

THE EVOLUTION OF SCIENCE POLICY AND INNOVATION STUDIES

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The Evolution of Science Policy and Innovation Studies

1. Introduction

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

The aims of this paper are to systematically identify and analyse

- the intellectual origins of the field
- the disciplines upon which the field has drawn and how this has evolved over time
- the key intellectual developments or contributions
- to assess whether the field is beginning to coalesce around a common conceptual framework and set of analytical tools

This review is intended to serve as an introduction to the field useful for research students and other ‘new comers’ to the field, or to academic faculty developing lecture courses and reading lists. It may also offer SPIS ‘insiders’ a more comprehensive overview or ‘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 currently rather separate bodies of research, and hence offer guidance as to where they might most fruitfully concentrate their efforts. Lastly, the paper 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 paper is as follows: Section 2 defines the scope of the field of ‘science policy and innovation studies’. Next, we review the literature on previous attempts to map or review the field, but also examine similar studies in neighbouring social science fields. Section 4 sets out the methodology employed here to identify those contributions from SPIS 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

¹ See Fagerberg and Verspagen (2006); using a ‘snow-ball technique’, they identified several thousand researchers working in the field of ‘innovation studies’ (which is slightly narrower than the field of SPIS studied here – see later definition).

² However, detailed analysis of factors affecting the impact of influential publications is left to a later paper.

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 it 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 first need to specify exactly what is the focus of analysis in this review. One problem to contend with is that different people have labelled the field 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 vital ‘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’.

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 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).

⁶ Examples include the Centre for Research in Innovation Management (CENTRIM) at Brighton University (established in 1990) and Hitotsubashi University’s Institute of Innovation Research (created in 1997).

Over time, it likewise became apparent that the term ‘policy’ was too narrow and misleading, with many researchers focusing more specifically on the ‘management’ of R&D, technology or innovation, while the involvement and influence of economists also grew rapidly, particularly following the development by Nelson and Winter of an evolutionary approach to economics. Rather than attempting to come up with a label involving some cumbersome combination of ‘policy’, ‘management’ and ‘economics’ (let alone the other social sciences that, by the 1990s, were making a major contribution to the field – for example, organisational studies), many have therefore opted for the simple and succinct label of ‘innovation studies’. However, I have chosen not to adopt this here for two main 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 of ‘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 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 part of endogenous growth theory (which also gives particular prominence to technology and innovation);
- economic history – more specifically, the history of technology and innovation⁸ and the relationship of technology and innovation to economic growth;

[Could also give examples based on names of new journals established at different times – see Linton and also my list of journals scanned]

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’. As we shall see, the latter has generally operated rather separately from SPIS.

⁸ But not, in general, the history of science – see below.

- management – this includes R&D management (again, a somewhat older term now less in favour), industrial R&D, new product development, technology management,⁹ innovation management, much of entrepreneurship, a significant part 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 (a topic that is 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 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;¹⁰)
- most scientometrics or bibliometrics research – again, this is a rather separate research community from SPIS, 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 (e.g. the *Limits to Growth* debate, work on global environmental change, etc.), 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 a key element (for example, ‘technology transfer’ or ‘appropriate technology’);¹¹
- 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.

⁹ Drejer (1997) analyses various phases in the development of research on the management of technology.

¹⁰ Examples of prominent researchers who have engaged significantly in both fields include Michel Callon, Arie Rip, John Ziman and Susan Cozzens.

¹¹ This includes work, for example, by Alexander Gershenkron, Stanislaw Gomulka, 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.

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 only one highly cited publication relating to this area;¹²
- ‘engineering management’ – this began somewhat earlier as a field (the journal *IEEE Transactions on Engineering Management* was established in 1954¹³); while it clearly overlaps with ‘R&D management’ or ‘technology management’, there were 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/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 well integrated 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 attempted 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.¹⁴

3. Literature review

Next, let us consider the relationship of this exercise to previous efforts to map or review the field. There have been several attempts to do this, most notably in various textbooks or handbooks, but also in a number of major review articles. Highly cited examples include Freeman (1974, 1982 & 1997), Nelson & Winter (1977), Dosi (1988), Griliches (1990) and Brown & Eisenhardt (1995).¹⁵ A recent and particularly comprehensive attempt is that by

¹² Brown and Duguid (2000) – see below. The next highest cited publication appears to be Rip et al. (1995) with ~150 citations, well below the threshold adopted here.

