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). In particular, it seeks to 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. Along with other studies reported in this Special issue, it represents one of the first and most systematic attempts to identify and analyse the most influential contributions to an emerging field on the basis of highly cited books and articles. 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, SPIS started to become a more coherent field centred on the adoption of an evolutionary (or neo-Schumpeterian) economics framework, and 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.

Key words: innovation studies, science policy, history, evolution, highly cited publications, key contributions

JEL codes: O30; O31: O32; O35: B25: B521

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1. Introduction

The field of science policy and innovation studies (SPIS) is now approximately 50 years old. From humble beginnings involving just a few researchers in late 1950s, it has grown to become a significant field involving several thousand researchers.[1] Some of its contributions have had a major impact on neighbouring social science disciplines as well as within the field itself. It is therefore timely to look back and analyse more systematically what has been achieved, and in particular to identify the main intellectual contributions to the field.

The aims of this article are to systematically identify and analyse the intellectual origins of the field, the disciplines upon which the field has drawn and how these have evolved over time, and the key intellectual developments or contributions. In addition, we examine whether the field is beginning to coalesce around a common conceptual framework and set of analytical tools. The intention is to provide a synthetic overview of the field useful for research students and other 'new comers' 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 sometimes seen as less directly linked (for example, work on medical or health innovations, or on organisational and other non-technological forms of innovation). In particular, 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.[2]

The structure of article is as follows: Section 2 defines the scope of the field of 'science policy and innovation studies'. Next, Section 3 reviews the literature on previous attempts to map or review the field, but also examines similar studies in neighbouring social science fields. Section 4 sets out the methodology employed here 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. We identify the most influential contributions during this period, while Section 6 focuses on those from the 1980s 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. Finally, in Section 7 we discuss the broad findings from the study, in particular 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 to contend with is that different people have labelled the various research activities on which we are focussing in a number of ways. Another is that those labels have changed over time. For example, in the 1960s, a common designation was 'science policy' (or sometimes 'research policy').[3] At that time, 'science' was broadly interpreted as including 'technology' and even 'innovation'. The emphasis on 'science' at that stage reflected the key role that science was then assumed to play in relation to the development of technology and innovation.[4] Moreover, 'policy' was taken to include wider issues relating to the *management* of science, technology or innovation (in particular within the firm) and to the *economics* of science, technology and innovation. However, from studies in the 1960s and 1970s, it became clear that science was just one of several essential 'ingredients' of innovation. Consequently, 'science' became too narrow and misleading a label, and various combinations of science, technology and innovation (and variations on these such as engineering and R&D) were instead employed during the 1970s and '80s.[5] By the 1990s, however, the preference of many was to use 'innovation' as the generic noun for characterising the field,[6] 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' of R&D, technology or innovation, while the involvement and influence of economists also grew rapidly, particularly following Nelson and Winter's development of an evolutionary approach to economics. Rather than attempting to come up with a label involving some cumbersome combination of 'policy', 'management' and 'economics', many have therefore opted for the simple, succinct label of 'innovation studies'. However, I have chosen not to adopt this here for two reasons. First, there may be a tendency on the part of some using this label to interpret it rather narrowly as focusing on 'innovation' largely to the exclusion of 'technology' and particularly 'science'. Secondly, as this brief history of the topic has shown, the term 'innovation studies' is a comparatively recent one, while the term 'science policy' goes back over four or more decades. Instead, I have opted for the fuller, if slightly clumsier, label of 'science policy and innovation studies' (or SPIS).[7] The working definition of this used here is 'economic, management, organisational and policy studies of innovation, technology and science'.

Having decided upon on a suitable label, we next need to specify exactly what areas of research are to be incorporated under the heading of 'science policy and innovation studies'. In what follows, I have included the science, technology and innovation-related components of the following:

- policy – as we have seen, this includes the older terms 'science policy' and 'research policy' (terms that are still in use, although they are generally now seen as covering only part of the SPIS field); 'technology policy' (where similar comments apply); and more recently 'innovation policy';
- 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 also a significant component of endogenous growth theory (which also gives particular prominence to technology and innovation);
- economic history and business history – more specifically, the history of technology and innovation,[8] and the relationship of technology and innovation to industrial development and economic growth;
- management – this includes R&D management (again, a somewhat older term[9] now less in favour), industrial R&D, new product development, technology management,[10] 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 (focusing, for example, on routines, core competences, dynamic capabilities, absorptive capacity and so on), along with aspects of organisational learning (closely linked to knowledge management – see above);
- sociology – especially sociological work on the diffusion of technologies and innovations; however, most sociology of science and technology has been excluded, since this comes more under 'science and technology studies' (see below).

I have specifically chosen to specifically exclude the following:

- most sociology of science and technology, along with much of the history and philosophy of science – these form part of the field of 'science and technology studies', a largely separate field and research community (with just a few researchers operating to a significant extent in both fields[11]);
- most scientometrics or bibliometrics research – again, this is a rather separate research community from SPIS,[12] so it has been largely 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 (for example, recent work relating innovation and sustainability);
- most literature on economic development, except where technology or innovation is again a key element (for example, ‘technology transfer’ or ‘appropriate technology’);[13]
- most research on public sector innovations (for example, as covered in *The Innovation Journal*) except where technology is a significant component – again, this is a largely separate research community from SPIS.

There are also certain areas that, although not specifically excluded, may have been only partially covered here:

- ‘technology assessment’ – a search for major contributions has so far revealed few highly cited publication relating to this area;[14]
- ‘engineering management’ – this began rather earlier as a field (the forerunner of *IEEE Transactions on Engineering Management* was established in 1954[15]); while it clearly overlaps with ‘R&D management’ or ‘technology management’, there are parts of it less strongly linked to SPIS which therefore may not have been fully captured here;
- work on the implementation of new technology (in particular IT) – for example, by researchers in the field of information systems, which again is less strongly linked to SPIS;
- some literature on technology or innovation diffusion – for example by marketing researchers; they have written extensively about the diffusion of new products, clearly an essential part of successful innovation, yet this marketing literature does not seem to be particularly closely linked with the SPIS field;
- contributions by psychologists, for example, on the relationship between organisations and innovation, or on creativity in research and innovation; such work was previously rather separate from science policy and innovations studies, although in recent years it has become more closely linked.

This delimitation of the field of science policy and innovation studies is inevitably 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 spells out in some detail what has and has not been included and why.[16]

3. Literature review

Next, let us consider the relationship of this study to previous efforts to map or review the field. There have been several attempts to do this, most notably in textbooks or handbooks, but also in a number of major review articles. Highly cited examples include Freeman (1974 & 1982), Freeman and Soete (1997), Nelson and Winter (1977), Dosi (1988), Griliches (1990) and Brown and Eisenhardt (1995).[17], [18] A particularly comprehensive attempt is that by Fagerberg (2004) in the introductory chapter of *The Oxford Handbook of Innovation* (Fagerberg et al., 2004). However, all of these reviews were conducted on an ultimately rather subjective basis of what the author(s) judged to have been the most significant contributions. In addition, most such efforts have focused on a slightly narrower set of research activities (e.g. the 'economics of innovation', or the 'management of technology'[19]) than the field of SPIS as defined here.[20]

A few authors have attempted a more quantitative approach to identifying the most important contributions. One of the first was Cottrill et al. (1989), who carried out a co-citation analysis of the literature on 'innovation diffusion' and on 'technology transfer', showing there was surprisingly little interaction between these two research streams. However, their focus was very much narrower than the study reported here. A few years later, Granstrand (1994) produced an overview of the economics of technology. However, as the title suggests, he focused on *economic* contributions, largely ignoring those from management, organisational studies, sociology and elsewhere. Secondly, he concentrated primarily on identifying books[21] that had made important contributions;[22] while books were often the vehicle for major contributions in the early decades of the subject, this is by no means the case in more recent times, as we shall see later. Thirdly, although Granstrand made some use of bibliometric analysis to identify major contributions, his list of key 'books and early seminal works' does not reveal their respective citation scores, only that some were 'among the most cited works in SSCI in the field' (ibid., p.15). Fourthly, although he identifies the 'most cited authors' (ibid., p.22), the numbers of citations on which this table is based are small, with the result that it is unclear what significance can be attached to the relative positions of authors.[23] Lastly, this analysis is based on data that is now over 15 years old, so it is well worth looking again at what has changed over the intervening years.
More recently, Verspagen and Werker (2003 & 2004), and Fagerberg and Verspagen (2009) have analysed the development of innovation studies. However, they used the results from an extensive survey of researchers rather than bibliometric analysis. Subsequently, Fagerberg et al. (2011) have adopted an empirical approach based on analysing the chapters contained in authoritative handbooks on innovation studies, using these to identify which publications have had most impact on those authors.[24] However, apart from this and the earlier Granstrand (1994) study mentioned above, there have been only a few other attempts to use bibliometric techniques to analyse the field. One was by Dachs et al. (2001) but their focus was evolutionary economics, while Meyer (2001) focused even more narrowly, just looking at citations to the Nelson and Winter 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 'The scientometric world of Keith Pavitt'). Other examples of such studies are in the subfield of technology and innovation management (TIM), where Shane and Ulrich (2004) identified the 30 authors who had published most on innovation in the journal *Management Science*, while Ball and Rigby (2006) identified the 75 most prolific authors in a broader range of TIM journals. [25], [26]

As we shall see in the next section, the approach adopted here focuses on highly cited publications (HCPs). Apart from the recent study by Fagerberg et al. (2011) focussing on 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 in articles in a single journal (*Technovation*) so the citation figures involved here are relatively small. This raises questions about the significance of the findings, although in fairness the great majority of the highly cited publications they identify also appear in the list generated in the more extensive study reported here. More recently, Silva and Teixeira (2008) have conducted a similar study of the most highly cited publications as cited in *Structural Change and Economic Dynamics*, where there is again a significant overlap with the field of SPIS.[27]
Among the social sciences, the nearest equivalent study seems to be in economics, where Kim et al. (2006) identified approximately 150 articles in 41 leading economics journals published over the period 1970-2005 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).[28] However, they made no attempt to identify highly cited books (or book chapters).

