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The evolution of science policy and innovation studies

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ABSTRACT

This article examines the origins and evolution of the field of science policy and innovation studies (SPIS). Like other studies in this Special Issue, it seeks to systematically identify the key intellectual developments in the field over the last 50 years by analysing the publications that have been highly cited by other researchers. The analysis reveals how the emerging field of SPIS drew upon a growing range of disciplines in the late 1950s and 1960s, and how the relationship with these disciplines evolved over time. Around the mid-1980s, substantial parts of SPIS started to coalesce into a more coherent field centred on the adoption of an evolutionary (or neo-Schumpeterian) economics framework, an interactive model of the innovation process, and (a little later) the concept of 'systems of innovation' and the resource-based view of the firm. The article concludes with a discussion of whether SPIS is perhaps in the early stages of becoming a discipline.

1. Introduction

The field of science policy and innovation studies (SPIS) is now around 50 years old. From humble beginnings involving just a few researchers in the late 1950s, it has grown to become a significant field involving several thousand researchers (Fagerberg and Verspagen, 2009). Some of its contributions have had a major impact on neighbouring disciplines as well as within the field itself. It is therefore timely to look back and analyse what has been achieved.

The overall aim of this exploratory study is to systematically identify the most influential intellectual developments in the field of SPIS and analyse how these have evolved over time with a view to addressing the following research questions. First, what are the intellectual origins of the field and the disciplines upon which it has drawn, and how have these relationships evolved over time? Secondly, is the field beginning to coalesce around a common conceptual framework and set of analytical tools? Thirdly, are there potential links with other fields that are either absent or only weakly developed, and, if so, why? Fourthly, what is the geographical breakdown of important SPIS advances, in particular with regard to the relative contributions of North America and Europe, and what might explain that breakdown? Finally, is SPIS perhaps in the early stages of becoming a discipline?

To address these questions, however, we first need to construct a systematic overview of the field. Such an overview may be useful for research students or 'newcomers' to the field, and to academic faculty developing lecture courses and reading lists. It may also offer SPIS 'insiders' a more comprehensive 'map' of field as a whole, especially of areas seen as less directly linked (e.g. work on medical or health innovations, or on organisational and other non-technological forms of innovation). More specifically, it might enable researchers to identify 'gaps' in the field, or potential synergies between previously rather separate bodies of research, and hence offer guidance as to where they might most fruitfully concentrate their efforts. Lastly, the article may provide some insights as to how ideas originate and come to exert a major influence and how research fields develop. (However, detailed analysis of the factors affecting the impact of influential publications is left to future research.)

In what follows, Section 2 first defines the scope of the field of 'science policy and innovation studies', while Section 3 reviews the literature on previous attempts to map or review the field, including similar studies in neighbouring social science fields. Section 4 sets out the methodology employed to identify the SPIS contributions that have had most impact on the academic community. Section 5 then analyses the origins and early development of the field, as social scientists from a number of disciplines began to become interested in science, technology and innovation, while Section 6 focuses on the most influential contributions from the 1980s

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onwards, showing how SPIS by then was becoming a more coherent field centred on the adoption of an evolutionary economics framework, an interactive model of the innovation process, the concept of 'systems of innovation', and the resource-based view of the firm. Lastly, Section 7 discusses the broad findings with regard to the original research questions, assessing how far SPIS has coalesced as a field and whether there are any 'missing links' with neighbouring fields that, if developed, might further strengthen the field. We consider the large and growing dominance of US authors and identify possible reasons for this. Finally, we explore the question of whether SPIS is perhaps in the early stages of becoming a discipline.

2. Definition and scope of field of 'science policy and innovation studies'

Before proceeding further, we need to specify exactly the focus of analysis in this review. One problem is that different people have labelled the various research activities on which we are focussing in different ways. Another is that those labels have changed over time. For example, in the 1960s, a common designation was 'science policy' (or 'research policy'), while in the 1970s and 80s various combinations of science, technology and innovation (and variations on these such as engineering and R&D) were employed. By the 1990s, however, the preference of many was to use 'innovation' as the generic noun for characterising the field, with this term being assumed to include aspects of 'science' and 'technology'. Over time, it likewise became apparent that the term 'policy' was too narrow and misleading, with many researchers focusing more on the management or economics of R&D, technology or innovation. Rather than coming up with a label involving some combination of 'policy', 'management' and 'economics', many have therefore settled on the simple, succinct label of 'innovation studies'. However, I have opted for the fuller, if slightly clumsier, label of 'science policy and innovation studies' (or SPIS) to reflect the earlier history.

How might this field be defined? It is difficult to give an exact definition of an emergent field like SPIS (Fagerberg et al., 2012). A natural starting point may the definition provided by the leading journal in this area (ibid.; Fagerberg and Verspagen, 2009), namely *Research Policy*. Consequently, the definition of SPIS used here is studies "devoted to analyzing, understanding and effectively responding to the economic, policy, management, organizational, environmental and other challenges posed by innovation, technology, R&D and science. This includes a number of related activities concerned with the creation of knowledge (through research), the diffusion and acquisition of knowledge (e.g. through organizational learning), and its exploitation in the form of new or improved products, processes or services."[1]

This definition of 'science policy and innovation studies' is quite broad but the essential element is that the subject matter, characterised by the terms innovation, technology, R&D and science, is studied using a range of social science disciplines (economics and economic history, policy studies, management science, organisational studies, sociology, etc.). Included within it are the science, technology and innovation-related components of the following:

- economics—including the economics of science, research or R&D, of technology, and of innovation; also included is (neo-) Schumpeterian economics (with its central focus on the role of innovation), a considerable part of evolutionary economics (likewise), and a significant component of endogenous growth theory (which also gives particular prominence to technology and innovation);
- economic history and business history—the history of technology and innovation, and the relationship of technology/innovation to industrial development and economic growth;
- policy—this includes the older terms 'science policy' and 'research policy', 'technology policy', and more recently 'innovation policy';
- management—R&D management, industrial R&D, new product development, technology and innovation management, much of entrepreneurship and of knowledge management, and those parts of strategic management relating to R&D, technology and innovation;
- organisational studies—including organisational innovation, and a large part of the resource-based view of the firm (e.g. focusing on routines, core competences, dynamic capabilities, absorptive capacity), along with certain aspects of organisational learning;
- sociology of innovation—especially sociological work on the diffusion of innovations; however, most sociology of science and technology has been excluded, since this comes more under 'science and technology studies' (see below).

Excluded under the above definition of SPIS are the following areas (which tend to have their own research communities and separate journals):

- most sociology of science and technology, along with much of the history and philosophy of science—these form part of 'science and technology studies', a largely separate field and research community (Bhupatiraju et al., 2012; Martin et al., 2012);
- most scientometrics or bibliometrics research—again, this is a rather distinct research community from SPIS (ibid.), so it has been excluded here except where the research is clearly linked to 'science policy', 'technology management', etc.;
- most energy and environment policy research, except where technology or innovation is a key element (e.g. recent work relating innovation and sustainability);
- most literature on economic development, again except where technology or innovation is again a key element (e.g. 'technology transfer' or 'appropriate technology').

There are also certain areas that, although not specifically excluded, may be only partially covered (perhaps because the search revealed few highly cited publications for these). They include 'technology assessment', 'engineering management', public sector innovations, work on implementation of new technology (e.g. IT), some literature on innovation diffusion (e.g. by marketing researchers), and contributions by psychologists (e.g. on the relationship between organisations and innovation, or on creativity in research and innovation).

Any attempt at a definition of the field of science policy and innovation studies may seem somewhat arbitrary and subjective; in the world of social science, there are no simple, unambiguous boundaries differentiating one set of research activities from another. However, the above specifies exactly what has (and has not) been included here and why.

3. Literature review

Next, let us consider the relationship of this study to previous efforts to review the field. There have been several such attempts in textbooks or handbooks and in review articles. Highly cited examples include Freeman [1974 & 1982], Freeman and Soete [1997], Nelson and Winter [1977], Dosi [1988], Griliches [1990] and Brown

[1] See http://www.elsevier.com/wps/find/journaldescription.cws_home/505598/description (accessed October 2011).

and Eisenhardt [1995].[2] Particularly comprehensive reviews are those by Fagerberg (2004) in *The Oxford Handbook of Innovation* and Cohen (2010) in the *Handbook of the Economics of Innovation*. However, all these reviews were conducted on an ultimately rather subjective basis of what the author(s) judge to have been the most significant contributions. In addition, most such efforts focused on a narrower set of research activities (e.g. the 'economics of innovation', or the 'management of technology') than the field of SPIS as defined here.

A few authors have attempted a more quantitative approach to identifying important contributions. For example, Cottrill et al. (1989) carried out a co-citation analysis of the literature on 'innovation diffusion' and on 'technology transfer', showing there was little interaction between these two research streams. However, their focus was much narrower than the study reported here. A few years later, Granstrand (1994) produced an overview of the economics of technology, but he focused on *economic* contributions and (primarily) on books that had made important contributions (as opposed to journal articles). Moreover, this analysis is now over 15 years old, so it is worth looking at what has since changed.

More recently, Verspagen and Werker (2003, 2004), and Fagerberg and Verspagen (2009) analysed the development of innovation studies. However, they used the results from a survey of researchers rather than bibliometric analysis. One bibliometric study was that by Dachs et al. (2001) but their focus was evolutionary economics, while that of Meyer (2001) was even narrower, just looking at citations to Nelson and Winter's [1982] book, *An Evolutionary Theory of Economic Change*. Another bibliometric study was by Meyer et al. (2004), but that, too, had a rather specific focus ('The scientometric world of Keith Pavitt').

The approach adopted here centres on highly cited publications (HCPs). Apart from the study by Fagerberg et al. (this issue) analysing handbook chapters, there have apparently been no such prior exercises specifically focusing on SPIS. The closest is perhaps the analysis of the narrower area of technology management by Pilkington and Teichert (2006). They identified the 30 publications most highly cited by articles in a single journal (*Technovation*) so the citation figures involved are relatively small. This raises questions about the significance of the findings, although in fairness most of the highly cited publications they identify also appear in the list generated here. More recently, Silva and Teixeira (2008) have conducted a similar study of the publications most highly cited in *Structural Change and Economic Dynamics*, where there is again a significant overlap with the field of SPIS.

Among the social sciences, the nearest equivalent study is in economics, where Kim et al. (2006) identified 146 articles in 41 leading economics journals published between 1970 and 2005 that earned 500 or more citations. Their list includes some articles identified here as key contributions to SPIS, including David [1985], Arthur [1989], Cohen and Levinthal [1989], Romer [1990], and Jaffe et al. [1993]. However, they made no attempt to identify highly cited books (or book chapters). In addition, there have been studies of economics-related subfields such as finance (Alexander and Mabry, 1994; Arnold et al., 2003).

With regard to other 'neighbouring' disciplines on which SPIS draws, a literature search has yet to locate any quantitative attempt to identify key contributions in business or management science as a whole. However, there have been analyses of various sub-fields, including management information systems (MIS) (Culnan, 1986), decision support systems research (Eom and Lee, 1993; Eom, 1996), small enterprise research (Ratnatunga and Romano, 1997), advertising (Pasadeos et al., 1998), production and operations management (Pilkington and Liston-Heyes, 1999), knowledge management (Ponzi, 2002), strategic management (Ramos-Rodriguez and Ruiz-Navarro, 2004), international management (Acedo and Casillas, 2005), entrepreneurship (Cornelius et al., 2006), operations management (Pilkington and Fitzgerald, 2006; Pilkington and Meredith, 2009), and family business research (Casillas and Acedo, 2007).

To sum up, although there have been numerous reviews of key developments in science policy and innovation studies, these have either been based on the subjective judgements of the authors or have focused on a subcomponent of the broader field of SPIS. In particular, aside from the work based on analysing references in handbooks (Fagerberg et al., 2012; Landström et al., 2012; Martin et al., 2012), there has apparently been no attempt to identify the most influential contributions on the basis of highly cited publications, the approach adopted by Kim et al. (2006) with regard to economics and in several of the reviews of different management sub-fields described above. In most of the latter, however, only citations from a few selected journals were included so the citation counts were often rather small, while in Kim et al. (2006) the focus was exclusively on journal articles. Consequently, the work reported here would appear to be one of the first large-scale quantitative studies to treat books on an equal basis with journal articles. As we shall see later, to disregard books in any analysis of the high-impact contributions from SPIS would be a serious omission.

4. Methodology for identifying the main academic contributions to SPIS

In what follows, we focus on the main 'academic' contributions to the field of SPIS. One might ask why we do not instead attempt to identify the most important contributions to policy or management practice, given that many would see the ultimate aim of field as being to contribute to more effective policy or management. Certainly, there have been numerous instances of impact on policy or management practice,[3] but there is unfortunately no obvious objective measure of such impact. In principle, one could perhaps examine policy or strategy documents for evidence of impact by SPIS publications, but such an approach would entail a huge amount of effort and still be ultimately rather subjective. Furthermore, much impact on practice may never show up in written documents, especially impact on management.

The main academic contributions to SPIS have been identified though a systematic search for highly cited publications. The assumption here is that the most academically influential publications in a given field will tend to be those that have been most highly cited.[4] Over the last 40 years or so, various studies have confirmed the correlation between citations and impact (e.g. Bayer and Folger, 1966; Cole and Cole, 1973; Koenig, 1983; Martin and Irvine, 1983; Moed et al., 1985; Culnan, 1986). Nevertheless, it is essential to bear in mind various caveats with this approach, caveats that become increasingly important as one moves the focus of bibliometric analysis from science to social science. These include an English-language bias (non-English publications are much less

[2] Highly cited publications listed in Table 1 are indicated using [], while 'outside' contributions to SPIS listed in Table 2 are denoted by { }. All other references are listed in the bibliography at the end of the paper, these being shown using ().