¹³ See Allen & Sosa (2004) for the early history of engineering management.

¹⁴ Moreover, data for other, closely adjacent fields of activity (such as ‘science and technology studies’) have also been compiled for comparative purposes.

¹⁵ P. Kelly and M. Kranzberg (1978), *Technological Innovation: A Critical Review of the Literature* (San Francisco press) – extensive review of literature on technological innovation – may have used some quantitative tools? (J Utterback – to scan and send to BM). But only ~40 citations.

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’,¹⁶) than the field of SPIS as defined here.¹⁷

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 the researchers involved in these two research streams. However, their focus was much narrower than the study reported here. A few years later, Granstrand (1994) produced an overview of the economics of technology. However, as the title suggests, he focused on *economic* contributions, largely ignoring those from management, organisation studies, sociology and elsewhere. Secondly, he concentrated primarily on identifying books¹⁸ that had made important contributions;¹⁹ 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 (from 4 to 31), with the result that it is unclear what significance can be attached to the relative positions of authors.²⁰ Lastly, this analysis is based on data that is now 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 (2006) have analysed the development of innovation studies. However, they used the results from an extensive survey of researchers rather than bibliometric analysis. Moreover, these studies again focused on the *economics* of innovation and technological change rather than the

¹⁶ 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.

¹⁷ 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.

¹⁸ The search algorithm used here 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.

¹⁹ 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).

²⁰ 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.

somewhat broader field of SPIS as specified here. Aside from Granstrand (1994), there have been 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 & 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.^{21 22}

As we shall see in the next section, the approach adopted in this study focuses on highly cited publications (HCPs). There have apparently been no such prior exercises for the field of SPIS.²³ The closest is perhaps the analysis of the rather 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 (ranging from 10 to 31). 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 our more extensive study. [Also recent studies of (i) structural change and economic dynamics by Silva & Teixeira (2008) – identifies HCPs in this specialty – some overlap with HCPS in SPIS; and (ii) evolutionary economics by Silva & Teixeira (2009) – again, significant overlap with SPIS)

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).²⁴ However, they made no attempt to identify highly cited books (or book chapters).

²¹ Both these lists of authors have been included in the author list used here.

²² In addition, Linton (2004) has ranked TIM departments, while Linton (2006) and Linton and Embrechts (2006) have ranked TIM journals.

²³ Fagerberg and Verspagen (2007) have carried out an analysis of those authors who are most frequently cited in chapters of the 1994 *Handbook of Industrial Innovation* edited by Dodgson and Rothwell and the 2004 *Oxford Handbook of Innovation* edited by Fagerberg et al., and this research is now being extended by Fagerberg and his colleagues to include other handbooks. Their approach is similar to that adopted by Goodin and Klingemann (1996b) with regard to political science (see below).

²⁴ 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 *JEEA*, 1 (6), 2003, the articles here citing numerous earlier studies), journals or individual economists (e.g. Medoff, 1996; Coupé, 2003) rather than identifying key research contributions. There have also been studies of other economics-related fields such as finance. For example, Alexander and Fabry (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.

With regard to other ‘neighbouring’ disciplines on which SPIS draws, in the case of sociology, Halsey and Donovan (2004) identified the sociologists held in the highest respect as researchers or as teachers, their results being based on peer review (more specifically, a survey of UK sociology professors) rather than bibliometric analysis. In political science, one of most comprehensive studies of 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 to sub-fields of political science, to the discipline as a whole, and to the integration of the discipline.²⁵

In management and business²⁶, there are many rankings of leading business schools, some ‘academic’ (e.g. Erkut, 2002), others produced by newspapers and magazines (e.g. *The Financial Times*²⁷). 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 business²⁸). Nevertheless, there have been numerous empirical analyses of various sub-fields of management.²⁹ One of the first (Culnan, 1986) focused on *management information systems* (MIS), identifying highly cited authors and then using co-citation analysis to investigate the changing sub-field structure of MIS research.³⁰ 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)

Both these studies only considered citations from other articles within their journal set (i.e. from within finance).