With regard to other 'neighbouring' disciplines on which SPIS draws, in the case of political science, a comprehensive history of the field is to be found in Goodin and Klingemann (1996a), *A New Handbook of Political Science*. In particular, in Chapter 1 (Goodin and Klingemann, 1996b) and Chapter 2 (Almond, 1996), the authors identify leading political scientists and contributions. In the former case, Goodin and Klingemann carry out a simple bibliometric analysis based on work cited in the 35 chapters of the Handbook to identify leading intellectual contributors[29] to sub-fields of political science, to the discipline as a whole, and to the integration of the discipline.[30]

In management and business[31], there are many rankings of business schools, some 'academic' (e.g. Erkut, 2002), others produced by newspapers and magazines (e.g. *The Financial Times*[32]). However, a search of the literature has yet to locate any quantitative attempt to identify key contributions in business/management science as a whole (although ISI, the producers of the *Citation Index*, have identified the most highly cited researchers in field of economics and business[33]). Nevertheless, there have been numerous empirical analyses of various sub-fields of management.[34] One of the first (Culnan, 1986) focused on *management information systems* (MIS), identifying highly cited authors and using co-citation analysis to investigate the changing sub-field structure of MIS research.[35] Another early study was that by Eom and Lee (1993), who identified leading US universities and researchers in *decision support systems* research using publication and citation data, with the analysis subsequently being extended by Eom (1996). Elsewhere, Ratnatunga and Romano (1997) identified the most highly cited papers in *small enterprise* research, although they focused only on articles in six journals over a six-year period so the citation totals are quite small.[36] Similarly, Pasadeos et al. (1998) examined the most highly cited publications and authors among *advertising* scholars, in their case counting only citations from seven US journals so the numbers of citations for the most cited publications are again rather small. Likewise, Pilkington and Liston-Heyes (1999) identified key intellectual contributions to *production and operations management,* while Ramos-Rodriguez and Ruiz-Navarro (2004) did the same for *strategic management* research, and Casillas and Acedo (2007) for *family business* research; however, in all three cases the authors considered only citations from a single journal, which raises questions about the generalisability of the findings. Ponzi (2002) analysed the emerging field of *knowledge management*,[37] identifying the most cited authors and how they are clustered in terms of key themes.[38] However, this analysis was limited to publications appearing over the five-year period 1994-1998, so the citation numbers involved are small, again raising issues about the statistical significance of the results. Similar comments apply to the studies by Acedo and Casillas (2005) in the field of *international management*, and by Pilkington and Fitzgerald (2006) in *operations management*.[39]

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 only on a subcomponent of the broader field of SPIS. In particular, aside from the work based on analysing references in handbooks (Fagerberg et al., 2011; Landström et al., 2011; Martin et al., 2011), 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,[40] 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,[41] 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 from SPIS have been identified here though a systematic search for highly cited publications (HCPs) in the field. 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.[42] Over the last 40 years or so, various studies have tended to confirm 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:

- English-language bias – non-English publications are much less likely to be cited by researchers, while many references in non-English sources are not counted by the *Citation Index*/Web of Science with the result that such citations are 'lost';
- only journals[43] are scanned by the *Citation Index*/Web of Science; this means that, while citations in these journals *to* books are counted, citations *from* books are not;
- North American journal bias – proportionately more US social science journals are scanned by the *Citation Index*; the normal justification is that these journals tend to have higher 'impact factors' and are therefore perceived by the academic community as 'more important', but the argument here is somewhat circular;[44]
- 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;
- 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.

In most previous studies attempting 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 those journals to establish which publications have been most highly cited (the approach adopted in the studies of different branches 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 demonstrated, if one starts with a different set of core journals, one can end up with a quite different list of highly cited publications. For these reasons, a more open-ended approach has been 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;[45] and (ii) a reasonably comprehensive list of 90 journals in which SPIS researchers have published the great majority of their articles. 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', 'new product development' and so on[46] to identify those where the titles[47] suggest they fall within SPIS field.[48] At this preliminary stage, Google Scholar was useful in helping to draw up a short-list list of potential candidate HCPs for more careful scanning in the *Citation Index*,[49] 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 systematically scanned in the *Citation Index*/Web of Science (WoS) to identify all publications with more than 300 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[50] 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 volume or page number in the reference, or where for some other reason the references have not been unified by the WoS software). For books, a similar approach was used, searching on the author's name (with one or more initials) together 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).[51] 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). For example, no attempt has been made to include cases where the citing author misspelt the author's name, omitted *all* the initials of the author, or gave the wrong year for the journal article. For the second and third of these sources of 'error', the effect probably cancels out approximately across authors and HCPs, but the first type of error may result in a small amount of bias against authors with easily misspelt names (although against this is the fact that authors of papers cited several hundred times tend to be well known, so instances of this are probably comparatively rare).[52]

Thus far, the search has identified within SPIS:

- ~55 HCPs with ≥1000 citations
- ~130 HCPs with ≥500 citations
- ~205 HCPs with ≥300 citations

The results are summarised in Table 1 at the end of the paper, while Table 2 lists contributions from authors outside SPIS whose publications 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 130 SPIS HCPs with 500 or more citations compares favourably with the top 150 journal articles in economics.[53] 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.[54]

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 latter part of the 1950s, there are clearly important 'pre-cursor' publications that appeared before that. In this 'pre-history' phase, the central figure is Schumpeter, with two books (1934[55] & 1942[56]) cited well over 2000 times and a third (1939) 1300 times (see Table 1). Schumpeter was one of the few economists of the first half of the twentieth 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.[57] 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.[58] In addition, one should mention Vannevar Bush and his influential 1945 science policy report to the US Government entitled *Science the Endless Frontier*. In this, he set out what he saw as the role of science in relationship to innovation, describing what became known as the 'science-push' linear model of innovation,[59] and 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 history), 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 beginning 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.

5.1.1 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 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). However, in another highly cited article, Solow (1957) added technology as a third factor of production in addition to capital and labour in a paper that alerted the wider economics profession to the importance of technical change.[60] Other leading economists such as Moses Abramovitz and Simon Kuznets, 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.[61]

One of the central 'building blocks' of what was to become the field of science policy and innovation studies 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.[62] Another key contribution from the late 1950s was that by Nelson (1959), who, together with Arrow (1962a), set out the economics of research.[63] 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 (what became known as the concept of 'market failure'), and used this to construct a rationale for government funding of research.[64] 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,[65] a model that for the next ten years or so was locked in competition with the 'science-push' model mentioned earlier.[66] 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).
Important 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's 1975 book on *Technical Choice, Innovation and Economic Growth*. Another key contributor was Rosenberg with his 1976 book on *Perspectives on Technology*.[67]

In addition, there are a number of HCPs by economists who, like Solow, were not working 'within' the SPIS field but whose work undoubtedly had a significant impact upon its development.[68] 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).[69] 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' (see Godin, 2008). A third example was 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 work was important as it 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.

5.1.2 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 the 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 by a sociologist to SPIS came from Rogers. In 1962, he published the first of several editions of his book on *Diffusion of Innovations*. Building on work by rural sociologists and others, he showed that the diffusion of technology and innovation often followed a logistic curve (or 'S-curve'), and that those who responded to innovative opportunities can be differentiated into a number of categories (e.g. innovators, early adopters, early and late majority, and laggards). In 1971, Rogers and Shoemaker published what was effectively a second edition of the book, although it was now entitled *Communication of Innovations*; in subsequent editions (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).

5.1.3 Management

One of the earliest HCPs to focus on the management of technology was that by Woodward. In her 1958 book, *Management and Technology*, she analysed the relationship between organisational structure and organisational 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.[70] 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.[71] The next significant contributions came from researchers at Harvard and MIT.[72] 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 organization to the wider environment, and to the influence of architecture on information flows.

5.1.4 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.[73] 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 the less successful ones were more dispersed. In other words, technology seemed to strongly influence the optimal structure of an organization.

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 set ‘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 below.[74]

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.

5.1.5 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 that has been identified so far is 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).

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, 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 the 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, especially the emergence of the multidivisional firm in the early 20th Century in the US. 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 entitled *The Visible Hand*, Chandler (1977) extended his historical analysis to the emergence of large, integrated corporations in latter part of the 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. A number of historians of science and technology were also active in the emerging area of SPIS in the early decades, with one prominent contribution being that by Habakkuk (1962) on American and British technology in the nineteenth century and the search for labour-saving inventions as a response to high wages and scarce labour.

5.1.6 Interdisciplinary contributions, in particular by SPRU

The above sections reveal how the field of science policy and innovation studies has, right from the early decades, 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, particularly 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.[75] 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 one 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.[76] 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 a definitive textbook on the emerging field. Indeed, it was during the 1980s that SPRU contributions to SPIS were probably most prominent. 1982 was a particularly fruitful year, with the publication of the 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, Nelson (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 the chapters in this was by Freeman and Perez (1988) on structural crises of adjustment and this, too, was highly cited.

