24	0.62	0.32	1.00	0.62	0.46
Economic	0.24	0.97	0.21	0.28	0.24	0.63	0.21	0.24	0.42
Technology	0.40	0.44	0.38	0.20	0.40	0.32	0.38	0.40	0.34
Sector/Industry	0.48	0.26	0.12	0.16	0.48	0.21	0.12	0.48	0.17
Organization	0.50	0.00	0.25	0.00	0.50	0.00	0.25	0.50	0.04
Firm	0.42	0.07	0.00	0.16	0.42	0.12	0.00	0.42	0.06
R&D	0.04	0.00	0.05	0.72	0.04	0.36	0.05	0.04	0.22
Knowledge	0.16	0.05	0.06	0.28	0.16	0.17	0.06	0.16	0.12
Macro	0.02	0.23	0.31	0.08	0.02	0.16	0.31	0.02	0.23
Management	0.32	0.00	0.00	0.00	0.32	0.00	0.00	0.32	0.00
Spill-over	0.00	0.00	0.00	0.44	0.00	0.22	0.00	0.00	0.11
System	0.00	0.04	0.56	0.00	0.00	0.02	0.56	0.00	0.28
Science	0.04	0.05	0.00	0.32	0.04	0.19	0.00	0.04	0.10
Patents	0.00	0.02	0.00	0.24	0.00	0.13	0.00	0.00	0.07
User Characteristics									
Social Sciences & Humanities	0.16	0.20	0.09	0.27	0.16	0.18	0.09	0.16	0.20
Management	0.28	0.11	0.27	0.19	0.28	0.11	0.27	0.28	0.18
Economics	0.12	0.51	0.28	0.35	0.12	0.42	0.28	0.12	0.32
Business	0.55	0.24	0.24	0.26	0.55	0.24	0.24	0.55	0.24
Engineering	0.26	0.10	0.23	0.13	0.26	0.11	0.23	0.26	0.13
Information & Computer Science	0.13	0.04	0.08	0.08	0.13	0.04	0.08	0.13	0.06
Planning & Development	0.07	0.19	0.36	0.15	0.07	0.16	0.36	0.07	0.21
Geography & Environment	0.05	0.13	0.13	0.10	0.05	0.13	0.13	0.05	0.13
Health	0.06	0.02	0.01	0.04	0.06	0.02	0.01	0.06	0.02
Political Science	0.05	0.11	0.03	0.02	0.05	0.11	0.03	0.05	0.07
RP	0.18	0.15	0.37	0.30	0.18	0.15	0.37	0.18	0.25
SMJ	0.33	0.13	0.12	0.20	0.33	0.16	0.12	0.33	0.14
Outsider	0.55	0.50	0.29	0.46	0.55	0.48	0.29	0.55	0.45

* denotes the groups which are integrated at the subsequent level.

Appendix D. Keywords in the core literature

Keyword	Share of publications with the keyword, per cent
Innovation	50.77
Economic	48.46
Technology	36.15
Sector/Industry	29.23
Organization	21.54
Firm	20.77
R&D	14.62
Knowledge	13.85
Macro	13.85
Management	12.31
Spill-over	8.46
System	8.46
Science	8.46
Patents	5.38