²⁵ 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.

²⁶ 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*).

²⁷ See <http://media.ft.com/cms/9753d360-a6ee-11db-83e4-0000779e2340.pdf>).

²⁸ See <http://www.in-cites.com/nobel/2005-eco-top100.html> .

²⁹ 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 & Levinthal, 2004) as well as that on technological innovation (Shane & Ulrich, 2004).

³⁰ 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.

identified the most highly cited papers in *entrepreneurship* research, although they focused only on articles in six journals over a six-year period so the citation totals are quite small (in the range 10-40).³¹ 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 (the highest is 37 and the great majority are under 20). 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*,³² identifying the most cited authors and how they are clustered in terms of key themes.³³ However, this analysis was limited to publications appearing over the five-year period 1994-1998, so the citation numbers involved are small (highly cited authors are those with just 4 or more citations), again raising issues about the statistical significance of the results. Similar comments apply to the studies by Acedo et al. (2005) in the field of *international management*, and by Pilkington and Fitzgerald (2006) in *operations management*.

To sum up, while 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, 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.

³¹ In a more recent study of the field of *entrepreneurship*, Cornelius et al. (2006) identified 'core researchers' and produced co-citation 'maps' showing how there 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 of these clusters.

³² His search algorithm involved the use of the term 'knowledge management' so publications without this term in the title will apparently have been omitted.

³³ 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, Leonard-Barton and Nelson).

4. Methodology for identifying the main academic contributions from SPIS

In what follows, we shall focus on the main ‘academic’ contributions from 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 the ultimate aim of field is arguably to contribute to more effective policy or management. Certainly, there have been many instances of impact on policy or management practice,³⁴ 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,³⁵ 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 practice.

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.³⁶ Over the last 40 years, various studies have tended to confirm the correlation between citations and impact (e.g. Bayer & Folger, 1966; Cole & Cole, 1973; Koenig, 1983; Martin & 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 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

³⁴ 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. Perhaps more 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 the teaching in business schools as well as through research publications.

³⁵ 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’.

³⁶ As Kim et al. (2006) note: “Although the number of academic citations accumulated by a published research paper is an imperfect measure of 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. They are reasonably comprehensive across subject areas within economics” (and the same is true in SPIS).

have higher ‘impact factors’ and are therefore perceived by the academic community as ‘more important’, but the argument here is somewhat circular;³⁷

- self-citations have not been excluded in this analysis; however, they represent a trivially small percentage of the total citations for HCPs with more than 250 citations (the threshold adopted here), and they are also present to some extent in 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, and 1979; Garfield, 1975 and 1979), 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 500 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;³⁸ and (ii) a comprehensive list of 80 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’,

³⁷ 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*.

³⁸ 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).

‘entrepreneurship’, ‘new product development’ and so on³⁹ to identify those where the titles⁴⁰ suggest they fall within SPIS field.⁴¹ 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*,⁴² it being an especially flexible search-tool for books (one can only search in the *Citation Index* if you already know 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 250 citations.

The citation-counting procedure adopted here is very similar to that of Kim et al. (2006) – i.e. one starts with the automated WoS citation count (but using a lower citation threshold – in this case, a total of 200 or more citations), and then carries out a manual count (using the ‘Cited Reference Search’ facility⁴³ in the WoS) to add in references to the same publication but in a slightly different form (e.g. where citing authors give a page number for a specific part of the text later in the publication rather than the first page, or where there is a typo in the reference, or where for some other reason the references have not been unified by the WoS software).⁴⁴ Where a book was immediately reprinted within one or two years, it was treated as the same publication; but where separate editions of books were published three or more

³⁹ 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).

⁴⁰ 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 almost certainly have been ‘captured’ in some other way, for example through scanning the bibliographies of important review articles. Hence, the only 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).

⁴¹ 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.