6 The field matures

In the period 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 of the contributions came from individual social sciences with little direct engagement, at least initially, between them.[77] However, by the early 1980s, this was starting to change and the field of SPIS began to mature, its researchers now 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 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 1977, they published an article entitled 'In search of useful theory of innovation'.[78] In this, 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, evolutionary theory of economic change, the subject of their 1982 book, *An Evolutionary Theory of Economic Change*. This is *the* most highly cited single publication[79] in the SPIS field (by some margin). In it, the authors argue that technological change[80] 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)[81]; 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 (among the exceptions are 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, standardization 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.[82]

6.1.3 Technology, innovation and growth

Other economists and economic historians focused more on the relationship between technology, innovation and economic growth. One of the most detailed analyses was carried out by Rosenberg (1982), who attempted to look inside the 'black box' to which technology had previously been consigned by many economists. Together with Mowery and Steinmueller, 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.[83] 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.

6.1.4 Increasing returns, endogenous technical change and new growth theory

Aside from 'evolutionary economics', the most influential economic contribution during this period was the development of what became known as the 'endogenous growth theory'.[84] This built on the earlier work on externalities and on increasing returns (see above), which was also 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 technical 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 evidence on R&D spending and growth rates. While all these authors would probably regard themselves as part of 'economics' rather than innovation studies, they attached great importance to technology and innovation, drawing extensively on the work of SPIS scholars as well as exercising considerable influence upon them.

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

During the 1980s and '90s, there were growing numbers of HCPs relating to technology and innovation from those working in the field of management. To a large extent, these reflected our growing knowledge about the nature of the innovation process in its various forms. One contribution here was Tornatzky and Klein (1982), who carried out a meta-analysis of empirical findings relating to the characteristics of innovation. Particularly influential was the paper by Kline and Rosenberg (1986), which effectively ended the 'science-push' versus 'demand-pull' debate that had been raging since the second half of the 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, which has become the standard model since then. This seems to be the only contribution to the 20-year long debate between rival innovation models to obtain more than 300 citations, the threshold adopted here.

An influential management book from this period 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 encompassing looser job remits, non-routine and even ambiguous assignments, and strong local autonomy, all of which were more 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 that appeared in the 1980s dealt with innovation. One by Drucker (1985) focused on *Innovation and Entrepreneurship*, arguing that entrepreneurship[85] 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 the 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) drew on his experience at McKinsey with technology management to address 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 over 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 the reasons 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), in an effort to address the perennial question of whether small or large firms are more innovative, developed a more direct measure of innovative activity, and showed that the number of innovations increased with industrial R&D spending but at a decreasing rate. In a later book (1990), they provided evidence of the growing importance of small firms in generating innovations and economic growth, while Audretsch's 1995 book investigated further 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 handbook contains an important review by Reinganum (1989) of the timing of the adoption and diffusion of innovations among firms in competition. Although most researchers have tended to concentrate 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 apparently been little cited within the SPIS field.

One major figure who is not located within the SPIS community but whose work has made major contributions that have been heavily cited by SPIS researchers is Michael Porter, who has produced three of the most highly cited books in the social sciences. Porter (1980) and Porter (1985) focused on strategic management at the firm level. In the former (*Competitive Strategy*), technological change and innovation received only limited attention, but in the latter (*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 (the other two being 'demand conditions' and 'firm strategy, structure and rivalry') interact as a system, shaping the emergence of particular sectoral or national competitive advantages in a continuous struggle for enhanced productivity and competitiveness. Porter (1990) also sets out a four-stage model of national competitive advantage, one of the stages 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 was subsequently to influence the development of the concept of the regional and the sectoral system of innovation.

Like the work by Porter, another management contribution that had an enormous impact outside the academic community as well as within is the book by Womack et al. (1990), *The Machine that Changed the World*, which introduced Western companies to Japanese approaches to production processes as well as 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.

Other authors instead 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 management 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 previous researchers had previously classified innovations as either 'radical' or 'incremental', Henderson and Clark (1990) argued that this categorisation may have misleading effects on those responsible for managing industrial innovation; they introduced the important new category of 'architectural innovation' and examined the management challenges that this poses. Another prominent contributor during this period was von Hippel, who identified 'lead users' as an important source of very novel or high-technology products, processes and services (1986), reviewed the sources of innovation (1988), and also 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 final 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, Utterback, von Hippel, Wheelwright and Womack). From the early 1980s onwards, the MIT Sloan School of Management and the Harvard Business School had apparently become the leading institutions with respect to the management of innovation.

6.2.2 Resource-based view of the firm[86]

A crucial conceptual development emerging from the work of researchers 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 and 1985) and others. The resource-based view as to why firms exist built upon earlier heavily cited 'classics' such as Coase (1937) and Penrose (1959).[87] One of the first formulations of the 'resource-based view of the firm' was put forward by Wernerfelt (1984), in which 'in-house knowledge of technology' was seen as one of a firm's resources, although he made little direct reference to innovation. Grant (1991) attempted to develop this further into a resource-based 'theory' of competitive advantage (in which innovation played a rather more significant part), and later (1996) into a full 'knowledge-based theory of the firm'.[88] Other influential contributions were made by Prahalad and Hamel (1990) with their focus on the core competences of the company, by Hamel (1991) who described the competition for competence, by Conner (1991) who was one of the first to consider whether the resource-based view offered a new theory of the firm, and by 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.

While many of the above authors would perhaps be seen as somewhat 'outside' the SPIS community, there are several SPIS researchers who have also made important contributions to the resource-based view, including Winter (1987) with his identification of knowledge and competence as strategic assets, and Cohen and Levinthal (1989) who described the 'two faces' of R&D, and later defined the enormously influential concept of 'absorptive capacity' (Cohen and Levinthal, 1990).[89] During the 1990s, other significant 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 highly 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. 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.

6.3 Organisations and innovation

6.3.1 Organisational innovation

While most SPIS researchers have tended to focus more on technological innovations, they recognise that organisational innovations can often be at least as important. Some of the highly cited work on organisational innovation has been carried out by researchers in organisational studies rather than SPIS. For example, in what is apparently one of earliest HCPs to contain the term ‘organizational innovation’ in its title, Kimberly and Evanisko (1981) analysed the influence of individual, organisational and contextual factors on the adoption by hospitals 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 by modifying institutionalised roles and interaction patterns. Ettlie et al. (1984) developed a model of the organisational innovation process, arguing that the strategy-structure relationship is very different for radical innovations compared with that for incremental innovations, with a more aggressive technology strategy and centralised decision-making being required to promote the former. Likewise, Dewar and Dutton (1986) found that radical and incremental innovations have different predictors, with organisational size being important for the adoption of radical process innovations. Markus and Robey (1988) analysed the role of information technology in organisational change, asking what are the structural characteristics of ‘good theory’ to ensure that IT is introduced in a beneficial manner. Subsequently, Damanpour (1991) conducted a meta-analysis of the relationships between organisational innovation and its main determinants, including technical knowledge resources, and 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 in the previous section 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 the phenomenon of ‘institutional isomorphism’ and, amongst other things, also looked at the adoption and spread of organisational innovations. Another, rather different contribution on the relationship between organisational factors and innovation was that of Piore and Sabel (1984), who argued that capitalism had reached a turning-point, where it has to choose between two alternatives. One is to continue along the existing trajectory of mass-production technology (the course chosen at the first ‘industrial divide’), while the other is 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 the point of view of business history, came from Chandler (1990), who analysed how, over the 100 years from the 1870s onwards, industrial managers in the US, UK and Germany had developed the organisations and made the investments needed to realise the economies and scale and scope offered by the technological and organisational innovations of the second industrial revolution. Chandler 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.[90] He also chronicled how, from 1920s 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 to the industry. These two authors later looked at the 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 model' based on the perceived usefulness and ease of use of a new technology.[91]

6.3.3 Organisations, organisational learning and knowledge management

A central concept emerging from the field of organisation studies is that of 'organisational learning', first put forward by Argyris and Schön (1978). This concept is linked to the resource-based view of the firm described above, 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. Authors of HCPs on this topic include Levitt and March (1988) and Huber (1991), who published highly cited reviews of the literature on this topic, the former in particular including literature pertaining to technology and innovations. 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 that was central in Senge's (1990) book on 'the fifth discipline'). Quinn (1992) used a slightly different but closely related term of the 'intelligent enterprise' to describe an approach to management that flexibly integrates innovative technologies and new service paradigms in an effort to improve business performance. Also relevant here is the work by Brown and Duguid (1991), who related organisational learning to ‘communities of practice’ and attempted to formulate a unified view of working, learning and innovation, work that was further developed in Brown and Duguid (2001).[92] Another scholar more closely linked to the SPIS community is Levinthal, who together with March, examined the constraints on organisational learning processes and identified three forms of learning ‘myopia’ (Levinthal and March, 1993). A few years later, Hurley and Hult (1998) attempted to relate innovation to organisational learning in an empirical study focusing on a government agency rather than a company, 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 here include Drucker (1993) with his argument 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), who argued that the effective management by companies of knowledge, competence and related intangibles is increasingly important in the information age. Another major contribution from within SPIS is Leonard-Barton’s (1995) analysis of why some companies are more successful at innovating than others, something that she attributes to their ability to develop and manage knowledge effectively.[93] Knowledge management was also the focus in the paper by Sanchez and Mahoney (1996), who examined how modularity in product and organisation designs could facilitate the task of knowledge management, in Gupta and Govindarajan’s (2000) analysis of knowledge flows within multinational corporations (MNCs), and in Tsai’s (2001) study of knowledge transfer in intra-organisational networks within MNCs.