[3] For example, the 'systems of innovation' concept has undoubtedly had a significant impact on policy makers (Lundvall, 2007), while research on the nature of the innovation process and on factors affecting the success and failure of innovation has been particularly influential in industry.

[4] As Kim et al. (2006, p. 189) note: "Although the number of academic citations accumulated by a published research paper is an imperfect measure of the quality or influence of that paper, citation counts do have certain virtues: they are not subjective; they are widely used in studies of academic productivity; and they are reasonably comprehensive across subject areas within economics" (and the same is true in SPIS).

likely to be cited by researchers), a North American journal bias (proportionately more US social science journals are scanned by the *Citation Index*), and the fact that until recently only journals[5] were scanned by the *Citation Index*/Web of Science (i.e. while citations in these journals *to* books are counted, citations *from* books are not). Moreover, self-citations have not been excluded in this analysis; however, they represent a trivially small percentage of the total for HCPs with more than 300 citations (the threshold adopted here), and they are also present to some extent in virtually all cases so the (very small) effect partly cancels out in any comparisons. Another problem is that, after a time, a particular HCP may no longer be explicitly cited as the reference source, citing authors instead using some short-hand expression (e.g. 'Schumpeter', 'Nelson and Winter') rather than the full bibliographic reference; however, to get to this stage of 'obliteration by incorporation' (Merton, 1968, pp. 25–38; Garfield, 1975), the relevant work will almost certainly first have to have been very highly cited by earlier authors.

Perhaps a more fundamental criticism of the methodology, however, is that it focuses only on a relatively few highly cited publications, ignoring the great mass of publications falling below the threshold level. Although the latter may have made smaller or more incremental advances, collectively they may have contributed more to the development of the field than the small number of high impact publications (often referred to as 'the Ortega hypothesis'). This has been the subject of much debate among sociologists of science and bibliometric researchers (e.g. Cole and Cole, 1972; MacRoberts and MacRoberts, 1987). It is not our task to attempt to resolve this debate. However, the starting point of this Special Issue is that established fields tend to be defined in terms of a fairly small number of core contributions, and the task of this paper, like others in the collection, is to try to identify these.

In most previous studies to identify high-impact publications, researchers have started with a limited set of core journals that are taken as defining the field in question, and either searched these for the most highly cited articles (e.g. Kim et al., 2006) or scanned the references in the journals to establish which publications have been most highly cited (the approach generally adopted in the studies of different subfields of management described above). The limitation of the first approach is that it excludes highly cited books and book chapters. The problem with the second approach is that, as Gallivan and Benbunan-Fich (2007) and Whitley and Galliers (2007) have shown, if one starts with a different set of core journals, one can end up with a different list of HCPs. Hence, a more open-ended approach is adopted here.

There are two starting points for this analysis: (i) a list of over 600 leading SPIS authors and another 500 important contributors to the SPIS field who work in adjacent fields, both lists being constructed via a 'snow-ball' technique;[6] and (ii) a comprehensive list of 90 journals in which SPIS researchers have published the great majority of their articles.[7] These authors and journals have been systematically searched for relevant publications using key words such as 'innovation'; 'invention'; 'technology'; 'technical change'; 'science'; 'research'; 'development'; 'R&D'; 'evolutionary economics'; '(neo-)Schumpeterian economics'; 'entrepreneurship' and 'new product development'; to identify those where the titles[8] suggest they fall within SPIS. At this preliminary stage; Google Scholar was useful in drawing up a short-list list of candidate HCPs for more careful scanning in the *Citation Index*; it being an especially flexible search-tool for books (one can only search in the *Citation Index* if one already knows the author and title of a book). Those publications were then scanned in the *Citation Index*/Web of Science (WoS) to identify all those with 300 or more citations.

The citation-counting procedure adopted here is similar to that of Kim et al. (2006). For journal articles, one starts with the automated WoS citation count (but using a lower citation threshold), and then carries out a manual count (using the 'Cited Reference Search' facility in the WoS) to add in references to the same publication but in a slightly different form (e.g. where citing authors omit a second or subsequent initial, or give a page number for a specific part of the text later in the publication rather than the first page, or where there is a typo in the volume or page number, or where the references have not been unified by the WoS). For books, a similar approach was used, searching on the author's name (with one or more initials) with a truncated version of the book's title (using the character *) and publication date (including one year before and two years after to allow for almost immediate reprinting or publishing in a second city/country, as well as for the inevitable 'mistakes' in the date cited).[9] Because citations are being continuously added to the WoS database, citation totals were calculated as of the end of 2010. Despite the care taken, the citation totals of each HCP should still be regarded as approximate (hence they have been rounded to nearest 5).

Thus far, the search has identified within SPIS just under 100 HCPs with 1000 or more citations[10], approximately 185 with 500 citations, and around 270 with 300 citations. The results are summarised in Table 1 at the end of the paper, while Table 2 lists contributions from outside[11] SPIS which have nevertheless had a major impact on the field. For comparative purposes, it should be noted that Kim et al. (2006) found a total of 146 economics articles with over 500 citations, so the total of around 185 SPIS HCPs with 500 or more citations compares very favourably with the top 150 articles in economics.[12] In other words, although SPIS is a relatively new and still quite small field, its researchers have made a significant number of advances comparable in impact with the best of those from the established discipline of economics. In the next two sections, we analyse these HCPs to see what they reveal about the origins and evolution of the field of SPIS.

[5] In the last few years, certain published conference proceedings have also been scanned for citations and now books are starting to be added.

[6] There were several starting points for this, including lists of key contributors produced in previous reviews and analyses, the editors and advisory editors of journals, the author's own knowledge, and suggestions from colleagues. Identified HCPs (especially review articles) were then scanned to identify other key authors and publications, with the process being iterated until diminishing returns set in.

[7] Both lists are available from the author.

[8] This approach means that a book or journal article where the title contains none of the key words used in this search may have been overlooked, at least initially. However, if its content relates to the SPIS field and if it has been highly cited by other SPIS researchers, then it will most probably have been 'captured' in some other way, for example through scanning the bibliographies of important review articles.

[9] But where separate editions of books were published three or more years apart, they were treated as different publications on the assumption that the latter will often contain new or substantially updated material.

[10] As noted in the concluding discussion, there is an important methodological issue to be aware of here. For the most cited HCPs (e.g. those with citation totals of 1000 or more), many of those citations may come from authors *outside* the SPIS field. In such cases, the high citation total reflects the impact of that particular publication in other social sciences. (If one were solely concerned with the impact of publications *within* the SPIS field, one could try looking at just citations from a few specialist journals central to the SPIS field.)

[11] See the footnote to Table 2.

[12] However, Kim et al. (2006) only included articles published over the period 1970–2005, whereas a somewhat longer period has been examined here, and books have been included as well as articles.

Table 1
High-impact SPIS contributions.[a]

	Citations
'Pre-history'	
JA Schumpeter (1911/12), Theorie der wirtschaftlichen Entwicklung	500
WF Ogburn (1922 + later eds), Social Change with Respect to Culture & Original Nature	520
JA Schumpeter (1934), Theory of Economic Development	2470
JA Schumpeter (1939), Business Cycles: Theoretical, Historical & Statistical Analysis	1305
JA Schumpeter (1942), Capitalism, Socialism and Democracy	2395
V Bush (1945), Science the Endless Frontier	560
JA Schumpeter (1947), Capitalism, Socialism and Democracy (2nd ed)	430
JA Schumpeter (1950), Capitalism, Socialism and Democracy (3rd ed)	1410
HG Barnett (1953), Innovation: The Basis of Cultural Change	370
The pioneers	
J Coleman et al. (1957), 'Diffusion of an innovation among physicians', *Sociometry*	310
Z Griliches (1957), 'Hybrid corn . . . economics of tech change', *Econometrica*	840
RM Solow (1957), 'Tech change & aggregate production function', *Rev Ec & Stat's*	1790
J Woodward (1958), Management and Technology	300
RR Nelson (1959), 'The simple economics of basic research', *J Pol Econ*	460
T Burns, GM Stalker (1961), *The Management of Innovation*	2555
E Mansfield (1961), 'Technical change & the rate of imitation', *Econometrica*	585
KJ Arrow (1962a), 'Econ welfare & alloc of resources for invention' in *Rate & Direction*	1460
KJ Arrow (1962b), 'Economic implications of learning by doing', *Rev Econ Stat's*	1605
H.J. Habakkuk (1962), American and British Technology in the Nineteenth Century	325
EM Rogers (1962), Diffusion of Innovations	1685
DJD Price (1963), Little Science, Big Science	1475
J Woodward (1965), Industrial Organization: Theory and Practice	1420
FM Scherer (1965), 'Firm size . . . & output of patented innovations', *Am Econ Rev*	320
JS Coleman et al. (1966), Medical Innovation: A Diffusion Study	815
RR Nelson, ES Phelps (1966), 'Invest't in humans, tech diffusion . . .', *Am Econ Rev*	400
DC Pelz, FM Andrews (1966), Scientists in Organizations: Productive Climates for R&D	610
J Schmookler (1966), Invention and Economic Growth	880
E Mansfield (1968a), The Economics of Technological Change	395
E Mansfield (1968b), Industrial Research and Technological Innovation	655
FM Bass (1969), 'New product growth model for consumer durables', *Mngt Sc*	1150
DS Landes (1969), The Unbound Prometheus: Tech Change & Econ Devlpt	830
JL Walker (1969), 'Diffusion of innovations among American states', *Am Pol Sc Rev*	650
FM Scherer (1970), Industrial Market Structure & Economic Performance	930
EM Rogers, FF Shoemaker (1971), *Communication of Innovations*	1820
G Zaltman et al. (1973), Innovations & Organizations	890
C Freeman (1974), Economics of Industrial Innovation	305
R Rothwell et al. (1974), 'Project SAPPHO Phase II', *Res Policy*	330
ER Berndt, DO Wood (1975), 'Tech'y, prices & derived demand for energy', *Rev Ec Stat*	520
PA David (1975), Technical Choice, Innovation and Economic Growth	330
JM Utterback, WJ Abernathy (1975), 'Dynamic model of innovation', *Omega*	505
GW Downs, LB Mohr (1976), 'Conceptual issues in study of innov'n', *Admin Sc Q*	300
N Rosenberg (1976), Perspectives on Technology	700
JA Schumpeter (1976), Capitalism, Socialism and Democracy (6th ed)	500
TJ Allen (1977), Managing the Flow of Technology	1105
RR Nelson, SG Winter (1977), 'In search of a useful theory of innovation', *Res Policy*	480
ML Tushman (1977), 'Special boundary roles in innovation process', *Admin Sc Q*	330
WJ Abernathy (1978), The Productivity Dilemma: Roadblock to Innovation	315
WJ Abernathy, JM Utterback (1978), 'Patterns of ind innov'n', *Tech'y Rev*	640
RG Cooper (1979), 'Dimensions of industrial new product success & failure', *J Mktg*	345
Z Griliches (1979), 'Assessing contribution of R&D to productivity growth', *Bell J Econ*	640
GC Loury (1979), 'Market structure and innovation', *Q J Econ*	320
The field matures	
RH Hayes, WJ Abernathy (1980), 'Managing our way to econ decline', *Harv Bus Rev*	610
FM Scherer (1980), Industrial Market Structure & Economic Performance (2nd ed.)	1970
JR Kimberly, MJ Evanisko (1981), 'Organizational innovation . . .', *Acad Mngt J*	475
G Dosi (1982), 'Technological paradigms and trajectories', *Res Policy*	1045
C Freeman (1982), Economics of Industrial Innovation (2nd ed)	565
C Freeman et al. (1982), Unemployment & Tech Innov'n: long waves & econ develpt	305
M Jahoda (1982), Employment and Unemployment	450
MI Kamien, NL Schwartz (1982), *Market Structure & Innovation*	545
RR Nelson & SG Winter (1982), An Evolutionary Theory of Economic Change	5500
N Rosenberg (1982), Inside the Black Box: Technology & Economics	1000
LG Tornatzky, KJ Klein (1982), 'Innov'n characteristics . . .', *IEEE Trans Eng Mngt*	425
RM Kanter (1983), The Change Masters: Innovation & Entrepreneurship. . .	1245
EM Rogers (1983), *Diffusion of Innovations* (3rd ed.)	3300
JE Ettlie et al. (1984), 'Org strategy . . . for radical vs incremental innov'n', *Mngt Sc*	310
Z Griliches (1984), R&D, Patents and Productivity	385
J Hausman et al. (1984), 'Econ models . . . patents-R&D relationship', *Econometrica*	805
RH Hayes, SC Wheelwright (1984), *Restoring Our Competitive Edge*	960
DA Hounshell (1984), From the American System to Mass Production	410
K Pavitt (1984), 'Sectoral patterns of tech change', *Res Policy*	780
WJ Abernathy, KB Clark (1985), 'Innov'n: mapping winds of creative destr'n', *Res Policy*	435
PA David (1985), 'Clio and economics of QWERTY', *Am Econ Rev*	1030

Table 1 (*Continued*)