⁴² Among bibliometric experts, the 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.

⁴³ The ‘General Search’ facility in the WoS only works for articles in journal scanned by the *Citation Index* – books, book chapters and other publications are excluded.

⁴⁴ Kim et al. (2006, p.4): “If an individual has only one article for a specific journal and year, all mis-referenced citations that have the correct journal and year are credited to the article. If the individual has multiple articles in the journal for the year searched, we credit all cites with the correct issue or page number to the appropriate article. For the remaining mis-references for individuals with multiple papers in the same journal year, we calculate the ratio of correct citations between the multiple articles and apply the ambiguous cases in the same proportion. These rules, however, do not capture mis-references when the last name of the author is incorrectly spelled ...” or indeed where no initial at all was given for the author. 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 *) 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). For edited books, the editor may be cited either as the editor for the entire book or as the author of one or more individual chapters; in such cases (e.g. Dosi et al., 1988), the citation figure given in Table 1 represents the combined total of citations to that individual for the book and any chapters they have authored in it.

years apart, they were treated as different publications.⁴⁵ Because citations are being continuously added to the WoS database, citation totals were calculated as of the end of 2006.⁴⁶

Despite the care taken, the citation totals of each HCP should still be regarded as approximate (hence they have been rounded to nearest 5, or the nearest 10 in case of most highly cited publications). 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).⁴⁷

Thus far, the search has identified

- 17 HCPs with ≥ 1000 citations
- ~50 HCPs with ≥ 500 citations
- ~150 HCPs with ≥ 250 citations⁴⁸

The results are summarised in Table 1. For comparative purposes, it is worth pointing out that Kim et al. (2006) found a total of 146 economics articles with ≥ 500 citations, so the 50 or so SPIS HCPs with ≥ 500 citations compare with the top 150 journal articles in economics.⁴⁹ 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 those HCPs to see what they reveal about the origins and subsequent evolution of the field of SPIS.⁵⁰

⁴⁵ 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 had to be adopted for all books, and the former approach was the one eventually adopted.

⁴⁶ [update to end of 2007]

⁴⁷ As we note later in the concluding discussion, there is an important methodological issue that should be noted here. For the most cited HCPs (those with citation totals of 1000 or more), it is likely that most 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 four or five specialist journals that are 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. [do in later paper?]

⁴⁸ [recheck totals as of end of 2007]

⁴⁹ 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.

⁵⁰ [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, can be done

5. Origins and early development of the field

5.1 ‘Pre-history’

Although the SPIS field began to emerge some 50 years ago in the late 1950s, there are clearly important ‘pre-cursor’ publications that appeared before that. In this ‘pre-history’ phase, the central figure is undoubtedly Schumpeter, with two books cited over 1500 times and a third nearly 1000 times. 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. Other important contributions in the early years came from sociologists studying the diffusion of new agricultural and medical technologies (see the work summarised in Rogers, 1962). However, apart from the article by Coleman et al. (1957) [245 cites at end of 2006] on the diffusion of a new medical drug, none of these earlier contributions (pre-1960) appears to have earned more than 250 citations.⁵¹ In addition, we should mention Vannevar Bush and his 1945 report to the US Government on *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,⁵² and from which a rationale for government funding of basic research could later be constructed.

5.2 The pioneers

5.1.1 Economics

One of the most highly cited economists from the early years was Solow (1956), who set out the neo-classical growth model; in this, technology was treated as exogenous so this paper clearly falls outside the field of SPIS. However, in another highly cited article and one that was to influence early work in SPIS, 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.⁵³ Even so, it would be misleading to regard Solow as ‘in’ the innovation field, given how he treated technology. While he has been highly cited by SPIS scholars, this was often for critical reasons – i.e. as exemplifying neo-classical economics and the fact that it largely ignored innovation. Economists like Abramovitz and Kuznets, although not so highly cited, were arguably more important to the

relatively easily for articles in journals scanned by WoS, but not for books etc., 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. Again, leave this for future research?]

⁵¹ [Ryan & Gross (1943) came close with ~210 cites – recheck at end of 2007]

⁵² 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.