Finally, one should mention the work by Brown[94] and Duguid (2000) on *The Social Life of Information*, which examines the wide-ranging effects of today’s most generic technology – information and communication technology. This contains an important chapter on ‘innovating organization, husbanding knowledge’, drawing extensively on Brown’s experiences at Xerox. It is also one of very few HCPs identified in this study that is concerned with assessing the broader impact of technology.

6.3.4 Networks and inter-organisational collaboration

Since the mid-1990s, the SPIS community has given considerable attention to the role of networks and collaboration. This is closely related to the work on systems of innovation (especially sectoral and regional systems) described below. One highly cited contribution here is Powell et al. (1996), who studied inter-organisational collaboration and described how, in fields characterised by rapid technological development, the locus of innovation is increasingly to be found within networks of learning rather than in individual firms. Others include the analysis by Mowery et al. (1996) of inter-firm knowledge transfers within strategic alliances using a novel technique for measuring change in firm's technological capabilities, Gulati's (1999) study of the role of network resources in influencing 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 a high-performance knowledge-sharing network, and the exploration by Kale et al. (2000) of how reputational capital based on mutual trust and interaction between individuals helps firm protect proprietary assets in strategic alliances. Sako's 1992 book also includes a chapter discussing the influence on technological factors on contractual relations and trust between collaborating companies. In addition, there has been related work in recent years by authors such as Chesbrough (2003) and von Hippel (2005) on what has been variously characterised as 'open innovation' and '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.[95] 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). Other important contributions analysing the national systems of innovation in various countries were made 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, which examined how firm interact with their regional milieux, engaging in interactive innovation based on collective learning). This builds on earlier work by economic geographers and others,[96] 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 highly cited contributions include Audretsch and Feldman (1996), who also focused on R&D spillovers[97], and Morgan (1997), who analysed 'the learning region' and the part played in this by institutions and innovation.[98] Florida, in contrast, has focused more on cities; in his 2002 book *The Rise of the Creative Class*, he argues that the ability of cities to attract the creative class and to translate that underlying advantage into creative economic outcomes in the form of 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 (including Malerba, Breschi, Orsenigo and McKelvey), none of the publications on this topic appear to have reached the citation threshold used here thus far.

6.4.4 Technological systems, regimes, niches etc.

Another body of work on systems is that focusing on technical or technological systems (e.g. by Carlsson) and other related concepts such as 'technological regimes' and 'niches'. The 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 the field of SPIS, since the notion of 'technological systems' was made popular by three STS researchers, Bijker, Hughes and Pinch (1987), with their highly cited book on *The Social Construction of Technological Systems*.[99] The notions of technological systems, regimes and niches have also featured in recent work on the relationship between innovation and sustainability. However, nothing in this area by SPIS researchers seems to have been highly cited yet.

6.5 Sociological and other contributions to SPIS

In addition, there have been important contributions to the study of innovation from sociologists. In particular, at roughly 10-year intervals, Rogers (1983, 1995, and 2003) has continued to produce new editions of his hugely influential book on *Diffusion of Innovations*. Another contribution from sociology was Burt (1987), who re-examined the data of Coleman et al. (1966) on the diffusion of a major medical innovation (see above) in the light of recent developments in network theory. He concluded that 'social contagion' was not the dominant factor in the diffusion of the antibiotic studied, as Coleman et al. had claimed, adoption instead being strongly influenced by doctors' personal preferences. However, just as the Coleman et al. study has not been greatly cited by the SPIS community, so Burt's paper makes little reference to the SPIS literature (apart from Rogers, 1983), nor has it been much cited by SPIS researchers, reinforcing the impression that there has been relatively little interaction between SPIS and sociologists focusing on the diffusion of medical innovations.

In contrast, the paper by Granovetter (1985), although it did not specifically focus on innovation,[100] has been much more cited by SPIS scholars. Granovetter suggested that analysis of social networks offered a potentially valuable tool for linking the micro and macro levels in sociological theory. Observing that most previous network models focused on strong ties, he pointed to the importance of 'weak ties' in explaining the interactions *between* groups and other aspects of social structure not easily defined in terms of primary groups. A few years 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 does contain a section on entrepreneurs and, more importantly, his notion of 'structural holes' has had a certain impact on SPIS scholars.[101]

The final contribution to be considered here is more difficult to classify since the six authors came from sociology and higher education studies as well as science policy.[102] This is the book by Gibbons et al. (1994) on *The New Production of Knowledge*, which distinguishes between the 'Mode 1' and 'Mode 2' forms of knowledge production, and argues that we are witnessing a historical shift towards the latter. This HCP is interesting because it is one of the very few located on the boundary between SPIS and 'science studies'. The thesis it puts forward has significant policy implications and it has certainly provoked much debate among SPIS researchers and policy-makers as well as in the 'science studies' community.

6.6 Measuring technology and innovation

6.6.1 Patents and other IP measures

Over the years, SPIS researchers have developed a number of methodological 'tools' for empirical research. One of the most important of these is the use of patents as an indicator of inventive activity. Schmookler (e.g. 1966), who had been working on patents from the early 1950s, and Scherer (1965) were early pioneers in the use of patent statistics.[103] 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 various 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 one of the most influential papers of the late 1990s. In this, Heller and Eisenberg (1998) raised the issue of 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[104] (e.g. 'R&D intensity'), innovation indicators and 'technometric' indicators as well as developing scientometric indicators for SPIS purposes (for example using citations in patents to scientific publications to trace the links between technology and science). They have also developed various methods for analysing such indicators, based on such concepts as 'revealed comparative advantage'. Again, however, few indicator[105] or methodological publications seem to have been particularly highly cited, apart from those by the early pioneers of bibliometrics (e.g. Garfield, 1955 and 1979; Price, 1963) working outside of the SPIS field. Given the importance of such methodological tools, one might ask whether this points to a possible limitation of the HCP approach adopted here. However, there are at least three other possible explanations that may account 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 possibility 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 research 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 evident that SPIS is rather different from some social science fields where 'methods' papers are often amongst most highly 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. In SPIS, by contrast, when authors use a particular indicator or methodological approach, there seems not to be the same tradition of citing a single, universally accepted source for that indicator or approach. This may be a reflection of the fact that SPIS is still a more fragmented and heterogeneous field than established social science disciplines, an issue we take up in the final section.

7 Discussion and conclusions

7.1 The coalescence of SPIS as a field?

In this review, we have seen how the key intellectual 'foundations' of science policy and innovation studies 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', with the field starting to coalesce around them. While we are still clearly at a relatively early stage, we may even perhaps be witnessing the beginnings of an embryo 'paradigm' for science policy and innovation studies.

The SPIS field has come a long way in 50 years from relatively humble origins. In the latter part of the 1950s, there were a number of individuals and a few 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 between the leading figures in each of these camps, which is recorded in the pages of *Rural Sociology* (see Griliches, 1960 & 1962; Rogers and Havens, 1962). One unfortunate consequence of this early rivalry was limited cross-fertilisation between these two streams of research over subsequent decades (Skinner and Staiger, 2007). For example, although economists and other SPIS scholars cited Rogers (1962, 1971, 1983, 1995 and 2003), they largely ignored Coleman et al. (1966)'s important work on the diffusion of medical innovation.

Besides economists and sociologists, there were also a few early contributions from senior scientists or engineers like 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. Gradually, some of those initially separate research activities began to interact with each other and even to coalesce to a certain extent, although some elements still remained largely isolated. That process of coalescence was partly catalysed by the activities of intrinsically multi- or inter-disciplinary teams of researchers such as those at SPRU and Manchester, who were less constrained by disciplinary boundaries than colleagues 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 was still quite fragmented – witness the debates between economists and sociologists regarding the diffusion of technology, 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 and colleagues have somewhat provocatively termed 'the Stanford-Yale-Sussex synthesis' (Dosi et al., 2006 a & b), although this rather down-plays other important streams of work.

7.2 Missing links?

Although SPIS has over the decades succeeded in developing fruitful links with a number of 'adjacent' social sciences and drawing parts of these into SPIS, there remain some areas where, even though researchers may have focused on various aspects of research or R&D, new product development, new technologies or innovations, they have remained relatively unconnected to the growing body of SPIS. We have already remarked upon the rather limited interaction between sociologists studying medical innovations and the wider SPIS community. Another example is work in marketing. Researchers in 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.[106] Thirdly, given the strong 'policy' dimension to SPIS, one might have expected to see greater interaction with political science. However, this review has identified relatively few SPIS HCPs by political scientists in SPIS, although SPIS researchers have undoubtedly drawn on theories and concepts from political science, such as the notion of epistemic communities (Haas, 1992). A fourth 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 hence becoming part of organisational studies. Nevertheless, one might perhaps have expected to see more prominent interaction with SPIS, for example with regard to the links between creativity (both individual and institutional) and research and innovation.[107]

However, arguably the most prominent example of another field that might have forged closer links with SPIS than it did is ‘science and technology studies’ (STS) – i.e. the work by sociologists of science and technology, along with historians and philosophers of science.[108] There are relatively few instances of interactions between the two fields. For example, the work of Kuhn (1962, 1970 & 1996) has been quite frequently cited by SPIS researchers. In particular, Kuhn’s concept of a scientific ‘paradigm’ was picked up by Dosi (1982), who developed the notion of a ‘technological paradigm’. Merton’s work on the sociology of science (e.g. 1973) and that of certain philosophers of science such as Polanyi (in particular, 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’. However, 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 communities. For example, in the late 1970s, Cole and Cole, two sociologists of science, examined peer review in an explicitly science policy-oriented study. However, the fierce criticism that this study (Cole et al., 1978; Cole and Cole, 1981) attracted from other sociologists of science[109] as well as from scientists (e.g. Harnad, 1985) may well have deterred others from such bridge-building efforts. Another factor is that many in the SPIS may have been sceptical about what a field that often seemed from the outside to have become dominated by ‘social constructivists’ might offer the more practically oriented field of science policy and innovation studies.