	Citations
PF Drucker (1985), Innovation and Entrepreneurship	625
J Farrell, G Saloner (1985), 'Standardization, compatibility & innovation', *RAND J Ec*	550
M Abramovitz (1986), 'Catching up, forging ahead & falling behind', *J Econ Hist*	505
SR Barley (1986), 'Technology as an occasion for structuring', *Admin Sc Q*	575
RD Dewar, JE Dutton (1986), 'Adoption of radical & incremental innov'ns', *Mngt Sc*	375
J Farrell, G Saloner (1986), 'Installed base & compatibility – innov'n . . .', *Am Ec Rev*	415
RN Foster (1986), Innovation: The Attacker's Advantage	440
AB Jaffe (1986), 'Tech opportunity & spillovers of R&D', *Am Ec Rev*	595
ML Katz, C Shapiro (1986), 'Technology adoption . . . network externalities', *J Pol Econ*	540
SJ Kline, N Rosenberg (1986), 'Overview of innovation', in *Positive Sum Strategy*	475
DJ Teece (1986), 'Profiting from technological innovation', *Res Policy*	1410
ML Tushman, P Anderson (1986), 'Tech discontinuities & org envts', *Admin Sc Q*	1200
AH Van de Ven (1986), 'Central problems in management of innovation . . .', *Mngt Sc*	515
E von Hippel (1986), 'Lead users – source of novel product concepts', *Mngt Sc*	460
RS Burt (1987), 'Social contagion & innovation . . .', *Am J Sociology*	505
RG Cooper, EJ Kleinschmidt (1987), 'New products – what separates winners', *JPIM*	320
C Freeman (1987), Technol Policy & Econ Perf: Lessons from Japan	545
RC Levin et al. (1987), 'Appropriating the returns from ind R&D', *Brookings Papers*	785
SG Winter (1987), 'Knowledge & competence as strat assets', *Competitive Challenge*	560
ZJ Acs, DB Audretsch (1988), 'Innovation in small and large firms', *Am Econ Rev*	325
G Basalla (1988), The Evolution of Technology	305
G Dosi (1988), 'Sources & microeconomic effects of innovation', *J Econ Lit*	810
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WM Cohen, DA Levinthal (1989), 'Innov'n & learning: 2 faces of R&D', *Econ J*	1095
FD Davis et al. (1989), 'User acceptance of computer technology', *Mngt Sc*	1865
AB Jaffe (1989), 'Real effects of academic research', *Am Econ Rev*	505
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JF Reinganum (1989), 'Timing of innovation: R&D & innov'n', in *Handbook of Ind Org*	300
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P Anderson, ML Tushman (1990), 'Tech discontinuities & dom designs', *Admin Sc Q*	485
WM Cohen, DA Levinthal (1990), 'Absorptive capacity', *Admin Sc Q*	3625
RB Cooper, RW Zmud (1990), 'IT implementation res: tech diffusion approach', *Mngt Sc*	460
KM Eisenhardt, CB Schoonhoven (1990), 'Org growth: strategy, env't'. . ., *Adm Sc Q*	400
Z Griliches (1990), 'Patent statistics as economic indicators', *J Econ Lit*	840
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V Mahajan et al. (1990), 'New product diffusion models in marketing – review', *J Mktg*	465
P Milgrom, J Roberts (1990), 'Econ's of mod mfg: tech'y, strategy & org'n', *Am Ec Rev*	560
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FM Scherer (1990), Industrial Market Structure & Economic Performance (3rd ed.)	1185
WG Vincenti (1990), What Engineers Know and How They Know It	310
JP Womack et al. (1990), The Machine that Changed the World	2200
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D Dougherty (1992), 'Interpretive barriers to successful product innov'n . . .', *Org Sc*	525
Z Griliches (1992), 'Search for R&D spillovers', *Scandinavian J of Economics*	405
B Kogut, U Zander (1992), 'Knowledge of firm . . . & replic'n of technology', *Org Sc*	1695
D Leonard-Barton (1992), 'Core capabilities and core rigidities', *Strat Mngt J*	895
BÅ Lundvall (1992), National Systems of Innovation	1375
JB Quinn (1992), Intelligent Enterprise: a Knowledge & Service Based Paradigm	535
SC Wheelwright, KB Clark (1992), *Revolutionizing Product Development*	725
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H Hagedoorn (1993), 'Understanding rationale of strategic tech'y partnering', *Str Mngt J*	430
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RM Henderson, I Cockburn (1994), 'Measuring competence . . . firm effects', *Str Mngt J*	520
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Table 1 (*Continued*)

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DB Audretsch (1995), Innovation and Industry Evolution	345
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DT Coe, E Helpman (1995), 'International R&D spillovers', *Europ Ec Rev*	610
K Eisenhardt, BN Tabrizi (1995), 'Accelerating adaptive processes', *Admin Sc Q*	520
AB Jaffe et al. (1995), 'Environmental regulation & competitiveness of US mfg', *J Ec Lit*	360
CI Jones (1995), 'R&D-based models of economic growth', *J Pol Economy*	445
D Leonard-Barton (1995), *Wellsprings of Knowledge*	860
RR Nelson (1995), 'Recent evol'y theorizing about econ change', *J Econ Lit*	305
I Nonaka, H Takeuchi (1995), *The Knowledge Creating Company*	4335
EM Rogers (1995), *Diffusion of Innovations* (4th ed.)	4620
U Zander, B Kogut (1995), 'Knowledge & speed of transfer & imitation . . .', *Org Sc*	545
DB Audretsch, MP Feldman (1996), 'R&D spillovers', *Amer Econ Rev*	705
CM Christensen, JL Bower (1996), 'Customer power, strategic invest't. . .', *Strat Mngt J*	330
B Kogut, U Zander (1996), 'What firms do?', *Org Sc*	490
DC Mowery et al. (1996), 'Strategic alliances & interfirm transfers', *Strat Mngt J*	510
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R Sanchez, JT Mahoney (1996), 'Modularity, flexibility & knowledge mngt', *Str Mngt J*	355
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CM Christensen (1997), *The Innovator's Dilemma*	1390
C Freeman, L Soete (1997), *The Economics of Industrial Innovation* (3rd ed.)	380
A Griffin (1997), 'PDMA research on new product devlpt', *JPIM*	300
A Hargadon, RI Sutton (1997), 'Technology brokering & innovation . . .', *Ad Sc Q*	300
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JS Brown, P Duguid (2000), *The Social Life of Information*	630
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KM Eisenhardt, JA Martin (2000), 'Dynamic capabilities: what are they?', *Strat Mngt J*	1035
H Etzkowitz, L Leydesdorff (2000), 'From national systems . . . to Triple Helix', *Res Pol*	355
AK Gupta, V Govindarajan (2000), 'Knowledge flows within MNCs', *Strat Mngt J*	420
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S Shane, S Venkatamaran (2000), 'Promise of entrepreneurship as field of res', *Acad Mngt Rev*	630
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JA Dimasi et al. (2003), 'The price of innovation', *J Health Econ*	780
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[a] High-impact publications with ≥300 citations in the *Web of Science – Citation Index* in the period up to the end of 2010 from all ISI journals (and published conference proceedings from 1990) in *SCI*, *SSCI* & *A&HCI*. Only abbreviated titles and references are given here to save space. These publications are cited in the text using [].

5. Origins and early development of the field

5.1. Pre-history

Although the SPIS field can be said to have begun to emerge just over 50 years ago in the late 1950s, there were important 'pre-cursor' publications before that. In this 'pre-history' phase, the central figure is undoubtedly Schumpeter, with two books [1934 & 1942] cited well over 2000 times and a third [1939] 1300 times (see Table 1).[13] He was one of the few economists in the first half of the 20th century to recognise the importance of innovation to economic development, along with the role of entrepreneurs and later of organised industrial R&D in developing innovations. Other significant contributions in the early years came from sociologists and anthropologists studying the effects of technological innovations on society, such as Ogburn's [1922] theory of social change, in which technology is seen as a primary source of progress but one which can give rise to 'cultural lags', and Barnett's [1953] anthropological study of the process of innovation in different ethnic groupings and its profound effects in terms of cultural change.[14] In

[13] Godin (2011, p. 28) argues that the economic historian "[WR] Maclaurin is the real 'father' of technological innovation studies, not Schumpeter". However, his most cited work (Maclaurin, 1949) had only received around 90 citations by 2010, well below the citation threshold used here.

[14] Early work by sociologists on the diffusion of new agricultural technologies was also quite prominent but none if it apparently earned over 300 citations, the threshold adopted here.

Table 2
Other work from 'outside' SPIS that has had an influence on the field.[a]

	Citations
F List (1841 + later eds), National System of Political Economy	325
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RH Coase (1937), 'The nature of the firm', *Economica*	3655
E Garfield (1955), 'Citation indexes for science', *Science*	485
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SB Linder (1961), Essay on Trade and Transformation	480
AD Chandler (1962), *Strategy and Structure*	2840
A Gerschenkron (1962), Economic Backwardness in Historical Perspective	1165
TS Kuhn (1962), The Structure of Scientific Revolutions	8350
F Machlup (1962), The Production & Distribution of Knowledge in the United States	635
RM Cyert, JG March (1963), A Behavioral Theory of the Firm	4870
M Polanyi (1966), *The Tacit Dimension*	2720
R Vernon (1966), 'Internat invest't & internat trade in the product cycle', *Q J Econ*	1575
PR Lawrence, JW Lorsch (1967), *Organization and Environment*	3500
JD Thompson (1967), Organizations in Action	5530
JM Ziman (1968), *Public Knowledge*	535
TS Kuhn (1970), The Structure of Scientific Revolutions (2nd ed)	11010
R Vernon (1971), Sovereignty at Bay: the Multinational Spread of US Enterprises	790
RK Merton (1973), *Sociology of Science*	1820
OE Williamson (1975), *Markets and Hierarchies*	6425
MC Jensen, WH Meckling (1976), 'Theory of the firm', *J Financial Economics*	5875
AD Chandler (1977), *The Visible Hand*	2565
C Argyris, DA Schön (1978), *Organizational Learning*	2410
E Garfield (1979), *Citation Indexing*	925
OE Williamson (1979), 'Transaction-cost economics', *J of Law & Economics*	1460
ME Porter (1980), *Competitive Strategy*	5410
PJ DiMaggio, WW Powell (1983), 'The iron cage revisited', *Amer Soc Rev*	3895
MJ Piore, CF Sabel (1984), *The Second Industrial Divide*	2820
B Wernerfelt (1984), 'A resource-based view of the firm', *Strategic Management J*	2365
M Granovetter (1985), 'Econ action & social structure', *Amer J of Sociology*	4340
ME Porter (1985), Competitive Advantage	4070
OE Williamson (1985), The Economic Institutions of Capitalism	6405
M Callon (1986), 'Some elements of a sociology of transition', in *Power, Action, Belief*	820
M Callon et al. (1986), Mapping the Dynamics of Science and Technology	575
PM Romer (1986), 'Increasing returns & long-run growth', *J Pol Economy*	2480
WE Bijker et al. (1987), The Social Construction of Technological Systems	890
B Levitt, JG March (1988), 'Organizational learning', *Ann Rev Sociology*	1360
RE Lucas (1988), 'On the mechanisms of econ devlpt', *J of Monetary Economics*	2785
AD Chandler (1990), Scale and Scope: the Dynamics of Industrial Capitalism	1180
DC North (1990), Institutions, Institutional Change & Econ Performance	4585
ME Porter (1990), The Competitive Advantage of Nations	4075
CK Prahalad, G Hamel (1990), 'The core competence of the corp'n', *Harv Bus Rev*	2660
PM Senge (1990), The Fifth Discipline . . . the Learning Organization	4425
J Barney (1991), 'Firm resources & sustained comparative advantage', *J of Mngt*	4415
KR Conner (1991), 'Historical comparison of resource-based theory . . .', *J Mngt*	530
RM Grant (1991), 'Resource-based theory of competitive advantage', *Calif Mngt Rev*	950
G Hamel (1991), 'Compet'n for competence & inter-partner learning', *Strat Mngt J*	850
GP Huber (1991), 'Organiz'nal learning: contributing processes & literatures', *Org Sc*	1330
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RM Grant (1996), 'Towards a knowledge-based theory of the firm', *Strat Mngt J*	1440
TS Kuhn (1996), The Structure of Scientific Revolutions (3rd ed)	895
P Aghion, P Howitt (1998), *Endogenous Growth Theory*	795
T Davenport, L Prusak (1998), Working Knowledge: How Org's Manage . . .	2085
SDN Cook, JS Brown (1999), 'Bridging epistemologies: generative dance . . .', *Org Sc*	335
M Alavi, DE Leidner (2001), 'Knowledge mngt . . . conceptual found'ns', *MIS Qu*	820
RL Priem, JE Butler (2001), 'Is the resource-based view useful?', *Acad Mngt Rev*	315

[a] High impact publications with ≥300 citations in the *Web of Science – Citation Index* – see the footnote to Table 1. The boundary between publications produced 'within' SPIS (in Table 1) and those from 'outside' SPIS (Table 2) is inevitably rather 'fuzzy'. Research specifically focussing on innovation, technology, etc. has been categorised within the former, while work primarily addressing other issues but which has nevertheless been drawn upon extensively by SPIS researchers has been listed under Table 2. The latter references are cited in the text using { }. For publications close to the boundary (e.g. on endogenous growth theory or the resource-based view of the firm), there may well be disagreement as to which side they should be located, although whether they have been listed in Table 1 or Table 2 ultimately makes little difference to the analysis in the text.

addition, one should mention Vannevar Bush's influential [1945] science policy report to the US Government entitled *Science the Endless Frontier*. This set out what he saw as the role of science in relationship to innovation, loosely describing what became known as the 'science-push' linear model of innovation,[15] from which a rationale for government funding of basic research could later be constructed.