⁵³ 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 a couple of dozen times).

future development of SPIS in that they wrote explicitly about technical change and innovation, and provided a link back to work on technical change by economists in earlier decades.⁵⁴

One of the ‘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. His 1958 paper on research costs and social returns was also highly cited.⁵⁵ Another key contribution from the late 1950s was that by Nelson (1959), who, together with Arrow (1962a), set out the economics of research.⁵⁶ Starting from the notion of scientific knowledge as a ‘public good’, they developed the concept of ‘market failure’ (the failure of firms to invest in R&D at the socially optimal level), and used this to construct a rationale for government funding of research.⁵⁷ Arrow’s (1962b) paper on the economic implications of learning by doing is another very highly cited contribution from this period that in later years was to be very influential in the SPIS community.

Among other economists who had begun to focus on technology and innovation, one was Mansfield, who analysed the relationship between technical change and the rate of imitation (Mansfield, 1961), and later wrote a book on industrial R&D and technological innovation (Mansfield, 1968). Another was Schmookler, who had been working on the relationship between technical change and economic growth since the beginning of the 1950s. His 1966 book on *Invention and Economic Growth* is often credited with putting forward the ‘demand-pull model’ of innovation,⁵⁸ a model that for the next decade or so was locked in competition with the ‘science-push model mentioned earlier.⁵⁹ A third was Scherer, one of the main

⁵⁴ Jan Fagerberg (private communication). The extensive survey of economic theories of growth by Hahn and Mathews (1964) includes several references to economists from earlier decades who had analysed the role of technology or innovation.

⁵⁵ It had a total of 245 citations by the end of 2006, just below the citation threshold of 250 used here. [recheck at end of 2007]

⁵⁶ 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, 2001). 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.

⁵⁷ 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.

⁵⁸ 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’.

⁵⁹ [Also need to check theory of ‘induced innovation’ e.g. Fellner (1961), Kennedy (1964), Samuelson (1965), Ahmad (1966), and critique in Nordhaus (1973) – need to check whether any of this is highly cited. Nordhaus (1969) {cited 225 times by end of 2006} also came up with his own growth theory in which tech change figured prominently, altho treatment v theoretical (even admits that most of his assumptions “unrealistic”!). In addition, there was work on neo-technological trade theory – e.g. by Posner (1961) who

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; this book 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 a number of economic historians. For many of them, a source of inspiration was Gerschenkron and his 1962 book on *Economic Backwardness in Historical Perspective*. While this is again not strictly ‘within’ the field of SPIS, it undoubtedly 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*. Together with Mowery, he also produced an influential review of empirical studies on the influence of market demand on innovation (Mowery & Rosenberg, 1979). 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 were undoubtedly quite influential at the time.⁶⁰ In addition, there are a number of HCPs by economists where, as with Solow, it is debateable whether they should or should not be included as part of the ‘foundations’ of SPIS field.⁶¹ 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).⁶² 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

formulated the ‘technology gap’ theory of trade {but only ~175 citations}; also Gomulka, Cornwall – see Fagerberg, *RP*, 1987. Need to check to check if any of this work was highly cited.]

⁶⁰ These include the Project Hindsight report by Sherwin & Isenson (1967) {with ~60 citations}; the TRACES report by IITRI (1968) {~55 cites}; Myers and Marquis (1969) {~145 cites}; the *Wealth from Knowledge* book by Langrish et al. (1972) {195 cites}; the Battelle report on the *Interaction of Science and Technology in the Innovative Process* (1973) {apparently with only ~20 cites}; Gibbons and Johnston (1974) {~85 cites}; and Comroe and Dripps (1976) {~185 cites}.

⁶¹ 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 250 citations adopted here.

⁶² 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.

and then spread to developing countries as the product matures. This work, along with later refinements (in particular that by Krugman (1979), who formalised the product-cycle model), was important as it subsequently opened up the way for neo-Schumpeterian and evolutionary views on innovation developed by authors such as Dosi and his colleagues at SPRU, and Nelson and Winter.⁶³ 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. (1957⁶⁴ & 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 little cited within the SPIS community. By far the most influential contribution by a sociologist to the field of innovation studies, however, 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 in the SPIS field by some margin (with a total of over 8150 citations as of the end of 2006, far ahead of the next most highly cited publication).