7.3 The US dominance – artefact or reality?

There is one aspect of the list of HCPs in Table 1 that is most striking and which merits further comment. This is the heavy, and indeed growing, dominance of US authors. In their study of highly cited economics articles, Kim et al. (2006, p.200) observed a heavy preponderance of US authors, accounting for 85% of economics HCPs. For SPIS, the picture is not dissimilar. Although initially European researchers like Freeman, Pavitt and Dosi were very prominent, in the last 20 years US authors have seemingly come to dominate. This raises two questions. First, is this effect ‘real’ or is it 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 bibliometric analysis. Some who have 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 extent 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 the *growing* US dominance over the last 20 years.

It was precisely to avoid the need for subjective judgements that I chose to adopt an approach based on citation analysis. In science and even more so in social sciences, it has often been asserted that US researchers can be rather 'parochial' in their referencing, tending to cite predominantly US literature, whereas researchers from Europe and elsewhere are perhaps more international in terms of the references upon which they draw. If true, the effect would be to inflate the average citation totals for US publications. Moreover, 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 in this study. The counter-argument is that citations reflect the outcome of a 'democratic' choice as to which references have been most influential and therefore should be cited. It may well be, for example, that US researchers attend a lower proportion of conferences overseas than their foreign counterparts, with the result that they tend to be less familiar with non-US work and hence to cite it less frequently. To this extent, the influence 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 influence academic publications *actually* have, not what influence they might have (or should have) in a completely 'free market'. To this extent, the highly cited publications identified in this study can be seen as corresponding to those that have had most influence, rightly or wrongly, in the imperfect market of academic publishing and referencing.

If we assume that 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.[110] If a publication is to earn over 300 citations, it must almost certainly have a major influence in the US. From the discussion in the previous paragraph, this is evidently easier for US authors to achieve than non-US authors. Secondly, to attain this level of citations, given the relatively small size of the SPIS community compared with that of established social science disciplines such as economics or management, an SPIS publication generally needs to create a significant impact in one or more adjacent social science disciplines.[111] Here, a key institutional difference in the affiliations of SPIS researchers may be significant; many SPIS researchers in Europe are part of a specialised and often interdisciplinary research unit (e.g. CIRCLE, DRUID, Fraunhofer ISI, MERIT, MIoIR (formerly PREST), NIFU-STEP, SISTER, SPRU),[112] 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, seem to 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 (or North American) academics are arguably better placed when it comes to trying to ensure that their publications will have an appreciable influence in at least one major social science discipline.

Thirdly, it may be that there are significant differences in the nature of the SPIS research carried out in the US compared with that in the rest of the world. If so, then it is conceivable that the type of research on which US researchers choose to focus is such that it tends to be more frequently cited by others. For example, Gallivan and Benbunan-Fich (2007) have pointed to a range of evidence that in information science there are different research traditions in North America and in Europe, with the former more positivist and empirical and the latter more qualitative and interpretive. A similar generalisation could perhaps be made about science policy and innovation studies. Even so, in the absence of some other method of operationalising the concept of 'influence', we are presumably then left with the conclusion that positivist and empirical research seemingly attracts more attention and hence more citations than qualitative and interpretive research, and that a higher proportion of American researchers have chosen to position themselves accordingly.

Lastly, there is one further factor that may have contributed to the US dominance of the lists complied here. As is well known from studies of the innovation process, it is not sufficient just to come up with a 'good idea'.[113] 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' than their overseas counterparts. Whether this might be due to the more competitive nature of the US academic market or to some other factor, I leave to the reader to judge.

7.4 Is SPIS in the early stages of becoming a discipline?

We have seen in this paper how SPIS has over time coalesced into a relatively coherent field of research, but has it embarked on the process of transformation into a ‘discipline’? Historians and sociologists of science have shown that the origins of disciplines such as experimental psychology (Ben-David and Collins, 1966) or biochemistry (Kohler, 1982) 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’ in nature, and perhaps at a later stage (when researchers from those different disciplines start to communicate more directly with each other) as ‘interdisciplinary’. Gradually, the accumulating body of research may begin to 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.[114] 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 consider more carefully what we mean by a ‘discipline’. As should be clear from the above discussion, an academic discipline cannot be defined in terms of a single characteristic; there are several characteristics or dimensions that need to be considered. SPIS has certainly begun to acquire some disciplinary characteristics. For example, unlike 30 or more years ago, it now trains most of its own doctoral students rather than recruiting them from other disciplines. As we saw in the previous section, in Europe and various other countries outside the US, there are quite a number of 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, in which many of its publications appear. There has also been a shift in emphasis over the decades from books to journal articles as the primary ‘vehicle’ for researcher to put forward their major contributions,[115] another possible indication of a move towards a more discipline-like nature. Against this, however, is the fact that a large proportion of the most highly cited articles in more recent years continues 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 might be interpreted as reflecting a lack of self-confidence in the institutional standing of the field.[116] 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.[117]

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 innovation studies bring their best papers to present.[118], [119] 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. The field should show: (i) an increasing internal orientation, i.e. it should be self-reflective; (ii) stabilisation of topics around certain 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. [120] Let us examine SPIS with regard to each of these.

The first is concerned with the relative influence on the research agenda of ‘outsiders’ (such as 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 field 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.[121] One small piece of evidence in support of 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 more common in the more-professionally oriented journals, for example in technology and innovation management). This would suggest that SPIS has indeed become more self-contained and ‘self-reflective’, and hence more mature or ‘discipline-like’.[122]
Secondly, we have seen in this review that, from the 1980s onwards, there has been a gradual stabilisation of the topics pursued by SPIS researchers around key research questions, in many cases 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 (2006) revealed. In addition, from the list of HCPs produced here, one can begin to 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.[123]

The fourth criterion concerns the question of whether SPIS research exhibits increasing specialisation on particular theoretical issues. Again, this is difficult to establish, but my subjective impression is that in the last few years a significantly 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.[124] 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.

7.5 Concluding remarks

In conclusion, 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. (2011), it represents one of the first attempts to identify and analyse the most influential contributions to the field of SPIS on the basis of highly cited publications, and appears to be one of the most comprehensive and systematic studies of this type among social science fields 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 started to become a more coherent field centred on the adoption of an evolutionary (or neo-Schumpeterian) economics framework and 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 publications, many of which have had a substantial intellectual impact well beyond the field. After five decades of effort, SPIS has acquired at least some of the characteristics of a 'discipline', although it is still some way from developing a formal 'paradigm'.

Notes

[1] See Fagerberg and Verspagen (2009); using a ‘snow-ball technique’, they identified several thousand researchers working in ‘innovation studies’ (which is slightly narrower than the field of SPIS studied here – see the definition given in Section 2 below).
[2] However, detailed analysis of factors affecting the impact of influential publications is left to a later paper.
[3] Hence, when the research centre was set up at the University of Sussex in 1966, it was given the name ‘Science Policy Research Unit’. The term ‘research policy’ was preferred for the unit created a few months earlier at the University of Lund (the Research Policy Institute) and for the journal created in 1971 by Chris Freeman and others.
[4] This was the time when the ‘science-push’ linear model of innovation described later was most influential.
[5] For example, when the research activities within the Department of Liberal Studies in Science at the University of Manchester were organised into a separate unit in the mid-1970s, this was given the name ‘Policy Research in Engineering, Science and Technology’ (PREST). In 1983, Boston University created the ‘Center for Technology and Policy’, while in 1985 MIT brought together the former Center for Policy Alternatives and the Technology and Policy Program to create the ‘Center for Technology, Policy, and Industrial Development’ (CTPID) (Moavenzadeh, 2006). In the latter part of the 1980s, the Centre for Research on the Management of Technology (CROMTEC) was created at UMIST in Manchester.
[6] Examples include the Centre for Research in Innovation Management (CENTRIM) at Brighton University (established in 1990), Hitotsubashi University’s Institute of Innovation Research (created in 1997), and the Manchester Institute of Innovation Research (formed in 2007 when Manchester University and UMIST merged). Likewise, new journals set up in more recent times have often included ‘innovation’ in their title, for example, *Economics of Innovation and New Technology* (created in 1990).
[7] Another option considered was ‘science, technology and innovation studies’. However, this was rejected because it is too close to the label currently used for another field of research – ‘science and technology studies’ (STS). As we shall see, STS has generally operated rather separately from SPIS.
[8] But not, in general, the history of science – see below.
[9] The journal *R&D Management* was set up in 1970.
[10] Drejer (1997) analyses various phases in the development of research on the management of technology.
[11] Examples of prominent researchers who have engaged significantly in both fields include Michel Callon, Arie Rip, John Ziman and Sheila Jasanoff.