5.2. The pioneers

By the second half of the 1950s, a number of social scientists were beginning to work systematically on issues relating to innovation, technology or science. They included researchers from economics (including economic historians), sociology and management, and these were soon joined by others including industrial psychologists, organisation scientists and business historians. By the early 1960s, these different disciplinary 'tribes' were starting to come into contact with one another and to realise that they shared a common interest, even if their conceptual and methodological approaches were very different.

5.2.1. Economics

One of the most highly cited economists from the early years was Solow {1956}, who set out what became the accepted neo-classical growth model. In this, technology was treated as exogenous[16] so this paper falls outside the field of SPIS, although it has often been cited critically by SPIS scholars as an example of the failure of neo-classical economics to deal adequately with technology (it is therefore listed in Table 2). In another highly cited article more directly linked to SPIS (hence it appears in Table 1), Solow [1957] highlighted technology as a third factor of production in addition to capital and labour[17] in a paper that was central in the development of growth accounting (and subsequent work by authors such as Kendrick, Denison and Jorgenson). Other leading economists such as Abramovitz, Kuznets and Posner, although not so highly cited, were arguably more important to the future development of SPIS in that they wrote more explicitly about technical change and innovation, and provided a link back to work on technical change by economists in earlier decades (see the review in Hahn and Mathews, 1964).

A central 'building block' of what was to become the field of SPIS was the early work by Griliches [1957] on the economics of technical change and on rates of return to R&D as revealed by his case-study of hybrid corn.[18] Another key contribution was that by Nelson [1959], who, together with Arrow [1962a], set out the economics of research.[19] Starting from the notion of scientific knowledge as a 'public good', they showed how this led to a failure on the part of firms to invest in R&D at the socially optimal level (i.e. a case of 'market failure'), and used this to construct a rationale for government funding of research. These two authors produced other important contributions during this early period. Arrow's [1962b] paper on the economic implications of 'learning by doing' was later to prove very influential in the SPIS community, while Nelson and Phelps [1966] showed that investments in education speed up the process of technological diffusion and thus stimulate economic growth, with more educated managers being quicker to introduce new production techniques.

Among other economists who had begun to focus on technology and innovation was Mansfield, who analysed the relationship between technical change and the rate of imitation [Mansfield, 1961], and later published books on the economics of technological change, and on industrial R&D and technological innovation [Mansfield, 1968a & b]. Another was Schmookler, who had been working on the relationship between technical change and economic growth since the early 1950s. His [1966] book on *Invention and Economic Growth* is often credited with putting forward the 'demand-pull model' of innovation,[20] a model that for the next decade or so was locked in competition with the 'science-push' model mentioned earlier. A third was Scherer, one of the main contributors to the long-running debate on the relationship between innovation and firm size [Scherer, 1965] as well as the author of an important book [Scherer, 1970, with later editions in 1980 and 1990] on industrial market structure and economic performance, which includes an analysis of the relationship between market structure and technological innovation, the topic of subsequent highly cited publications by Loury [1979] and by Kamien and Schwartz [1982].

Prominent early contributions were also made by economic historians. For many of them, a source of inspiration was Gerschenkron's {1962} book on *Economic Backwardness in Historical Perspective*. While at the margins of SPIS (hence it is listed in Table 2), it stressed how backward countries could take advantage of the backlog of technological innovations from more advanced countries, and it stimulated later work on technology and innovation such as David [1975]. Other key contributors were Landes [1969] with his analysis of the role of technological change in the industrial development in Europe over the previous 200 years, and Rosenberg with his [1976] book on *Perspectives on Technology*.

In addition, there are a number of HCPs by economists who, like Solow, were not working 'within' the SPIS field but whose work undoubtedly made a significant contribution to its development.[21] One is Penrose, whose {1959} book, *The Theory of the Growth of the Firm*, was central in the subsequent development of the 'resource-based view' of the firm (discussed later). Another is Machlup {1962}, who had initially focused on patents but had come to realise that these were merely part of a much wider 'knowledge industry' which, by then, accounted for nearly 30% of US GDP; besides helping to found the field of information economics, Machlup provided perhaps the first formulation of what later became known as the 'knowledge economy' (Godin, 2008). A third example is Vernon {1966}, who set out a four-stage model of the product cycle, in which new goods (i.e. innovations) are generally developed first in industrialised countries and then spread to developing countries as the product matures. This product-cycle theory of trade was one of various 'neo-technology' trade theories (put forward to overcome the limitations of neo-classical and neo-endowment trade

[15] As Godin (2006) points out, Bush discussed the links between science and socio-economic development only in very broad terms rather than putting forward a formal 'model', while the origins of the linear model can actually be traced back several decades earlier.

[16] Unlike Kaldor {1957}, who assigned an explicit role to endogenous innovation and technical change in his model of economic growth.

[17] Nelson (1974) points out that Schmookler had arrived at broadly the same conclusions five years before Solow (and on the basis of stronger data), while others might trace the idea back another ten years to work by Tinbergen, but neither of these earlier publications has been particularly highly cited.

[18] 20 years later, Griliches [1979] produced another influential article in which he analysed the difficulties in using a production function approach to estimate the contribution of R&D to productivity growth.

[19] Nelson was part of a group of prominent economists then working at the RAND Corporation on the economics of R&D and technical change, headed by Klein and including Alchian, Arrow, Meckling, Peck and (from 1959) Winter (see Hounshell, 2000), several of whom went on to make contributions to SPIS.

[20] However, Schmookler's main focus was actually on 'invention' (and how changes in market demand influence the resources allocated to inventive activity), not 'innovations' (Mowery and Rosenberg, 1979).

[21] Another HCP on the edge of the SPIS field is Berndt and Wood [1975], who carried out an economic analysis of the relationship between technology, prices and derived demand for energy, one of the few HCPs relating to energy that have been identified in the search reported here.

theories with regard to their treatment of technology and innovation), others including the technology-gap theory[22] and work by Linder {1961}. These were important as they subsequently opened up the way for neo-Schumpeterian and evolutionary views on innovation developed by authors such as Dosi, Freeman, Nelson and Winter. Vernon also wrote an influential book on multinationals {Vernon, 1971} in which, amongst other things, he explored how those corporations respond to the increasing opportunities offered by technological change.

5.2.2. Sociology

As noted above, some of the first to study innovations were sociologists. For instance, Coleman et al. [1957 & 1966] examined the diffusion of a major medical innovation (a new antibiotic) among doctors, explaining the diffusion process in terms of 'social contagion' resulting from informal professional discussions among physicians. However, this research, although it had a significant impact in sociology, has been comparatively little cited within SPIS. By far the most influential contribution to SPIS by a sociologist came from Rogers [1962], in the first of several editions of *Diffusion of Innovations*. Building on work by rural sociologists and others, Rogers showed that the diffusion of technology and innovation often follows a logistic curve (or 'S-curve'), and that those who respond to innovative opportunities can be differentiated into various categories (e.g. innovators, early adopters, early and late majority, and laggards). Rogers and Shoemaker [1971] was effectively the second edition of the book, although this time entitled *Communication of Innovations*; in subsequent editions [Rogers, 1983, 1995 & 2003], however, it reverted to the earlier title of *Diffusion of Innovations*. If all the citations to these various editions are combined, this represents the most highly cited contribution to innovation studies by some margin (with a total of over 13,000 citations as of the end of 2010, far ahead of the next most highly cited publication).

5.2.3. Management

One of the earliest HCPs to focus on the management of technology was Woodward [1958], who analysed the relationship between organisational structure and performance, showing that the type of technology (e.g. small batch, large batch, or continuous process production) exercised a significant influence on that relationship, affecting such organisational attributes as centralisation of authority, span of control, and the formalisation of rules and procedures.[23] Another early advance came from the field of marketing, with Bass [1969] formulating a model of the diffusion for new consumer products, although this has been little cited by SPIS researchers.[24] The next significant contributions came from researchers at Harvard and MIT.[25] In particular, Utterback and Abernathy [1975] put forward a dynamic model of innovation with an initial phase of product innovation followed (once a 'dominant design' had become established) by one in which process innovation dominated, while in a later paper they analysed patterns of industrial innovation [Abernathy and Utterback, 1978]. Abernathy [1978] also produced an influential analysis of the innovation process in the automobile sector. In addition, Allen [1977] published a book on *Managing the Flow of Technology*, which focused on communication flows in R&D organisations, and how particular organisational structures enhanced productivity and improved interpersonal contact. He pointed to the key role of 'gatekeepers' in linking the organisation to the wider environment, and to the influence of organisational architecture on information flows.

5.2.4. Organisational studies

In the early 60s, Burns and Stalker [1961] published the first edition of their influential book on *The Management of Innovation*. Despite its title, this is more related to organisational theory and industrial sociology.[26] In particular, it considers how technical innovation relates to different forms of organisation (e.g. mechanistic VS organic) and the different communication patterns associated with those organisational forms. A related contribution is another book by Woodward [1965] on *Industrial Organization: Theory and Practice*, in which she examined the relationship between technology and the success of firms, showing that successful firms tend to be closely clustered around the organisational characteristics best suited to their technologies, while less successful ones were more dispersed. In other words, technology seemed to strongly influence the optimal structure of an organisation.

These two works were central in the emerging field of organisational studies, where several of the seminal works dealt in part with innovation and which have therefore been frequently drawn upon by SPIS researchers. For example, the book on *Organizations* by March and Simon {1958} contained a final chapter on 'planning and innovation in organizations'. They also put forward "a theory of rationality that takes account of the limits on the power, speed, and capacity of human cognitive faculties" (p. 172) – the notion of bounded rationality later to prove particularly influential in the development of SPIS. A little later, Cyert and March {1963} set out *A Behavioral Theory of the Firm*, noting that this theory "is of considerable relevance to the prediction of innovations" (p. 278). In contrast with the earlier view of March and Simon that it is poor performance that induces innovation, Cyert and March contended that successful organisations also innovate, possessing spare resources that they can channel towards innovative activity. Their theory also developed the concept of 'search' by linking it explicitly with the notion of 'organisational learning', a concept to which we return later.[27]

Other major contributions at the interface of innovation and organisational studies from the 1970s include the book by Zaltman et al. [1973] on *Innovations and Organisation*, Downs and Mohr's [1976] analysis of conceptual issues in the study of innovation, and Tushman's [1977] study of boundary roles in the innovation process.

5.2.5. Other fields

Given the emphasis of researchers in SPIS on 'policy', one might have expected to find significant contributions during the early years from political scientists. Yet the only HCP focusing on innovation from a political scientist identified thus far is that by Walker [1969], who looked at the diffusion of innovations (in the form of new programmes or policies) among American states. (It is possible, however, that there may have been other HCPs from political scientists looking at similar public sector innovations that have not been identified in the search here—see the discussion at the end of Section 2.)

[22] The technology-gap theory was put forward in Posner (1961), which had earned 205 citations by the end of 2010), i.e. below the threshold for inclusion here.

[23] Woodward's 1958 contribution could equally well be classified as part of 'organisational studies' (as her 1965 book has been—see below) rather than 'management'.

[24] It has been cited only six times by *Research Policy* authors. Likewise, another highly cited from marketing, Cooper's [1979] analysis of the factors affecting the success and failure of new industrial products, has been cited by relatively few SPIS researchers (cited four times in *Research Policy*).

[25] This built on earlier work at MIT in the 1950s on the management of R&D by Rubinstein, Shepard and Maclaurin, and later by Marquis (Allen and Sosa, 2004). However, none of this earlier work appears to have been particularly highly cited.

[26] Burns was a sociologist and Stalker an organisational psychologist.

[27] The pioneers of contingency theory also had some observations on the role of technology, for example, Lawrence and Lorsch {1967} and Thompson {1967}.

Other contributions to SPIS have come from psychology and particularly organisational psychology. In addition to the work by Stalker (see above) on the management of innovation, another influential study was that by Pelz and Andrews [1966], who examined the effects of organisations on the performance of scientists and engineers, identifying various factors that stimulated the productivity of researchers (e.g. autonomy, interaction with colleagues, the balance between pure and applied research, and some degree of tension between personal and organisational goals). This was one of first science policy studies to use objective measures such as publications and patents in combination with peer review to assess research performance. It is also one of very few HCPs from psychology identified in this review.

Another important contributor, although from somewhat 'outside' SPIS, was Chandler, a business historian. His {1962} book on *Strategy and Structure* analyses organisational changes and innovations, and the emergence of the multidivisional firm in the early 20th Century. His central thesis is that 'structure follows strategy', which in turn is influenced by market changes brought about by various factors including scientific advances and technological leaps. In a later book, *The Visible Hand*, Chandler {1977} extended his historical analysis to the emergence of large, integrated corporations in the late 19th Century, arguing that a key driving force was technology, especially the integration of processes of mass production (e.g. high-speed, continuous-process machinery) with those of mass distribution (in particular, by rail) within a single business firm. Historians of technology were also active in the emerging area of SPIS in the early decades, one prominent contribution being that by Habakkuk [1962] on American and British technology in the 19th Century and the search for labour-saving inventions as a response to high wages and scarce labour.