5.1.3 Management

One of the earliest HCPs to consider the management of innovation⁶⁵ was 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.⁶⁶ Another early

⁶³ Jan Fagerberg (private communication).

⁶⁴ [currently falls just below the 250 cites threshold – check at end of 2007]

⁶⁵ [Was there any other precursor research in the 1950s on the management of R&D/ technology/ innovation? Was any of it highly cited? Have searched WoS using various combinations of ‘management’ and ‘techn*’ or ‘innovat*’; also searched *IEEE T Eng Management*.]

⁶⁶ Woodward’s 1958 contribution could equally well be classified as part of ‘organisational studies’ (as her 1965 book has been) rather than ‘management’.

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.⁶⁷ The next significant contributions came from researchers at MIT.⁶⁸ 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). In addition, Allen (1977) produced his 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 1960s, 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.⁶⁹ 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 the book by Woodward (1965), *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 influential in the emerging field of organisational studies, where several of the seminal works dealt at least in part with innovation and which have therefore been frequently cited by SPIS researchers.⁷⁰ For example, the book by March & 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), i.e. the notion of bounded rationality that was later to

⁶⁷ 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.

⁶⁸ This built on earlier work at MIT in 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 & Sosa, 2004). However, none of this MIT work from the 1950s appears to have been highly cited.

⁶⁹ Burns was a sociologist and Stalker an organisational psychologist.

⁷⁰ [all cited >50 times by STIS core journals]

prove particularly influential in the development of SPIS. A little later, Cyert & March (1963) set out a behavioural 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.⁷¹

Another important contributor, again from a researcher somewhat ‘outside’ SPIS, was Chandler, a business historian. His 1962 book 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, 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 the 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. Other major contributions at the interface of innovation and organisational studies⁷² from the 1970s include the book by Zaltman et al. (1973) on *Innovations and Organisation*, and Downs and Mohr’s (1976) analysis of conceptual issues in the study of innovation.⁷³

5.1.5 Political science

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

⁷¹ 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.

⁷² A highly cited contribution to organisational studies at about this time is Mintzberg’s 1969 book on *The Structuring of Organizations*, which identifies five different components of organisations and five types of coordinating mechanisms, together with certain key parameters in organisational design. Mintzberg concludes that there are five viable configurations of organisations (simple structure, machine bureaucracy, professional, divisional form and ‘adhocracy’), each characterised by a particular set of design parameters. However, although drawn upon by SPIS researchers [check – if not large, then drop], this lies somewhat outside the SPIS field.

⁷³ [Cited 245 times by end of 2006. Tushman’s (1977) study of boundary roles in the innovation process also fell slightly below the citation threshold of 250 used here. check at end of 2007]

(1969), who looked at the diffusion of innovations (in the form of new programmes or policies). 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).

5.1.6 Psychology

Other contributions to SPIS have come from organisational psychology. In addition to the work by Stalker (see above) on the management of innovation, another influential study was that by Pelz & Andrews (1966), who examined the effects of organisations on the performance of scientists and engineers. Based on a survey of researchers in university, industrial and government laboratories, they identified a number of factors that stimulated the productivity of these researchers (e.g. autonomy, interaction with colleagues, balance between pure and applied research, 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.

5.1.7 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 inevitably 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.⁷⁴ 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 prominence⁷⁵ was Project SAPPHO, in which Rothwell et al. (1974)⁷⁶ identified the main factors affecting success and failure in innovation. Another influential contribution was Freeman's (1974) book on *The Economics*

⁷⁴ 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 Carter and 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 250 used here. In the US, the nearest equivalent to SPRU was the MIT Center for Policy Alternatives, but none of its publications exceeded our citation threshold (although some former CPA staff, along with SPRU collaborators, were responsible for the highly cited book, *The Machine that Changed the World* – see below).

⁷⁵ [ref also to SPRU's involvement in the *Limits to Growth* debate in early-mid 70s?]