[12] Scientometrics was originally part of 'science and technology studies' in the 1960s and 1970s, but began to drift apart from the rest of STS in the 1980s (Martin et al., 2011), since which it has become closer to SPIS.
[13] This includes some work, for example, by Alexander Gerschenkron and Stanislaw Gomulka, and more recently by Carlota Perez and Bengt-Åke Lundvall. Gomulka was far more influential 20-30 years ago than now. This highlights a potential problem with the approach adopted here – namely, that it is written from today's perspective, while 20-30 years ago, things may have looked quite different. In principle, one could investigate this by restricting the citations counted to those earned during a particular period, but that would entail a lot more work.
[14] Some of the highly cited publications identified below certainly contain aspects of technology assessment, for example Brown and Duguid (2000). However, the highest cited publication specifically on technology assessment appears to be Rip et al. (1995) with around 130 citations, well below the threshold adopted here.
[15] See Allen and Sosa (2004) for the early history of engineering management.
[16] Moreover, data for other, closely adjacent fields of activity (such as 'science and technology studies') have also been compiled by the author for comparative purposes.
[17] Highly cited publications such as these are listed in Table 1 (or Table 2 if written by 'outsiders' to SPIS). All other references are listed in the bibliography at the end of the paper.
[18] Another important (but less highly cited) review can be found in Kelly and Kranzberg (1978).
[19] For example, a 2004 issue of *IEEE Transactions on Engineering Management* (issue 4) was largely devoted to personal reflections on the previous 50 years of research in engineering management.
[20] One exception is the list of 'significant and influential' articles drawn up by the Editors of *Research Policy* (Bean et al., 1993). However, this was based solely on articles that had appeared in *Research Policy* over the previous 20 years, and again the list was constructed on the basis of subjective judgements.
[21] The search algorithm he used depends on combinations of certain words (e.g. 'economics' and 'technology' appearing in a book's title'; titles lacking one of the requisite combinations may therefore have been omitted.
[22] His list of 'books and early seminal works' does include a few early journal articles that were particularly important; however, the decision as to which to include seems to have been made on a subjective basis (rather than, say, on the basis of citation impact).
[23] For example, Freeman appears near the top (in 6th, 2nd and 7th position) in three of the columns but does not appear at all in the fourth. Similarly, Rogers is prominent in three of the columns but absent from the fourth.

[24] This approach has subsequently been extended to analyse entrepreneurship studies (Landström et al., 2011) and science and technology studies (Martin et al., 2011).
[25] Both these lists of authors have been included in the author list used here.
[26] In addition, Linton (2004) has ranked TIM departments, while Linton (2006) and Linton and Embrechts (2006) have ranked TIM journals.
[27] Silva and Teixeira (2009) have also carried out a bibliometric analysis of evolutionary economics, although in this case they did not use highly cited publications as an indicator.
[28] There have been numerous other bibliometrically-based studies of economics, mostly focusing on comparative rankings of economics departments (see e.g. the special issue of *Journal of the European Economic Association*, 1 (6), 2003, the articles here citing numerous earlier studies), journals or individual economists (e.g. Medoff, 1996; Coupé, 2003; van Ours and Vermeulen (2007) rather than identifying key research contributions. There have also been studies of other economics-related fields such as finance. For example, Alexander and Mabry (1994) analysed leading authors and publications in financial research, but this was based on only four journals and covered only four years. Arnold et al. (2003) carried out a later analysis of financial research, this time based on six journals and a 10-year period. Both these studies only considered citations from other articles within their journal set (i.e. from within finance).
[29] This is the approach adopted recently by Fagerberg et al. (2011) - see above.
[30] Other studies of political science include Berndtson (1987), who analysed the history of US political science and its rise to position of dominance; Farr (1988) who reviewed four recent histories of political science; and the book by Easton et al. (1991), which contains chapters on the development of political science in different countries and regions. A more recent article is that by Coakley (2004), who examines the organizational evolution of political science.
[31] So far, no similar bibliometric studies have been identified in the field of organizational studies (for example, in the 1996 *Handbook of Organization Studies* or the 1989 *Handbook of Industrial Organization*).
[32] See http://rankings.ft.com/businessschoolrankings/global-mba-rankings-2011 (accessed April 2011).
[33] See http://www.in-cites.com/nobel/2007-eco-top100.html (accessed April 2011).
[34] In 2004, the journal *Management Science* published reviews of major developments in the main management subfields over the previous 50 years. However, most of these focused exclusively on articles in that journal, with key papers being identified primarily on the basis of judgements by the authors of the reviews, although informed by data on papers in the journal cited over 50 times. SPIS authors feature prominently in the review of strategy (Gavetti and Levinthal, 2004) as well as that on technological innovation (Shane and Ulrich, 2004).

[35] Various other studies have since carried out of the information systems (IS) field, including that by Walstrom and Leonard (2000), who identified the most highly cited papers in nine IS journals over the period 1986-1995. However, such studies have been criticised by Gallivan and Benbunan-Fich (2007) and by Whitley and Galliers (2007) for their use of a small and selective set of 'leading' IS journals as the source of the citations analysed.

[36] In a later study of the field of *entrepreneurship*, Cornelius et al. (2006) identified 'core researchers' and produced co-citation 'maps' showing how these are clustered over time – i.e. maps of the evolving 'research front' of entrepreneurial studies; however, their focus was more on individual authors than key contributions. Another co-citation analysis was carried out by Schildt et al. (2006), who mapped the 25 most central research streams in entrepreneurship and identified 'representative works' at the heart of each cluster.

[37] His search algorithm involved the use of the term 'knowledge management' so publications without this term in the title will apparently have been omitted.

[38] One of the four main themes he identifies is 'knowledge-based strategy', an area in which several SPIS researchers have been prominent (e.g. Teece, Cohen, von Hippel and Leonard-Barton).

[39] More recently, Pilkington and Meredith (2009) have analysed the evolution of the intellectual structure of operations management over a much longer period (1980-2006), with the analysis being based on citations in three major journals in the field.

[40] For example, the 'systems of innovation' concept has undoubtedly had a significant impact on policy makers (Lundvall, 2007), this impact having been catalysed in the early 1990s by OECD. Also influential has been the work by SPIS researchers in developing various indicators of science, technology and innovation, with OECD, along with NSF, again playing a key role in diffusing these developments. In the case of impact on management, research on the nature of the innovation process and on factors affecting the success and failure of innovation has been particularly influential, often mediated through teaching in business schools as well as through 'professional' publications (such as *Harvard Business Review*).

[41] One could search with Google to identify the number of web documents citing a particular concept that has emerged from the work of SPIS researchers, as Lundvall (2007) has recently done for 'national systems of innovation'. However, it is far from obvious how one should treat the results of such a search since it is not clear what is (and what is not) included in the Google coverage, let alone whether all the citations should be treated as being of equal 'weight'.

[42]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).

[43] In recent years, certain published conference proceedings have been added to the sources scanned.

[44] A journal that is not scanned by the *Citation Index* ‘loses’ all the citations contained within it to articles published in that journal, so its apparent impact factor may remain low – below the threshold needed to justify the journal’s inclusion in the *Citation Index.*

[45]There were various 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, suggestions from colleagues, and so on. 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. Nevertheless, a few ‘gaps’ may possibly still remain, reflecting the starting point of this ‘snow-ball’ process and the biases of the author (see the earlier discussion as to where the coverage is perhaps less comprehensive).

[46] For a more complete list, see the various terms listed in Section 2 in defining the scope of the SPIS field (for example, those terms relating to the resource-based view of the firm).

[47] 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. Hence, the most likely omissions are books or articles where the title contains none of the key words used here, *and* where that work has then been largely ignored by the rest of the SPIS community (see the discussion about possible omissions at the end of Section 2).

[48] Despite the effort to carefully delimit the field of SPIS and its component parts (see above), an element of subjectivity in this process may inevitably remain.

[49] Among bibliometric experts, the general view seems to be that Google Scholar is not yet a sufficiently reliable source for counting citations, not least because Google have not made clear exactly what sources are scanned by their search-engine.

[50] The ‘General Search’ facility in the WoS only works for articles in journals scanned by the *Citation Index* – books, book chapters and other publications are excluded.