5.2.6. Interdisciplinary contributions, in particular by SPRU

The above sections reveal how the field of science policy and innovation studies has, right from the start, drawn on a wide range of social sciences. In many universities, these social sciences were (and often still are) pursued in separate departments, with the result that the interaction between SPIS researchers from different disciplines was rather limited, especially in those early years. One institution where this was not the case, however, was SPRU, the Science Policy Research Unit at the University of Sussex.[28] During the 1970s and 1980s, researchers from SPRU were particularly prominent in the development of the SPIS field. A defining characteristic of SPRU was the wide range of disciplines represented amongst its staff, which is why its work is not readily classified under any of the discipline-based categories described above. Indeed, this extensive interdisciplinarity was undoubtedly a factor accounting for the organisation's successes during this period.

One of the first studies that brought SPRU to prominence was Project SAPPHO, in which Rothwell et al. [1974] identified the main factors affecting success and failure in innovation.[29] Another influential contribution was Freeman's [1974] book on *The Economics of Industrial Innovation* [with a second edition appearing in 1982, which was even more highly cited, and a third in 1997, this time with Soete as a joint author]; for over two decades this was seen as the definitive textbook in the emerging field. It was during the 1980s that SPRU contributions to SPIS were most prominent. 1982 was particularly fruitful, with the publication of work by Freeman et al. [1982] on 'long waves' and economic development and the relationship between technology and unemployment, the book by Jahoda [1982] which also explored the relationship between technology and employment, and Dosi's [1982] path-breaking article on technological paradigms and trajectories. Two years later, Pavitt [1984] set out a sectoral taxonomy of technical change that was to be widely used by others. Later in the decade, Freeman [1987] put forward the concept of the 'national system of innovation' (see Section 6.4.2 below), and Dosi [1988] reviewed the sources and micro-economic effects of innovation. In the same year, Dosi, Freeman and colleagues [1988] jointly edited a book on *Technical Change and Economic Theory*, which was to play a major part in the development of evolutionary economics (see below). One of its chapters was by Freeman and Perez [1988] on structural crises of adjustment and this, too, was highly cited.

6. The field matures

Up to the end of the 1970s, much of the research carried out in the emerging field of SPIS was experimental in nature. In addition, although there were some exceptions (such as SPRU and PREST), many contributions came from individual social sciences with little direct engagement between them, at least initially.[30] However, by the early 1980s, this was starting to change and the field of SPIS began to mature, many of its researchers gradually coming to share a common body of literature, methods and concepts, as well as meeting more regularly at conferences and publishing in SPIS-specific journals such as *Research Policy*, *R&D Management* and *Technovation*. Moreover, as we shall see below, the early 1980s witnessed the emergence of what has gradually become for many a common conceptual framework based around evolutionary economics, the interactive model of the innovation process, and, a little later, the notion of 'systems of innovation' and the resource-based view of the firm.

6.1. The economics of innovation, technology and growth

6.1.1. Innovation and evolutionary economics

Arguably the most influential contribution by SPIS scholars has been the development of 'evolutionary economics' as an alternative to neo-classical economics. Central in this development have been Nelson and Winter. In Nelson and Winter [1977], entitled 'In search of useful theory of innovation',[31] they reviewed existing theoretical literature on innovation, pointing to its fragmented nature and to fundamental flaws in the strongest component of that literature, the work by economists. This was a starting point for their development of an alternative theory of economic change, the subject of Nelson and Winter [1982], *An Evolutionary Theory of Economic*

[28] Another example was the team of researchers at Manchester University, initially located in the Department of Liberal Studies in Science, out of which was later to form the group devoted to 'Policy Research in Engineering, Science and Technology' (PREST). This built on earlier work on technical change by Carter and Williams, who were based for a while at Manchester in the early 1960s. However, neither this nor the main contributions in subsequent decades (such as the book on *Wealth from Knowledge*) met the citation threshold of 300 used here. In the US, the nearest equivalent was the MIT Center for Policy Alternatives (Clausen et al., 2012), where Utterback (see above) was based for several years. Some former CPA staff, along with SPRU collaborators, were later responsible for the highly cited [1990] book by Womack et al., *The Machine that Changed the World* (see below).

[29] A similar study of the factors distinguishing success from failure in the development of new products was conducted a decade later by Cooper and Kleinschmidt [1987], who tested ten hypotheses using data on 200 new products, concluding that product superiority is the main factor influencing commercial success, while project definition and early pre-development activities are also critical.

[30] One of the few examples of such cross-discipline interaction was the debate between Griliches (from economics) and Rogers (from sociology) in the early 1960s—see Section 7.1 below.

[31] One can trace the origins of evolutionary economics back to the two authors' previous work in the late 1950s and early 60s at the RAND Corporation, where Winter had written an internal paper in 1960 on 'Economic natural selection and the theory of the firm' (Hounshell, 2000, pp. 292 & 310). See Nelson's (2003) reflections on the origins of evolutionary economics.

Change. This is *the* most highly cited single publication[32] in the SPIS field (by some margin). In it, the authors argue that technological change[33] and innovation are central to economic growth, generating 'variation' in the form of new products, services and so on. Firms compete on the basis of these new products or services, with the market providing a 'selection' mechanism. The development of new products or services is strongly influenced by 'routines' within firms (i.e. by standardised patterns of action)[34]; these provide a 'self-replication' mechanism somewhat akin to genes. In short, Nelson and Winter pointed to a clear analogy with biological evolution. Perhaps because the Nelson and Winter book is universally regarded as *the* work to cite when referring to evolutionary economics, few other works dedicated to evolutionary economics are particularly highly cited (two exceptions being Hodgson [1993] and Nelson [1995]).

6.1.2. Economics of technology and innovation

During the 1980s, other economists continued to make important contributions to the SPIS field. For example, David [1985] examined the economics of the QWERTY typewriter keyboard and how it survived against the challenge of a more 'efficient' keyboard layout, while Katz and Shapiro [1986] analysed technology adoption in industries where network externalities are significant. The issues that such studies raised about path-dependence, externalities, 'increasing returns' and 'lock-in' were later to be picked up by others (see below). Important economic contributions were also made by Farrell and Saloner [1985], who showed that, under conditions of incomplete information, standardisation can 'trap' an industry in an obsolete or inferior standard when a better alternative is available, resulting in 'excess inertia'. Later, Farrell and Saloner [1986] extended their analysis to demonstrate how an installed base of goods based on a particular technology can become 'stranded' if a new standard is adopted, creating a situation of 'excess momentum'. By the end of the 1980s, Milgrom and Roberts [1990] felt sufficiently confident in the results from the growing literature on technological change and innovation to construct a formal economic model of the interaction between technology, strategy and organisation.[35]

6.1.3. Technology, innovation and growth

Other economists and particularly economic historians focused more on the relationship between technology, innovation and economic growth. One of the most detailed analyses was by Rosenberg[36] [1982], who attempted to look inside the 'black box' to which technology had previously been consigned by many economists. He showed how certain characteristics of individual technologies can influence the rate of productivity improvement, the learning process involved in technological change, the speed of technology transfer, and the effectiveness of government technology policies. A little later, Hounshell [1984] looked at the historical emergence of manufacturing technology, while Abramovitz [1986] discussed the role of technology in the processes involved in catching up, forging ahead and falling behind, showing how countries need to have a 'social capability' if they are to absorb more advanced technologies and exploit them effectively. And at the end of that decade, Mowery and Rosenberg [1989] and Storper and Walker [1989] published important books on the relationship between technology and economic or industrial growth.[37] In the 1990s, Jaffe et al. [1995] produced an authoritative review on the effects of environmental regulation on manufacturing competitiveness, finding little evidence that such regulation either damaged economic competitiveness or stimulated innovation.

Aside from 'evolutionary economics', the most influential economic contribution during this period was the development of 'endogenous growth theory'. (About the same time, Lucas {1988} attempted to develop a neoclassical theory of growth and international trade that was consistent with the main features of economic development; one of the models he examined gave considerable emphasis to technological change, while another focused on specialised human capital accumulation through 'learning by doing'.) Endogenous growth theory is perhaps better seen not so much as a contribution to SPIS but rather as a response by mainstream economists to the challenge posed by evolutionary economics. It drew on earlier SPIS work on externalities and on increasing returns (see above), the subject of a highly cited paper by Arthur [1989]. The pioneer of endogenous growth theory is Romer, who firstly related increasing returns to long-run economic growth {Romer, 1986}, and subsequently developed a fuller theory of growth based on endogenous technological change [Romer, 1990]. Other major contributors to endogenous growth theory include Grossman and Helpman [1991], who pointed to the importance of investment in R&D and the resulting spillovers in explaining the relationship between innovation and growth, Aghion and Howitt {1992} with their article on growth through creative destruction and their {1998} book setting out endogenous growth theory in more detail, and Jones [1995] who produced a modified version of Romer's model more consistent with time-series data on R&D spending and growth rates. While many of these authors would probably regard themselves as part of 'economics' rather than innovation studies, they attached great importance to technology and innovation, drawing on the work of SPIS authors such as Nelson, Rosenberg, Freeman and Dosi as well as exercising an appreciable influence upon the SPIS community more widely.

6.2. Management of industrial innovation and the resource-based view of the firm

6.2.1. Management of innovation and the interactive model of the innovation process

While many mainstream economists have remained reluctant to become directly involved in SPIS, this has been far less true of management researchers. During the 1980s and 1990s, there were growing numbers of HCPs from those concerned with the management of innovation, reflecting growing knowledge about the nature of the innovation process in its various forms. One such contribution was by Tornatzky and Klein [1982], who carried out a meta-analysis of empirical findings relating to the characteristics of innovation. Particularly influential was the work by Kline and Rosenberg [1986], which effectively ended the 'science-push' versus 'demand-pull' debate that had been raging since the late 1960s. The authors argued that one needed to move beyond simple linear models and instead put forward an interactive 'chain-linked' model of the innovation process. (This seems to be the only

[32] It is more highly cited than any single edition of Roger's book on *Diffusion of Innovations*, although the combined total of citations to all five editions of the latter far exceeds that for Nelson and Winter [1982].

[33] Basalla [1988] later put forward an evolutionary theory of technology, drawing on the history of technology and economic history, and emphasising three themes—diversity, necessity and technological evolution.

[34] Here, they were influenced by the 'Carnegie School' of researchers such as Simon, Cyert and March, who had shown that organisational behaviour is strongly guided by decision-rules or 'routines' (Nelson, 2003).

[35] A recent HCP on the economics of innovation is DiMasi et al. [2003] on the costs of new drug development.

[36] Although the book was written by Rosenberg, three chapters were co-authored with either Mowery or Steinmueller.

[37] The reasons for the wide variations between the performance of economies over time was also at the heart of North {1990}, which is discussed later in a footnote to Section 6.3.2.

contribution to the 20-year debate between rival innovation models to obtain more than 300 citations.)

An influential management book was that by Kanter [1983], who demonstrated how overly 'segmentalist' management could create barriers to innovation, contrasting this with a more integrative style of management which is likely to result in productivity improvement and innovation. In a *Harvard Business Review* article, Hayes and Abernathy [1980] warned managers of the dangers of not keeping their companies technologically competitive. Another important management book was Hayes and Wheelwright [1984], several chapters of which focused on manufacturing technology, while Abernathy and Clark [1985] developed a framework for analysing the competitive implications of innovation, and Van de Ven [1986] analysed human, process, structural and strategic problems in the management of innovation.

Two popular management books in the 1980s dealt with innovation. Drucker [1985] focused on *Innovation and Entrepreneurship*, arguing that entrepreneurship[38] is not a specialist talent of a few gifted individuals but is pervasive in a healthy society, not just in the private sector but also in public service organisations. He also warned against infatuation with new technology-based innovation to the detriment of often more important social innovations. In the other, *Innovation: The Attacker's Advantage*, Foster [1986] addressed the question of when companies need to change from existing technologies to new ones, basing his analysis on the three concepts of the S-curve (a concept developed by Rogers two decades earlier), the attacker's advantage (small firms or new entrants are not entrapped by existing technology), and discontinuity (between the current S-curve and that for the next-generation technology).

In the most highly cited paper to appear in *Research Policy*, Teece [1986] examined how firms profit from innovation and why some fail to do so, while Levin et al. [1987] considered the related issue of appropriating the returns from industrial R&D. Acs and Audretsch [1988], addressing the perennial question of whether small or large firms are more innovative, developed a more direct measure of innovative activity, showing the number of innovations increased with industrial R&D spending but at a decreasing rate. Their later book [1990] provided evidence of the growing importance of small firms in generating innovations and economic growth, while Audretsch's [1995] book investigated the dynamic process by which firms and industries enter markets and grow or disappear. A review of the wider relationships between innovation, market structure, and industry and firm characteristics can be found in Cohen and Levin [1989], and the same book contains an important review by Reinganum [1989] of the timing of the adoption and diffusion of innovations among competing firms. Although most researchers have concentrated on innovation in relation to manufacturing, Bantel and Jackson [1989] focused on the service sector, looking at the relationship between the social composition of top management and innovation adoptions in banking. And one highly cited contribution from the field of marketing was the review of new product diffusion models by Mahajan et al. [1990], although this has again been little cited within SPIS (only half a dozen times in *Research Policy*, for example).