⁷⁶ The first report from Project SAPPHO by Robertson et al. (1972) was less well cited. {figs?}

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). 1982 was a particularly fruitful year for SPRU, 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) article on technological paradigms and trajectories. Two years later, Pavitt (1984) published his influential article setting out a sectoral taxonomy of technical change. Towards the end of the decade, 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*, a highly cited publication that played 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 widely 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 different social sciences with little direct engagement 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 literature as well as meeting more regularly at conferences and publishing in SPIS-specific journals such as *Research Policy*. 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, the resource-based view of the firm and, a little later, the notion of 'systems of innovation.'

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 theories of economic growth. Central in this development have been Nelson and Winter. In 1977, they published a highly cited article entitled 'in search of useful theory of innovation'.⁷⁸ In this, they reviewed the

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 Five years before that, 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, 1972), but this was not particularly highly cited. Indeed, one can trace the origins of evolutionary economics further back to the two authors' earlier 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

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. This is *the* most highly cited single publication⁷⁹ in the SPIS field (by some margin). In it, the authors argue that technological change 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)⁸⁰; 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 (the next most highly cited appears to be Hodgson (1993) with under 300 citations).

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 there is a better alternative 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.

written an internal paper in 1960 on ‘Economic natural selection and the theory of the firm’ (Hounshell, 2001, pp.292 & 310). See also Nelson (2003).

⁷⁹ It is more highly cited than any single edition of Roger’s book on *Diffusion of Innovations*, although the total number of citations to all five editions of that book far exceeds that for Nelson and Winter (1982).

⁸⁰ Here, they were heavily 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).

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 the decade, Mowery and Rosenberg (1989) and Storper and Walker (1989) published important books on the relationship between technology and economic or industrial growth. The reasons for the wide variations between the performance of economies over time was also at the heart of North’s 1990 book on *Institutions, Institutional Change and Economic Performance*, which is discussed later in Section 6.3.2.

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’.⁸¹ 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, and Aghion and Howitt (1992) with their article on growth through creative destruction and their (1998) book setting out endogenous growth theory in more detail. While all of these authors would probably regard themselves as part of ‘economics’ rather than SPIS, they attached great importance to technology and innovation, drawing extensively on the work of SPIS scholars as well as exercising considerable influence upon them.

⁸¹ At about the same time, Lucas (1988) attempted to develop a more 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.

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

6.2.1 Management and exploitation of innovation

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 a few years later by Kline & Rosenberg (1986), which effectively ended the 'science-push' VS 'demand-pull' debate that had been raging since the second half of the 1960s.⁸² The authors argued that one needed to move beyond simple linear models and instead put forward an interactive 'chain-linked' model of the innovation process. This seems to be the only contribution to the 20-year long debate between rival innovation models that obtained more than 250 citations, the threshold adopted in this study.

An influential management book from this period was that by Kanter 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. Another important management book was Hayes and Wheelwright (1984), several chapters of which focused on manufacturing technology. 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 is not a specialist talent of a few gifted individuals but something that is pervasive to a healthy society, not just in the private sector but also in public service organisations. He also warns 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. Although most

⁸² ['Demand-pull' model later transmogrified into user-led innovation (e.g. von Hippel)?]

researchers 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 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. ‘just in time’ and ‘lean production’). Also popular was the book by Davenport (1993), a management consultant, which 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), and Brown and Eisenhardt (1995). The last of these authors also examined the art of continuous change (Brown and Eisenhardt, 1997), while Eisenhardt and Tabrizi (1995) considered how best to accelerate adaptive processes. Two other influential books were Utterback (1994) on *Mastering the Dynamics of Innovation*, and Christensen (1997) on *The Innovator’s Dilemma*.

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 analysed 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 clearly become the leading institutions with respect to the management of innovation.

*6.2.2 Resource-based view of the firm*⁸³

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).⁸⁴ One of the first formulations of the ‘resource-based view of the firm’ was put forward by Wernfelt (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’.⁸⁵ Other influential contributions were made by Prahalad and Hamel (1990a and b) 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 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

⁸³ See also the closely related section on ‘organisational learning’ below.