[51] However, where separate editions of books were published three or more years apart, they were treated as different publications. In some cases, such as the different editions of Rogers' book on *Diffusion of Innovations* or Freeman's book on *The Economics of Industrial Innovation* , this seems sensible, since successive editions contain much new or substantially updated material. In other cases, such as later editions of Schumpeter (1942), one could argue that those later editions were essentially the same book so they should be treated as a single publication. However, it was felt that a consistent approach should be adopted for all books, and the former approach was the one eventually adopted.
[52] As we note in the concluding discussion, there is an important methodological issue to note here. For the most cited HCPs (those with citation totals of 1000 or more), it is likely that many of those citations come from authors *outside* the SPIS field in other social sciences. In such cases, the high citation total reflects the impact of that particular publication in other fields. 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. In this way, one could establish whether rankings on HCPs based on within-field citations are broadly similar to those based on total citations.
[53] In fairness, it should be noted that Kim et al. (2006) only included articles published over the period 1970-2005, while I have considered a somewhat longer period and have included books as well as articles.
[54] I have not, thus far, used co-citation analysis to cluster HCPs into intellectual themes, as has been done in several of the studies of subfields of management described above. If one is using WoS data, this can be done relatively easily for articles in journals scanned by WoS, but not for books and book chapters, or at least not without a huge amount of effort, as books are not scanned for citations by WoS and therefore are not included in the 'General Search' facility. Such an analysis has therefore been left for future research.
[55] As can be seen from Table 1, the original German edition of 1911/12 gained a further 500 citations.
[56] The second and third editions of the 1942 book together earned another 1800 citations, while the sixth edition in 1976 has been cited 500 times.
[57] Godin (2011, p.28) argues that the economic historian "[WR] Maclaurin is the real 'father' of technological innovation studies, not Schumpeter". However, Maclaurin's most cited work, *Invention and Innovation in the Radio Industry* (1949), had only received around 90 citations by the end of 2010, well below the citation threshold used here.
[58] Early work by sociologists on the diffusion of new agricultural technologies was also quite prominent (e.g. Ryan and Gross, 1943, although this has earned just under 300 citations, the threshold adopted here).
[59] As Godin (2006) points out, Bush only discussed the links between science and socio-economic development in very broad terms rather than putting forward a formal 'model'. Godin also shows how the origins of the linear model can actually be traced back a number of decades earlier.

[60] Nelson (1974) points out that Schmookler (1952) had arrived at broadly the same conclusions five years before Solow (and on the basis of stronger data), but this had been largely overlooked by economists (it has been cited only about 40 times).
[61] See the references cited in the review by Hahn and Mathews (1964).
[62] 20 years later in 1979, Griliches 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.
[63] 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 Burton Klein and including Armen Alchian, Kenneth Arrow, William Meckling, Merton Peck and (from 1959) Sidney Winter (see Hounshell, 2000). However, much of their work took the form of classified RAND reports rather than being published in journals, so none of this work from the 1950s seems to have been highly cited until Nelson's article on the economics of basic research was published in 1959.
[64] A key element of the historical context to Nelson's 1959 paper was the 1957 Sputnik-induced 'crisis' of confidence in the US, with questions being asked among economists and others as to why insufficient resources were apparently being allocated to research in the US.
[65] However, as Mowery and Rosenberg (1979, p.139) point out, Schmookler's main focus was actually on 'invention' (and how changes in market demand influence the resources allocated to inventive activity), not (commercially successful) 'innovations'.
[66] The 'demand-pull' model is not to be confused with the theory of 'induced innovation' put forward by other economists in the 1960s. Of these, Kennedy (1964) appears to have been the most highly cited (with 170 citations by the end of 2010). In addition, Nordhaus (1969) (290 citations) came up with a growth theory in which technical change figured prominently, and there was also work on neo-technological trade theory, for example, by Posner (1961) who formulated the 'technology gap' theory of trade (205 citations).
[67] Together with Mowery, Rosenberg also produced an influential review of empirical studies on the influence of market demand on innovation (Mowery and Rosenberg, 1979 – cited 205 times by the end of 2010). This represented one of the last contributions to the fierce debate that had been running since the latter part of the 1960s between proponents of the 'science-push' and 'demand-pull' models of innovation. However, none of the other contributions to that debate were particularly highly cited, even though they undoubtedly had an impact at the time. These include the Project Hindsight report by Sherwin and Isenson (1967) (with 75 citations); the TRACES report by IITRI (1968) (~100 cites); the NSF report by Myers and Marquis (1969) (170 cites); the *Wealth from Knowledge* book by Langrish et al. (1972) (205 cites); Gibbons and Johnston (1974) (100 cites); and the Comroe and Dripps (1976) article in *Science* (200 cites).

[68] Another HCP that is on the borderline 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. This is one of the few HCPs relating to energy that have been identified in the search reported here. (It is possible that papers on energy, in general, receive fewer citations and therefore most fall below the threshold of 300 citations adopted here.)
[69] In the preface to this, Penrose acknowledges significant contributions from Schmookler and Machlup, two other key figures in the early stages of the development of SPIS.
[70] 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'.
[71] Likewise, another highly cited from marketing, Cooper's (1979) analysis of the factors affecting the success and failure of new industrial products, has been rarely cited by SPIS researchers.
[72] This built on earlier work at MIT in the 1950s on the management of R&D. In the mid-1950s, there had been a short-lived 'R&D Management group' at MIT consisting of Albert Rubinstein (who subsequently founded a research group at Northwestern University), Herb Shepard and Rupert Maclaurin. Afterwards, a new group formed under Donald Marquis in the School of Industrial Management (before it was renamed the Sloan School of Management) (Allen and Sosa, 2004). However, none of this MIT work from the 1950s appears to have been particularly highly cited.
[73] Burns was a sociologist and Stalker an organisational psychologist.
[74] The pioneers of contingency theory also had some observations on the role of technology. Lawrence and Lorsch (1967) were central in developing the argument that organisations function best when designed and tailored to their environment. According to them, two basic elements in an organisation's design are differentiation and integration. Each sub-system in the organisation is designed to fit with its respective environmental sector (for example, R&D with latest technological developments). This process results in units that are differentiated from each other, and this may generate inter-unit conflict unless resolved by some process of integration. Thompson (1967) was another major contributor to contingency theory; in his view, "Uncertainties pose major challenges to rationality, and … technologies and environments are basic sources of uncertainty for organizations" (p.1). He argued that organisational structure and dynamics are strongly influenced by the type of technology employed as well as the organisation's goals, environmental pressures and problems of coordination.

[75] 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 at Manchester on technical change by Charles Carter and Bruce Williams in the 1950s. 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 to SPRU was the MIT Center for Policy Alternatives, where Utterback (see above) was based for a number of years. Some former CPA staff, along with SPRU collaborators, were subsequently responsible for the highly cited 1990 book by Womack et al., *The Machine that Changed the World* – see below).

[76] 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.

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

[78] Three years earlier, they had published a comparison of neo-classical and evolutionary theories of economic growth, which included a strong critique of the former (Nelson and Winter, 1974), but this was not particularly highly cited. Indeed, one can trace the origins of evolutionary economics further back to the two authors' previous work in the late 1950s and early '60s at the RAND Corporation, where, under the direction of Burton Klein, analyses of military R&D projects had highlighted uncertainty involved in carrying out and in managing R&D, and hence the importance of maintaining a diversity of approaches to technological development particularly in the early (and most uncertain) stages. During his time at RAND, Winter had written an internal paper in 1960 on 'Economic natural selection and the theory of the firm' (Hounshell, 2000, pp.292 & 310). See also Nelson's (2003) reflections on the origins of evolutionary economics.

[79] 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 that book far exceeds that for Nelson and Winter (1982).

[80] Later, Basalla (1988) was to put forward an evolutionary theory of technological change, drawing upon the history of technology as well as economic history, and emphasising three themes – diversity, necessity and technological evolution.

[81] Here, they were influenced by the 'Carnegie School' of researchers such as Herbert Simon, Richard Cyert and James March, who had shown that organisational behaviour is strongly guided by decision-rules or 'routines' (Nelson, 2003).
[82] One much more recent HCP on the economics of innovation is DiMasi et al.'s (2003) estimate of the costs of new drug development.
[83] 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.
[84] At 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'. However, compared with Romer, he drew relatively little on the work of SPIS researchers and others on technological change and innovation.
[85] Shane and Venkatamaran (2000) have produced a conceptual framework to explain empirical phenomena in the field of entrepreneurship and to make a number of predictions.
[86] See also the related section on 'organisational learning' below.
[87] Others who have attempted to develop a theory of the firm include Cyert and March (1963) (see Section 5.2.4) and Jensen and Meckling (1976) (who make no reference to innovation).
[88] The resource-based theory of the firm is debated in Organization Science, Vol.7, No.5 (1996). Other highly cited articles appearing there include those by Conner and Prahalad (1996) and Kogut and Zander (1996).
[89] Subsequently, Lane and Lubatkin (1998) came up with a modified construct of 'relative absorptive capacity', according to which one firm's ability to learn from another depends on certain similarities between them. Only a few papers published since 2000 have earned over 300 citations, one that has being Zahra and George (2002), who distinguish different dimensions of absorptive capacity (potential and realised) and put forward a reformulation of the concept.
[90] Somewhat related to this is North's 1990 book on *Institutions, Institutional Change and Economic Performance*, which is concerned with the interactions between institutions ("the rules of the game in society" – ibid., p.3) and organisations ("the players" – ibid., p.4) as they co-evolve. The book attempts to develop a theory of institutional change as well as to put forward a framework for explaining the ways in which institutions (and institutional change) affect the performance of economies, thereby accounting for the widely varying performance of economies over time. Although he drew on the work of only a few historians of technical change and innovation, this book has had a significant impact on SPIS scholars.

[91] The model was subsequently extended by Venkatesh and Davis (2000), while other influential articles on the diffusion of technology or innovations within organisations include Cooper and Zmud (1990) and Greenhalgh et al. (2004).
[92] Weick's (1995) book on sense-making in organisations is another significant contribution to organisational learning.
[93] A later, highly cited contribution to knowledge management is Davenport and Prusak's (1998) book on how organisations manage what they know, while one of the few highly cited post-2000 articles identified in this study is the review of KM by Alavi and Leidner (2001).
[94] In an earlier article, Cook and Brown (1999) distinguish knowledge from 'knowing', arguing that the 'generative dance' between the two is a powerful source of organisational innovation.
[95] Freeman traces the origin of the concept back to List (1841), with his notion of the 'national system of political economy' that he used to explain Germany catching up and overtaking Great Britain. Freeman had in fact written a paper on the concept a few years before his 1987 book, but this was only published 20 years later (see Freeman, 2004, and the introduction to it by Lundvall, 2004).
[96] 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 technology clusters. However, the underlying concept of clustering can be traced back to Alfred Marshal's (1890) work on 'industrial districts'.