One major figure from outside SPIS whose work has been heavily cited within it is Porter, the author of three of the most highly cited books in the social sciences. Two focused on strategic management at the firm level. In Porter {1980}, *Competitive Strategy*, technological change and innovation received only limited attention, but in Porter {1985}, *Competitive Advantage*, technology was identified as one of the means of achieving competitive advantage. In Porter {1990}, *The Competitive Advantage of Nations*, the focus broadened. Of the four elements making up the 'diamond' in Porter's conceptual framework, 'factor conditions' depend in part on knowledge and research, while 'related and supporting industries' are often clustered in a single region so as to enable them to share ideas on new opportunities, methods and technologies. All four elements interact as a system, shaping the emergence of particular sectoral or national competitive advantages. Porter {1990} also set out a four-stage model of national competitive advantage, one stage being 'innovation-driven', in which all four elements of the 'diamond' are interacting most effectively. One can see in this work certain similarities to the notion of a 'national system of innovation', which had emerged a couple of years earlier (see below), and indeed Porter's work later influenced the development of the concept of the regional and the sectoral system of innovation.

Another management contribution that had a large impact outside the academic community as well as within is Womack et al. [1990], *The Machine that Changed the World*, which introduced Western companies to Japanese approaches to production processes and innovation (e.g. the concepts of 'just in time' and 'lean production'). Also popular was the book by Davenport [1993], a management consultant, who pointed to the increasingly central role of information technology in implementing process innovation.

Others focused on product development and innovation, for example, Clark and Fujimoto [1991], Wheelwright and Clark [1992], Cooper [1993], Montoya-Weiss and Calantone [1994], Brown and Eisenhardt [1995], and Griffin [1997]. Brown and Eisenhardt [1997] also examined the art of continuous change, while Eisenhardt and Schoonhoven [1990] explored organisational growth in technology-based firms, and Eisenhardt and Tabrizi [1995] considered how best to accelerate adaptive processes. Two other influential books were Utterback [1994] on *Mastering the Dynamics of Innovation*, and Christensen [1997] on *The Innovator's Dilemma*. Christensen and Bower [1996] also produced a model to explain why firms may lose their position of industrial leadership when faced with technological change.

While most researchers had previously classified innovations as 'radical' or 'incremental', Henderson and Clark [1990] introduced the important new category of 'architectural innovation' and examined the management challenges that this poses. Another prominent contributor was von Hippel, who identified 'lead users' as an important source of novel or high-technology products, processes and services [1986], reviewed the sources of innovation (1988), and came up with the notion of 'sticky information' [1994], while Szulanski [1996] analysed the related concept of 'internal stickiness' and the transfer of best practice.

One point to note about the authors of the HCPs listed in this section is the high proportion coming from Harvard and MIT (e.g. Abernathy, Christensen, Clark, Henderson, Leonard-Barton, Utterback, von Hippel, Wheelwright and Womack). From 1980 onwards, these two had apparently become the leading institutions with respect to the management of innovation.

6.2.2. Resource-based view of the firm

A crucial conceptual development emerging from the work at the interface between organisational studies and SPIS is the notion of the resource-based view of the firm as an alternative to the transaction-cost theory of the firm developed by Williamson {1975, 1979 & 1985} and others. The resource-based view built upon earlier heavily cited 'classics' such as Penrose {1959} and to a lesser extent Coase {1937}. One of the first formulations was by Wernerfelt {1984}, who saw 'in-house knowledge of technology' as one of a firm's key resources. Grant {1991} attempted to develop this further into a resource-based 'theory' of competitive advantage (in which innovation played a more significant part), and later {1996}

[38] Shane and Venkatamaran [2000] later produced an influential conceptual framework to explain empirical phenomena in the field of entrepreneurship and to make various predictions (Landström et al., 2012).

into a full 'knowledge-based theory of the firm'.[39] Other influential contributions came from Prahalad and Hamel {1990} with their focus on the core competences of the company, Hamel {1991} who described the competition for competence, Conner {1991}, one of the first to consider whether the resource-based view offered a new theory of the firm, and Barney {1991} who developed a model for identifying key features of strategic resources and hence for defining those that constitute a source of comparative advantage. However, Priem and Butler {2001} have expressed doubts about whether the resource-based view has yet attained a satisfactory theoretical structure, outlining various conceptual challenges still to be addressed.

While many of these authors might be seen as somewhat 'outside' the SPIS community, there are several SPIS researchers who made important contributions to the resource-based view, including Winter [1987] who identified knowledge and competence as strategic assets, and Cohen and Levinthal [1989] who described the 'two faces' of R&D, and later re-defined the enormously influential concept of 'absorptive capacity' [Cohen and Levinthal, 1990],[40] a term previously employed in development economics since the mid-1960s. During the 1990s, other contributions were made by Kogut and Zander [1992] with their work on the knowledge of firms and the replication of technology, by Leonard-Barton [1992] on core capabilities and core rigidities, by Henderson and Cockburn [1994] on measuring competence, by Quinn and Hilmer [1994] on the relationship between core competences and strategic outsourcing, by Zander and Kogut [1995] on the speed of the transfer and imitation of organisational capabilities, and by Nahapiet and Ghoshal [1998] on how social capital can generate intellectual capital and organisational advantage. Lastly, in one of the most cited SPIS articles of the 1990s, Teece et al. [1997] developed the concept of dynamic capabilities (following an earlier [1994] paper by Teece and Pisano on the same subject). This concept was subsequently extended by Eisenhardt and Martin [2000], and by Zollo and Winter [2002] who examined how dynamic capabilities evolve over time.

6.3. Organisations and innovation

6.3.1. Organisational innovation

While many SPIS scholars have focused more on technological innovations, organisational innovations can be just as important. Some highly cited work on the latter has been carried out by researchers in organisational studies. In one of the earliest HCPs to contain the term 'organisational innovation' in its title, Kimberly and Evanisko [1981] analysed the influence of individual, organisational and contextual factors on hospitals' adoption of technological and administrative innovations. In another hospital-based study, Barley [1986] examined how new medical-imaging devices changed the organisational structure of radiological work, and developed a theory of how technology may stimulate different organisational structures. Ettlie et al. [1984] put forward a model of the organisational innovation process, arguing that the strategy–structure relationship differs between radical and incremental innovations, with an aggressive technology strategy and centralised decision-making being required to promote the former. Dewar and Dutton [1986] also found that radical and incremental innovations have different predictors, with organisational size being important for the former. Markus and Robey [1988] analysed the role of IT in organisational change, identifying the structural characteristics of a 'good theory' to ensure IT is introduced successfully. Subsequently, Damanpour [1991] conducted a meta-analysis of the relationships between organisational innovation and its determinants, including technical knowledge resources, while Woodman et al. [1993] developed a theoretical framework for understanding organisational creativity.

6.3.2. Interaction between technology/innovation, organisations and institutions – 'co-evolution'

The work described above points to the influence of organisational factors on innovation and vice versa. This has proved a fruitful area for SPIS scholars, many of whom have drawn upon insights offered by 'new institutionalism' and the work of pioneers such as DiMaggio and Powell {1983}, who identified the forces leading to 'institutional isomorphism' and, amongst other things, looked at the adoption and spread of organisational innovations. A different contribution on the relationship between organisational factors and innovation was Piore and Sabel {1984}, who argued that capitalism had reached a turning-point, where it has to choose between two alternatives – to continue along the existing trajectory of mass-production technology (the course chosen at the first 'industrial divide'), or to switch towards craft-based production and exploiting computer technology to make possible 'flexible specialisation', thus creating an environment in which firms compete on the basis of innovations but cooperate with regard to developing the necessary technological knowledge and skills.

A third, and again quite different contribution, this time from business history, came from Chandler {1990}, who analysed how, since the 1870s, industrial managers had developed the organisations and made the investments needed to realise the economies of scale and scope offered by technological and organisational innovations of the second industrial revolution. He challenged the conventional economic view in which organisations are shaped by markets, replacing it with one in which business organisations, markets and technologies co-evolve.[41] He also chronicled how, from 1920 onwards, large firms began to develop in-house R&D, initially to improve existing products and processes, and later to develop new ones.

Prominent contributors from more within the SPIS community include Tushman and Anderson [1986], who showed how "technology evolves through periods of incremental change punctuated by technological breakthroughs that either enhance or destroy the competence of firms in an industry", with the latter involving technological discontinuities often initiated by new entrants. They later looked at effects of technological discontinuities on dominant designs, developing a cyclical model of technological change [Anderson and Tushman, 1990]. Other HCPs were produced by Dougherty [1992], who identified certain 'interpretive barriers' that prevent technological and market possibilities from being effectively linked and so impede innovation, and DeSanctis and Poole [1994] who focused on the interaction between ICT use and organisational structure. Related to this is the analysis by Davis et al. [1989] of the factors influencing the acceptance of a new technology (computers) by users in an organisation, an analysis from which they developed a 'technology acceptance

[39] The resource-based theory of the firm is debated in Organization Science, Vol.7, No.5 (1996), including highly cited articles by Conner and Prahalad {1996} and Kogut and Zander [1996].

[40] Lane and Lubatkin [1998] later came up with a modified construct of 'relative absorptive capacity', where a firm's ability to learn from others depends on certain similarities between them. Only a few papers published since 2000 have earned over 300 citations, one being Zahra and George [2002], who distinguish different dimensions of absorptive capacity (potential and realised) and propose a reformulation of the concept.

[41] Somewhat related to this is North's {1990} book on *Institutions, Institutional Change and Economic Performance*, which, although it drew on the work of only a few historians of technical change and innovation, has nevertheless had a significant impact on SPIS scholars.

model' based on the perceived usefulness and ease of use of a new technology.[42]

6.3.3. Organisations, organisational learning and knowledge management

A central concept emerging from organisational studies is that of 'organisational learning', first put forward by Argyris and Schön {1978}. This is linked to the resource-based view of the firm, and again it is scholars from organisational studies rather than SPIS who have been most involved in its development, although they have often paid considerable attention to technology and innovation. Contributors include Levitt and March {1988} and Huber {1991} who published highly cited reviews on this topic, the former in particular including literature pertaining to technology and innovation. Within SPIS, Hayes et al. [1988] were among the first to put forward the notion of the 'learning organisation' and the benefits it could bring to manufacturing (a notion central in Senge's {1990} book on 'the fifth discipline'). Quinn [1992] used a closely related term of the 'intelligent enterprise' to describe an approach to management that flexibly integrates innovative technologies and new service paradigms to improve business performance. Also relevant here are Brown and Duguid [1991], who related organisational learning to 'communities of practice' {see also Lave and Wegner, 1991} and attempted to formulate a unified view of working, learning and innovation, work that was further developed in Brown and Duguid [2001].[43] Another scholar more closely linked to the SPIS community is Levinthal, who, with March, examined the constraints on organisational learning processes and identified three forms of learning 'myopia' [Levinthal and March, 1993]. Later, Hurley and Hult [1998] related innovation to organisational learning in a study focusing on a government agency rather than a firm, and Crossan et al. [1999] developed a conceptual framework for organisational learning, with four processes (intuiting, interpreting, integrating and institutionalising) linking the individual, group and organisational levels.

More recently, much attention has focused on knowledge management within organisations. Key figures include Drucker {1993}, who argued that we are witnessing the emergence of 'post-capitalist society', in which the primary resource for creating wealth is knowledge, and Nonaka [1994], who put forward a theory of organisational knowledge creation and developed the notion of 'the knowledge-creating company', in which knowledge management is crucially important [Nonaka, 1991; Nonaka and Takeuchi, 1995], a point taken up by Teece [1998]. Another contribution from within SPIS is Leonard-Barton's [1995] explanation of why some companies are more successful at innovating in terms of the ability to develop and manage knowledge effectively.[44] Knowledge management was also the focus of Sanchez and Mahoney [1996], who examined how modularity in product and organisation designs could facilitate the task of knowledge management, of Gupta and Govindarajan's [2000] analysis of knowledge flows within multinational corporations (MNCs), and of Tsai's [2001] study of knowledge transfer in intra-organisational networks within MNCs.

Finally, there is the work by Brown[45] and Duguid [2000] on *The Social Life of Information*, examining the wide – ranging effects of today's most generic technology – information and communication technology. This contains a chapter on 'innovating organization, husbanding knowledge', drawing on Brown's experiences at Xerox. It is also one of the few HCPs identified in this study that is concerned with assessing the broader impact of technology.

6.3.4. Networks, inter-organisational collaboration and open innovation

Since the early-1990s, SPIS researchers have given much attention to the role of networks and collaboration. (This is closely related to the work on systems of innovation described below.) One of the first to explore why firms collaborate in their technological efforts was Hagedoorn [1993], while Powell et al. [1996] described how, in fields characterised by rapid technological development, the locus of innovation is increasingly found within networks of learning rather than in individual firms. Other HCPs include Mowery et al.'s analysis [1996] of inter-firm knowledge transfers within strategic alliances using a novel technique to measure change in a firm's technological capabilities, Hargadon and Sutton's [1997] examination of the role of technology brokering in product development, Gulati's [1999] study of how network resources influence the formation of alliances, Stuart et al.'s [1999] investigation of how the inter-organisational networks of young companies affect their ability to acquire the resources needed for survival and growth, Dyer and Nobeoka's [2000] examination of how to create and manage an effective knowledge-sharing network, and Kale et al.'s exploration [2000] of how reputational capital based on trust and interaction between individuals helps firms protect proprietary assets in strategic alliances. Sako's {1992} book also includes a chapter discussing the influence of technological factors on contractual relations and trust between collaborating companies. In addition, there has recently been related work by Chesbrough [2003] on 'open innovation' and von Hippel [2005] on 'democratized innovation'.

6.4. Systems of innovation

6.4.1. National systems of innovation

Aside from evolutionary economics, one of the most important concepts to emerge from SPIS is that of 'systems of innovation'. Freeman [1987] was the first to publish this concept, using it to explain Japan's economic success particularly in high-tech sectors.[46] Around the same time, Lundvall [1988] was developing similar ideas on innovation as an interactive process and the need to move from focusing on user-producer interactions to analysing the wider national system of innovation, ideas that were more fully developed in his 1992 book [Lundvall, 1992] and in the book edited by Nelson [1993].