[97] 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.
[98] See also the related contributions described above in Section 6.3.4.
[99] The chapter by Hughes on 'The evolution of large technological systems', with its discussion of 'reverse salients', has been particularly influential in the SPIS community; its total of 295 citations is just below the threshold used for HCPs in this study, but some authors may have chosen to cite the entire book rather than this specific chapter, thus diminishing its citation total.
[100] 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.
[101] 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, specifically those relating to the environment.

[102] Among the authors, Gibbons is part of the SPIS community, while Nowotny is very much in the 'science studies' community. As an academic, Limoges was likewise part of the latter community, although he also worked in the world of science policy, serving two terms as a Deputy Minister in the Quebec government. The other three authors come from the field of higher education studies/policy.

[103] They were not, however, the very first to use patent data; for example, in the 1930s Gilfillan and Merton were both analysing patent statistics, but none of their publications from the time were highly cited (perhaps because the *Citation Index* came too late to catch much of the impact of that early work).

[104] As noted in an earlier footnote, OECD and NSF (where in both cases a number of SPIS researchers have worked) have each been central in the development of R&D statistics, and the former has also helped to pioneer the development of innovation surveys.

[105] Nor have any of the *Science (and Engineering) Indicators* reports published by the US National Science Board been highly cited.

[106] One of the few SPIS papers that attempted to integrate these separate streams of research in marketing and SPIS on the diffusion of new technology and innovation is Karshenas and Stoneman (1992).

[107] While there certainly has been some work in this area, none of it has apparently been particularly highly cited.

[108] Kärki (1996) likewise found little interaction between STS researchers and information scientists; even when they were studying the apparently common area of scholarly communication, the two sets of researchers preferring mostly to "stay in their own respective territories" (p.323).

[109] As the author well remembers from science studies conferences at the time.

[110] 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.

[111] In a later paper, I plan to differentiate between 'global impact' (as investigated here) and 'impact within SPIS', with the latter being operationalised by looking only at citations within core SPIS journals. The aim is to see if the ranking of HCPS based on global impact is very different from that based on 'impact within SPIS'.

[112] And the same is often true in other parts of the world such as Japan (e.g. NISTEP, IIR Hitotsubashi), South Korea (STEPI), India (CSSP, CRISP) and China (NRCSTD).

[113] 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 should hold) when it comes to their own work having an impact!

[114] See also Eom (1996): ‘A review of the major works of Kuhn, Kaplan, and Cushing describes the process by which an academic discipline becomes establishment in terms of four steps: (1) Consensus building among a group of scientists about the existence of a body of phenomena that is worthy of scientific study; (2) Empirical study of the phenomena to establish a particular fact or a generalization; (3) Articulation of theories to provide a unified explanation of established empirical facts and generalizations; and (4) Paradigm building to reach a consensus on the set of elements possessed in common by practitioners of a discipline such as shared commitments, shared values, and shared examples (exemplars).’ Vessey at al. (2002) also discuss what constitutes a discipline and the extent to which the field of information systems is acquiring the characteristics of a discipline.

[115] As Pasadeos et al. (1998) found in the case of advertising studies, and Ramos-Rodriguez and Ruiz-Navarro (2004) in the case of strategic management.

[116] Cf. the discussion by Pilkington and Liston-Heyes (1999) on the field of production and operations management, and by Pilkington and Teichert (2006) on technology management.

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

[118] 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.

[119] As we saw in Section 6.6.2, the fact that key methodological papers are not highly cited (as they are in economics) might be further evidence that SPIS still lacks the maturity of established social sciences.

[120] 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’.

[121] Whether this is desirable or not is another matter.

[122] Cf. the discussion in Pasadeos et al. (1998) about whether the literature on advertising studies has begun to exhibit more disciplinary rigour, and similar discussions by Pilkington and Liston-Heyes (1999) in connection with operations and production management, and Cornelius et al. (2006) on entrepreneurial studies. See also the debate between Wade et al. (2006a & b) and Grover et al. (2006) over whether information science is yet a discipline.

[123] In a later paper, I intend to analyse more systematically which individual SPIS researchers have had the greatest influence on the development of the field.

[124] See the discussion in Schmenner et al. (2009) on the use of theory in the field of operations management.

[125] High-impact publications as reflected in ≥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 listed here.

[126] High impact publications as reflected in ≥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*. The boundary between publications produced within SPIS (in Table 1) and those outside SPIS (Table 2) is again inevitably a rather 'fuzzy' one. Research specifically focussing on innovation, technology etc. has normally be categorised within the former, while work primarily addressing other issues but which has nevertheless been drawn upon extensively by SPIS researchers has been grouped under Table 2.

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TABLES

Table 1. High-impact SPIS contributions[125]

'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
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
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
G Dosi, C Freeman et al. (eds) (1988), *Technical Change and Economic Theory*	735
C Freeman, C Perez (1988), ‘Structural crises of adjustment’, in Dosi et al., *Tech Change*	515
RH Hayes et al. (1988), *Dynamic Manufacturing: Creating the Learning Organization*	510
BA Lundvall (1988), ‘Innov’n as interactive process’, in Dosi et al., *Tech Change*	460
ML Markus, D Robey (1988), ‘Info technology & organizational change’, *Mngt Sc*	360
E von Hippel (1988), *Sources of Innovation*	1340
WB Arthur (1989), ‘Competing technologies, increasing returns …’, *Econ J*	1130
KA Bantel, SE Jackson (1989), ‘Top mngt & innov’ns in banking’, *Strat Mngt J*	485
WM Cohen, RC Levin (1989), ‘Emp studies of innovation …’, in *Handbook of Ind Org*	420
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
D Mowery, N Rosenberg (1989), *Technology and the Pursuit of Economic Growth*	320
JF Reinganum (1989), ‘Timing of innovation: R&D & innov’n’, in *Handbook of Ind Org*	300
M Storper, R Walker (1989), *Capitalist Imperative: Territory, Tech’y & Ind Growth*	600
ZJ Acs, DB Audretsch (1990), *Innovation and Small Firms*	365
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
RM Henderson, KB Clark (1990), ‘Architectural innovation’, *Admin Sc Q*	1270
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
PM Romer (1990), ‘Endogenous Technological Change’, *J Pol Econ*	2355
FM Scherer (1990), *Industrial Market Structure & Economic Performance* (3rd ed.)	1185
JP Womack et al. (1990), *The Machine that Changed the World*	2200
JS Brown, P Duguid (1991), ‘Org learning & comm’s of practice … innov’n’, *Org Sc*	1105
KB Clark, T Fujimoto (1991), *Product Development Performance*	1170
KR Conner (1991), ‘Historical comparison of resource-based theory …’, *J Mngt*	530
F Damanpour (1991), ‘Organizational innovation – a meta-analysis …’, *Acad Mngt J*	835
GM Grossman, E Helpman (1991), *Innovation & Growth in the Global Economy*	1750
I Nonaka (1991), ‘The knowledge-creating company’, *Harvard Business Review*	895
P Aghion, P Howitt (1992), ‘Model of growth thro creative destruction’, *Econometrica*	850
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
RG Cooper (1993), *Winning at New Products*	310
TH Davenport (1993), *Process Innovation: Reengineering Work thro Info Technology*	1010
GR Hodgson (1993), *Economics & Evolution*	370
AB Jaffe et al. (1993), 'Geographic localization of knowledge spillovers', *Qu J Econ*	1080
DA Levinthal, JG March (1993), 'The myopia of learning', *Strategic Management J*	850
RR Nelson (ed.) (1993), *National Innovation Systems*	1305
RW Woodman et al. (1993), 'Toward a theory of organizational creativity', *Ac Mngt Rev*	370
G DeSanctis, MS Poole (1994), 'Capturing the complexity in adv tech'y use', *Org Sc*	535
M Gibbons et al. (1994), *The New Production of Knowledge*	1560
RM Henderson, I Cockburn (1994), 'Measuring competence … firm effects', *Str Mngt J*	520
MM Montoya-Weiss, R Calantone (1994), 'Determinants of new prod perf', *J Prod Innov Mngt*	320
I Nonaka (1994), 'Dynamic theory of organizational knowledge creation', *Org Sc*	2125
JB Quinn, FG Hilmer (1994), 'Strategic outsourcing', *Sloan Mngt Rev*	325
AL Saxenian (1994), *Regional Advantage: Culture & Competition in Silicon Valley*	1625
D Teece, G Pisano (1994), 'Dynamic capabilities of firms', *Ind & Corp Change*	380
JM Utterback (1994), *Mastering the Dynamics of Innovation*	795
E von Hippel (1994), 'Sticky info & locus of problem-solving …', *Mngt Sc*	530
DB Audretsch (1995), *Innovation and Industry Evolution*	345
SL Brown, KM Eisenhardt (1995), 'Product development …', *Acad Mngt Rev*	670
DT Coe, E Helpman (1995), 'International R&D spillovers', *Europ Ec Rev*	610
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