6.4.2. Regional systems of innovation and the economic geography of innovation, spillovers, clusters, etc.

The concept of a national system of innovation has been extended in several ways. One is the development by Cooke and others of the notion of regional systems of innovation (e.g. Cooke and Morgan [1998], who examined how firms interact with their regional milieux, engaging in interactive innovation based on

[42] The model was extended by Venkatesh and Davis [2000], while other key articles on diffusion of technology or innovations within organisations include Cooper and Zmud [1990] and Greenhalgh et al. [2004].

[43] Weick's {1995} book on sense-making is another significant contribution to organisational learning.

[44] A later contribution is Davenport and Prusak's {1998} book on how organisations manage what they know, while a recent highly cited article is the review of knowledge management by Alavi and Leidner {2001}.

[45] Earlier, Cook and Brown {1999} distinguished knowledge from 'knowing', arguing that the 'generative dance' between the two is a powerful source of organisational innovation.

[46] Freeman traced the origins of the concept back to List {1841}, with his notion of the 'national system of political economy', which he used to explain the catching up and overtaking of Great Britain by Germany.

collective learning). This builds on earlier work by economic geographers and others,[47] including several studies by Jaffe [1986, 1989 & 1993] and by Griliches [1992] on R&D spillovers, the regional effects of academic research and the geographic localisation of spillovers, and Saxenian's [1994] analysis of regional advantages. Other contributions include Audretsch and Feldman [1996], who also focused on R&D spillovers[48], and Morgan [1997], who analysed 'the learning region' and the part played in this by institutions and innovation. Florida [2002], in contrast, has focused more on cities, arguing that the ability of cities to attract the creative class and to translate that advantage into new ideas and new high-tech businesses is essential to economic growth.

6.4.3. Sectoral systems of innovation

A second extension of the innovation system concept has been the development of the notion of sectoral systems of innovation. However, although a number of prominent SPIS researchers have been involved in this work (e.g. Malerba, Breschi, Orsenigo, McKelvey), no publications on this appear to have yet reached the citation threshold used here.

6.4.4. Technological systems, regimes and niches

Another body of work on systems focuses on technical or technological systems and related concepts such as 'technological regimes' and 'niches'. This appears to be one of the few cases where a development in the neighbouring field of 'science and technology studies' (STS) has had a significant impact on SPIS (Martin et al., 2012), since the notion of 'technological systems' was made popular by three STS researchers, Bijker, Hughes and Pinch {1987}, in a book on *The Social Construction of Technological Systems*. The notions of technological systems, regimes and niches have also featured in recent work on the relationship between innovation and sustainability, but nothing in this area seems to have been highly cited yet.

6.4.5. The Triple Helix

Related to the notion of systems of innovation is the work on the 'Triple Helix' by Etzkowitz and Leydesdorff [2000], who argue that the developing relationship between universities, industry and government can be characterised in terms of a triple helix. In this, universities are seen as playing a more central role in the knowledge economy. Entrepreneurial universities that successfully embrace the 'third mission' of contributing to the economy and society in addition to the two traditional roles of teaching and research are seen as undergoing a 'second academic revolution' (the first having been when they took on the function of research in the 19th Century).

6.5. Sociological and other contributions to SPIS

In addition, sociologists have made important contributions to the study of innovation. In particular, Rogers [1983, 1995, and 2003] has produced successive editions of his hugely influential book on *Diffusion of Innovations*. Another contribution from sociology is Burt [1987], who re-examined the data of Coleman et al. [1966] on the diffusion of a major medical innovation in the light of developments in network theory. He concluded that 'social contagion' was not the dominant factor in the diffusion process studied, as Coleman et al. had claimed, adoption instead being influenced by doctors' personal preferences. However, Burt's paper makes little reference to the SPIS literature, nor (like Coleman et al.) has it been much cited by SPIS researchers, reinforcing the impression that there has been limited interaction between SPIS and sociologists focusing on the diffusion of medical innovations.

In contrast, Granovetter's paper {1985}, although not specifically on innovation,[49] has been much cited by SPIS scholars. Granovetter suggested that analysis of social networks offered a tool for linking micro and macro levels in sociological theory. While most previous network models focused on strong ties, he pointed to the importance of 'weak ties' in explaining the interactions between groups. Later, Burt {1992} developed the concept of 'structural holes' based on his analysis of the social structure of economic phenomena (and his replacement of the notions of perfect competition and monopoly with a networked model of competition). Although this book falls outside the SPIS field, it contains a section on entrepreneurs and his notion of 'structural holes' has had a major impact on SPIS scholars.[50]

The final contribution considered here is difficult to classify since the six authors came from sociology and higher education studies as well as science policy. This is the book by Gibbons et al. [1994] on *The New Production of Knowledge*, which distinguishes between 'Mode 1′ and 'Mode 2′ forms of knowledge production, and argues that we are witnessing a historical shift towards the latter. This is one of the few HCPs located at the boundary between SPIS and STS. The thesis it puts forward has significant policy implications and it has provoked much debate among SPIS and STS researchers as well as policy-makers.

6.6. Measuring technology and innovation

6.6.1. Patents and other IP measures

Over the years, SPIS researchers have developed various methodological 'tools' for empirical research. One of the most important is the use of patents as an indicator of inventive activity, where Schmookler [e.g. 1966] and Scherer [1965] were early pioneers. Later, the central figure was Griliches with his book on *R&D, Patents and Productivity* [Griliches, 1984], a paper jointly authored with Hausman et al. [1984] on the patent-R&D relationship, and a highly cited review article on patents as economic indicators [Griliches, 1990]. Although SPIS researchers have developed other intellectual property (IP) indicators (e.g. based on royalties and licensing), none of the publications involved appear to have been highly cited. However, the effect of patents formed the focus of the paper by Heller and Eisenberg [1998], who considered whether patents might in certain circumstances proliferate to such an extent that they deter innovation, giving rise to an 'anti-commons' effect in which people underutilise scarce resources because too many IP owners can block each other.

6.6.2. Other indicators and methods

SPIS researchers have constructed a wide range of R&D indicators, innovation indicators and 'technometric' indicators as well as developing scientometric indicators for SPIS purposes (e.g. using citations in patents to scientific publications to trace the links between technology and science). Again, however, few indicator

[47] This includes such highly cited 'classics' as Porter {1990} with his emphasis on geographical clusters, and Krugman {1991} with his work on regional agglomeration, including high-tech clusters. However, the basic concept of clustering can be traced back to Marshal's {1890} work on 'industrial districts'.

[48] While much of the research on spillovers has concentrated on the regional effects, the impact can obviously be much wider. For example, Coe and Helpman [1995] have examined international R&D spillovers.

[49] Granovetter {1985} does, however, discuss the work of sociologists such as Rogers and Coleman on the diffusion of innovations and how that diffusion can be related to social networks and weak ties.

[50] The same is true of the notion of 'epistemic communities' developed by Haas {1992}, another 'outsider' to SPIS (a political scientist), who has written about the problems of ensuring effective international policy coordination in addressing global issues, and specifically those relating to the environment.

or methodological publications (including the recent innovation surveys) seem to have been particularly highly cited, apart from those by the early pioneers of bibliometrics such as Garfield {1955 & 1979} and Price [1963]. There are at least three possible explanations for this. The first is that there is apparently little tradition within SPIS of writing exclusively (or even primarily) methodological papers to introduce and justify a new approach. A second is that there is no great pressure to give a reference to the original source for the methodology or indicator that one adopts (unlike in certain other fields). A third is that there is no consensus as to which is *the* pioneering paper that one should cite when making use of a particular indicator or methodology. Whatever the explanation, it is clear that SPIS is rather different from some social science fields where 'methods' papers are often among the most cited publications. In the case of economics, for example, no less than seven out of the top ten most highly cited papers identified by Kim et al. (2006) are econometric (or statistical) methodology papers, unlike in SPIS. This may be a reflection of the fact that SPIS is still a rather more fragmented and heterogeneous field than established social science disciplines, an issue taken up in the final section.

7. Discussion and conclusions

In this review, we have seen how the key intellectual 'foundations' of SPIS have emerged and developed, in particular, the 'evolutionary economics' alternative to the neo-classical tradition, the interactive model of the innovation process, the notion of 'systems of innovation', and the 'resource-based view' of firm. Moreover, while research on each of these initially was rather independent of the others, over time these strands have come together and begun to 'fuse'. While we are still clearly at a relatively early stage, we may perhaps even be witnessing the beginnings of an embryo 'paradigm' for SPIS. However, before addressing this issue specifically, let us first return to the original research questions.

7.1. What were the disciplinary origins of SPIS?

SPIS has come a long way in 50 years from its humble origins. In the late 1950s, there were a few individuals and small teams (e.g. at MIT and RAND) working on innovation—mainly economists and sociologists (in particular, rural and medical sociologists). Initially, these two sets of researchers worked in isolation and apparent ignorance of one another. When they did finally meet, there was, as one might have anticipated from earlier examples in intellectual history or from Becher's (1989) work on 'academic tribes', a confrontational debate, which is recorded in the pages of *Rural Sociology* (see Griliches, 1960, 1962; Rogers and Havens, 1962). One unfortunate consequence of this was limited cross-fertilisation between the two streams of research (Skinner and Staiger, 2007). For example, although economists and other SPIS scholars cited Rogers [1962, 1971, 1983, 1995 & 2003], they largely ignored Coleman et al.'s [1966] important work on the diffusion of medical innovations.

Besides economists and sociologists, there were also a few early contributions from senior scientists or engineers such as Vannevar Bush, and from management or organisational researchers like Woodward. The 1960s and 70s' witnessed a growing contribution from economists (e.g. Nelson, Arrow, Mansfield, Schmookler, Scherer) and economic historians (e.g. Gerschenkron, Rosenberg, David), from sociologists (in particular, Rogers), and from the fields of organisational studies (e.g. Burns and Stalker), management (e.g. Abernathy, Utterback, Allen), business history (e.g. Chandler) and (to a lesser extent) political science.

7.2. The coalescence of SPIS as a field?

Gradually, some of those initially separate research activities started to interact with each other and even to coalesce to a certain extent. Such coalescence was partly catalysed by the activities of intrinsically inter-disciplinary teams of researchers, such as those at SPRU and Manchester, who were less constrained by disciplinary boundaries than those working in single-discipline university departments, with Freeman's [1974] book representing one of the main efforts to bring about such a coalescence. But SPIS remained quite fragmented for its first twenty years or so – witness the debates between economists and sociologists, or between scientists and economists over the 'science-push' and 'demand-pull' models of innovation.

It was not until the 1980s that SPIS began to become more integrated, principally around the notion of evolutionary economics put forward by Nelson and Winter [1982]. Together with other related work including Rosenberg's [1982] book, *Inside the Black Box*, and his joint article with Kline on the chain-linked model of innovation [Kline and Rosenberg, 1986], Dosi's article [1982] on technological paradigms and trajectories, various contributions in the book edited by Dosi et al. [1988] on *Technical Change and Economic Theory*, and the development of the concept of the 'national system of innovation' by Freeman [1987], Lundvall [1992] and Nelson [1993], these ideas began to form a central part of what Dosi et al. (2006a,b) have somewhat provocatively termed 'the Stanford-Yale-Sussex synthesis'[51], although this down-plays other important streams of work. Now, a significant part of the SPIS community – in particular, those from business or management schools and those from the interdisciplinary tradition typified by SPRU, but less so, perhaps, those from economics departments (see below) – have begun to coalesce around these ideas.

7.3. Missing links?

Although SPIS has succeeded over the decades in forging fruitful links with 'adjacent' social sciences and drawing parts of these into SPIS, there remain several fields where, even though researchers may have focused on certain aspects of research or R&D, new product development, new technologies or innovations, they remain relatively unconnected to SPIS. One is mainstream economics, which, despite recognising the importance of technology and innovation (as reflected in endogenous growth theory, for example), nevertheless remains somewhat sceptical about much SPIS research. Indeed, the development of endogenous growth theory may be seen at least in part as a response by mainstream economists to the heterodox challenge posed by evolutionary economics and SPIS – in other words, as a form of 'sailing ship effect' (see Gilfillan, 1935, and Rosenberg, 1972, although the effect has been challenged by Howells, 2002, and more recently by Mendonca, forthcoming).

Secondly, there is the limited interaction between sociologists studying medical innovations and the wider SPIS community. A third example is work in marketing; researchers from that field have made important contributions in terms of models of the diffusion of new products, a key aspect of the innovation process, yet HCPs on this, such as Bass [1969] and Mahajan et al. [1990], seem to have generally had little impact on SPIS researchers (one exception is Karshenas and Stoneman, 1992). Fourthly, given the strong 'policy' dimension to SPIS, one might have expected to see greater interaction with political science. However, this review has identified few SPIS HCPs by political scientists, although SPIS researchers

[51] Further research is needed to explore this coalescence in more quantitative terms.

have drawn on theories and concepts from political science, such as the notion of epistemic communities {Haas, 1992}. A fifth example is psychology, although one complication here is a change in terminology, with part of what was known as 'industrial psychology' morphing into organisational psychology and thus becoming part of organisational studies. Even so, one might have expected to see more prominent interaction with SPIS, for example with regard to the links between creativity (both individual and institutional), research and innovation.

However, the most prominent example of another field that might have forged closer links with SPIS is 'science and technology studies'—i.e. work by sociologists of science and technology, and by historians and philosophers of science.[52] There are only a few instances of interactions between the two fields. For example, the work of Kuhn {1962, 1970 & 1996} has been much cited by SPIS researchers; in particular, his concept of a scientific 'paradigm' gave rise to Dosi's [1982] notion of a 'technological paradigm'. Merton's work on the sociology of science {e.g. 1973} and that of philosophers of science such as Polanyi (e.g. his {1966} book on tacit knowledge) and Ziman {1968} has also been influential. Other examples include the development of 'actor-network theory' by Callon {1986} and others {e.g. Callon et al., 1986}, and the work mentioned earlier by Bijker et al. {1987} on 'technological systems'. Yet for much of the 1970s, 80s' and 90s', the two communities worked largely in isolation. On various occasions, individuals attempted to build bridges between the two. For example, Cole and Cole, two sociologists of science, examined peer review in a science policy-oriented study. However, the fierce criticism this study (Cole et al., 1978; Cole and Cole, 1981) attracted from sociologists of science as well as from scientists (e.g. Harnad, 1985) may have deterred others from such bridge-building efforts. Another factor is that many in SPIS may have been sceptical about what a field riven by doctrinal disputes (Martin et al., 2012) might offer the more practically oriented field of SPIS.

7.4. The US dominance – artefact or reality?

One aspect of the list of HCPs in Table 1 that is striking and merits further comment is the heavy and growing dominance of US-based authors. In their study of highly cited economics articles, Kim et al. (2006, p. 200) also observed a preponderance of US authors, accounting for 85% of HCPs. Although European researchers like Freeman, Pavitt and Dosi were very prominent in the 1970s and 1980s, in the last 20 years US authors have seemingly come to dominate (as they had done in the late 1950s and 1960s). This raises two questions. First, is this effect 'real' or merely an artefact of the methodology employed here? Second, if the effect is genuine, what might be the reasons for it?

To answer the first question, one ideally needs some unbiased source against which one can compare the results from this analysis. Some who read early drafts of this article have argued that the apparent US dominance is at odds with literature reviews as well as their own assessments. However, one must bear in mind that both these depend ultimately on subjective judgements. And subjective judgements are ultimately flawed to a greater or lesser degree by limited knowledge outside one's own area of interest or expertise and, indeed to some extent, outside one's own country. Furthermore, if methodological bias were to be the explanation, it is difficult to see how this could account for *growing* US dominance over the last 20 years.

It was precisely to minimise the need for subjective judgements that an approach based on citation analysis has been adopted. In science and especially social science, it is oft asserted that US researchers can be rather 'parochial' in their referencing, tending to cite mainly US literature, whereas researchers from Europe and elsewhere are perhaps more international in terms of what they cite. If so, the effect would be to inflate the average citation totals for US publications, and such an effect might be particularly pronounced at the extreme end of the citation distribution curve corresponding to the top 1% or so most highly cited publications included here. The counter-argument is that citations reflect a 'democratic' choice by authors as to which references have been most influential. It may well be that US researchers attend fewer overseas conferences than their foreign counterparts, so they tend to be less familiar with non-US work and cite it less often. To this extent, the impact of non-US research is less great than it would be in a completely 'free market' of academic ideas. Citations should therefore be seen as reflecting what impact academic publications *actually* have, not what influence they might have (or should have) in such a 'free market' (Martin and Irvine, 1983). Hence, the HCPs identified in this study can be seen as corresponding to those that have had most impact, rightly or wrongly, in the imperfect market of academic publishing and referencing.

If we assume the HCPs identified here do represent those publications that have had most impact on fellow academics, what factors might explain why US authors account for such a high proportion of the total, particularly over the last 20 years? The first point to note is that the US represents by far the largest single 'market' in the academic world.[53] If a publication is to earn over 300 citations, it must almost certainly have a major influence in the US. From the discussion above, this is evidently easier for US authors to achieve. Secondly, to attain this level of citations, given the small size of the SPIS community compared with established disciplines like economics or management, an SPIS publication generally needs to create a marked impact in one or more adjacent disciplines. Here, a key institutional difference in the affiliations of SPIS researchers may be significant; many SPIS researchers in Europe (and indeed in Asia) are part of a specialised and often interdisciplinary research unit[54], while SPIS researchers in North America tend to be located mainly in discipline-based departments (of economics, management or business, and so on). US researchers, perhaps for reasons to do with tenure and career advancement, seemingly retain a stronger attachment to their 'parent' discipline, continuing to attend 'economics' or 'management' conferences and to publish in the associated disciplinary journals—more so than their foreign counterparts. Consequently, US academics are arguably better placed when it comes to trying to ensure that their publications will have an appreciable influence in a social science discipline.

Thirdly, perhaps there are differences in the nature of the SPIS research carried out in the US compared with elsewhere. If so, then may be the type of research on which US researchers choose to focus is such that it tends to be more cited. Gallivan and Benbunan-Fich (2007) have pointed to evidence that in information science there are different research traditions in North America and Europe, with the former more positivist and empirical and the latter more qualitative and interpretive. A similar generalisation could perhaps be made about SPIS. If positivist and empirical research does indeed attract more attention and hence more citations than

[52] One exception here is Vincenti [1990], whose work on the epistemology of engineering has been very influential among SPIS researchers.

[53] Cf. Grupp et al. (2001), whose investigation leads them to conclude that language-bias effects are small compared with effects related to the large 'market' for research publications in the US.

[54] Examples include CIRCLE at Lund University, DRUID in Denmark, ISI (the Fraunhofer Institute for Systems and Innovation Research) in Karlsruhe, MERIT in Maastricht, MIoIR at Manchester University, NIFU-STEP in Oslo, and SISTER in Stockholm, as well as SPRU.

qualitative and interpretive research, perhaps a higher proportion of US researchers have chosen to position themselves accordingly.

Lastly, there is one further factor that may have contributed to the US dominance of the lists compiled here. As is well known from studies of the innovation process, it is not sufficient just to come up with a 'good idea'.[55] One also needs to give some attention to what 'gap in the market' it will address, what strategy is likely to prove most effective in developing 'the product' and positioning it in the market, how best to 'package', 'brand' and 'market' it, how to maximise 'sales', even how to provide effective 'after-sales service'. At the risk of offending some readers, I might venture to suggest, on the basis of observations over the last 30 years, that US researchers tend to be more focussed and systematic in attending to these matters—in other words, they are arguably rather better all-round 'academic entrepreneurs', perhaps due to the more competitive nature of the US academic market.

7.5. Is SPIS in the early stages of becoming a discipline?

We have seen how a substantial part of SPIS has over time coalesced into a relatively coherent field of research, but has it begun the process of transformation into a 'discipline'? Historians and sociologists of science (e.g. Ben-David and Collins, 1966; Kohler, 1982) have shown that the origins of disciplines can often be traced back to a stage when researchers from two or more existing disciplines began to address common problems somewhat outside those extant disciplines. Initially, the research might be characterised as 'multi-disciplinary', and perhaps at a later stage (when researchers from those disciplines start to communicate more directly with each other and to integrate the inputs from different disciplines) as 'interdisciplinary'. Gradually, the accumulating body of research may become more independent and more coherent, establishing its own conferences, journals, PhD programmes and university departments. A putative paradigm (or perhaps two or three competing candidate paradigms) may begin to emerge and develop. In some cases, consensus may form around one particular paradigm, which then starts to exert a growing influence in shaping the research agenda of the emerging discipline (see also Eom, 1996). However, as with the emergence of a new biological species, it is often impossible to say with any confidence whether a new discipline has formed until after the event.

In order to address the question of whether SPIS is in the early stages of becoming a discipline, we first need to first specify more carefully what we mean by a 'discipline'. An academic discipline cannot be defined in terms of a single characteristic; several facets need to be considered. SPIS has certainly begun to acquire some disciplinary characteristics. For example, unlike 30 years ago, it now trains most of its own doctoral students rather than recruiting them from other disciplines. In Europe and various other countries outside the US, there are well-established academic units with the name of the field apparent in the title. Likewise, over the last 30 or so years, the field has built up a set of SPIS-dedicated journals. There has also been a shift in emphasis over the decades from books to journal articles as the primary 'vehicle' for researchers to put forward their major contributions, another possible indication of a move towards a more discipline-like nature (Pasadeos et al., 1998; Ramos-Rodriguez and Ruiz-Navarro, 2004). Against this, however, is the fact that a large proportion of the most highly cited articles in more recent years continue to appear in mainstream disciplinary journals rather than dedicated SPIS journals. This might suggest that leading SPIS researchers prefer to publish their best work in the journals of their 'home' discipline, which in turn might be interpreted as reflecting a lack of self-confidence in the institutional standing of the field (Pilkington and Teichert, 2006). However, an alternative interpretation is that causality may run the other way—in other words, work that is published in disciplinary journals tends to be cited by the larger discipline-based community and so gains more attention and more citations than work of equal merit published in SPIS journals.[56]

In other respects, however, SPIS still lacks certain essential characteristics of a 'discipline', such as its own permanent, dedicated funding sources, a professional association to which most researchers belong, and a regular series of major international conference to which *all* 'wings' of SPIS bring their best papers to present.[57] Most importantly, it is still some way from possessing a well-established and widely accepted 'paradigm'.

If SPIS is not yet a discipline, how far has it come in terms of establishing its 'maturity' as a research field? Cornelius et al. (2006) propose four tests of a field's maturity. It should show: (i) an increasing internal orientation, i.e. it should be self-reflective; (ii) stabilisation of topics around key research questions; (iii) an identifiable community of researchers including a core group of leading authors; and (iv) increasing specialisation of research focused on particular theoretical research issues.[58] Let us examine SPIS with regard to each of these.

The first is concerned with the relative influence on the research agenda of 'outsiders' (e.g. policy-makers or managers of technology and innovation in industry) compared with that of 'insiders' (i.e. SPIS researchers). Unfortunately, there is no obvious objective way of assessing this. However, having worked in the area for 30 years, my sense is that a growing proportion of SPIS publications are more concerned with studies stimulated by the interests of academic researchers than by 'external' policy or management issues. One small piece of evidence to support this is the fact that in early volumes of *Research Policy* one used to find articles written by those working in industry whereas now this is extremely rare (although still fairly common in more professionally-oriented journals, for example in technology and innovation management). This would suggest that SPIS has indeed become rather more self-contained and 'self-reflective', and hence more mature or 'discipline-like'.

Secondly, as we have seen, from the 1980s there has been a gradual stabilisation of the topics pursued by SPIS researchers around key research questions, often linked to evolutionary economics, systems of innovation and the resource-based view of the firm. With regard to the third criterion, there is now a fairly readily identifiable community of SPIS researchers, as the survey by Fagerberg and Verspagen (2009) revealed. Moreover, from the list of HCPs produced here, one can identify a core group of leading figures such as Abernathy, Anderson, Christensen, Clark, Cohen, David, Dosi, Eisenhardt, Feldman, Freeman, Griliches, Hall, Henderson, Jaffe, Leonard-Barton, Levinthal, Lundvall, Mansfield, Mowery, Nelson, Pavitt, Powell, Rogers, Rosenberg, Scherer, Teece, Tushman, Utterback, von Hippel and Winter.

The fourth criterion concerns the question of whether SPIS research exhibits increasing specialisation on particular theoretical issues. While further research is needed to establish this empirically, my overall impression is that in recent years a significantly

[55] Even though most SPIS researchers have long since rejected the 'science-push' linear model of innovation, a surprising number still rather touchingly believe that such a model holds (or at least should hold) when it comes to their own work having an impact!

[56] See the discussion in McGrath (2007) on the development of management as a field.

[57] The DRUID conferences, for example, focus on industrial dynamics, the Schumpeter conferences on the economics of innovation, the Triple Helix conferences on university-industry interactions, and so on.

[58] But see also Whitley (1984) on management studies as an 'adhocracy', and Goles and Hirscheim (1999) on information systems for a critique of the positivistic notion of 'disciplines'.

higher proportion of the articles published in journals like *Industrial and Corporate Change* and *Research Policy* begin with hypotheses stemming from theory than was the case 20 or 30 years ago. This, again, would suggest a growing maturity on the part of science policy and innovation studies, even if it is still some way from becoming a discipline.

8. Concluding remarks

This article has attempted to identify the key intellectual contributions to the field of science policy and innovation studies over the last 50 years. Along with Fagerberg et al. (this issue), it represents one of the first attempts to identify and analyse influential SPIS contributions on the basis of highly cited publications, and appears to be one of the most comprehensive and systematic studies of this type among social sciences more generally. In the case of SPIS, we have seen how, beginning in the 1950s, a handful of researchers in economics, sociology and management started to make contributions to the embryo field. They were joined by others including industrial psychologists, organisation scientists and historians of various types (e.g. historians of technology, and economic and business historians). Over time, the interactions between these various disciplines grew and the field gradually took shape. From around the mid-1980s, SPIS began to become a rather more coherent field centred on the adoption of an evolutionary (or neo-Schumpeterian) economics framework, an interactive model of the innovation process, and (a few years later) the concept of 'systems of innovation' and the resource-based view of the firm. Several thousand researchers now count themselves as part of 'innovation studies', and they have succeeded in producing a large number of highly cited publications, many of which have had a substantial intellectual impact well beyond the field. After five decades of effort, although it is still some way from developing a formal paradigm, SPIS has apparently begun to acquire at least some of the characteristics of a 'discipline'.

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