⁸⁴ 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).

⁸⁵ The resource-based theory of the firm is debated in *Organization Science*, Vol.7, No.5 (1996). Of the articles appearing there, those by Conner & Prahalad (1996) and Kogut & Zander (1996) are already quite highly cited. [currently just under 250 cites threshold – check at end of 2007]

faces' of R&D, and later defined the enormously influential concept of 'absorptive capacity' (Cohen and Levinthal, 1990).⁸⁶ 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, 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. This concept was subsequently extended by Eisenhardt and Martin (2000), and by Zollo and Winter (2002) who examined how dynamic capabilities evolve over time.

6.3 Organisations and innovation

6.3.1 Organisational innovation

While 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. 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.⁸⁷ A more recognisable member of the SPIS community, perhaps, is Damanpour (1991), who conducted a meta-analysis of the relationships between organisational innovation and its main determinants, including technical knowledge resources.

6.3.2 Interaction between technology/innovation, organisations 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 to be a fruitful area for SPIS scholars, many of whom have drawn upon the insights offered by 'new institutionalism' and the work of pioneering authors 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

⁸⁶ Few papers published since 2000 have yet to earn over 100 citations. One that has is by Zahra and George (2002), who distinguish different dimensions of absorptive capacity and put forward a reformulation of the concept.

⁸⁷ The model was subsequently extended by Venkatesh and Davis (2000) {215 cites}, while another influential article on technology diffusion within organisations is Cooper and Zmud (1990) {230 cites}.

adoption and spread of organisational innovations. Another, rather different contribution here was that of Piore & Sabel (1984), who argued that capitalism had reached a turning-point, where it had to choose between two alternatives. One was to continue along the existing trajectory of mass-production technology (the course chosen at the first ‘industrial divide’) with its associated pressures towards vertically integrated firms, ‘Taylorism’ and confrontational labour relations. The other was to switch towards craft-based production and exploiting computer technology to make possible ‘flexible specialisation’, thus creating an environment in which firms competed on the basis of innovations but cooperated with regard to developing the necessary technological knowledge and skills (Brody, 1985).

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. 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.⁸⁸

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, and 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.

⁸⁸ An even broader sweep of history extending over several centuries was attempted by the economic historian, North (1990), he, too, being 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. His 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 gave relatively little attention to the work of historians of technical change and innovation such as Rosenberg, this book has had an impact on SPIS scholars.

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. Senge (1990) wrote a widely influential book on ‘the fifth discipline’, in which he set out his notion of ‘the learning organisation’. Somewhat closer to SPIS 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.⁸⁹ 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).

More recently, much attention has focused on knowledge management within organisations.⁹⁰ 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 then, with Takeuchi, developed the notion of ‘the knowledge-creating company’, in which knowledge management is crucially important (Nonaka & Takeuchi, 1995). 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 so that it is transformed into renewable assets and competitive advantage.⁹¹

Finally, let us mention the work by Brown 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. While some might question whether this book

⁸⁹ Ponzi (2002) identifies Weick’s (1995) book on sense-making in organisations as another influential contribution to organisational learning.

⁹⁰ Ponzi (2002) links some of the key ideas involved in knowledge management (KM) back to Mintzberg’s (1973) book on *The Nature of Managerial Work* and his discussion of different ‘managerial roles’, several of which incorporate key aspects of KM. In contrast, Gu (2004) traces knowledge management back to a set of four articles published in an issue of *Public Administration Review* in 1975; however, none of these was particularly highly cited, and apparently there were few other KM articles until the start of 1990s. Gu also provides a definition, one component of which is ‘managing innovation’ (the other listed components are somewhat outside the SPIS field, as is apparent from the main journals identified by Gu (see Table 5, p.180) as contributing to KM).

⁹¹ A later, highly cited contribution to KM 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).

forms part of SPIS, it does contain an important chapter on ‘innovating organization, husbanding knowledge’, drawing extensively on Brown’s experiences as Chief Scientist of Xerox and Director of the Xerox PARC research centre. 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. In addition, there has been closely related work in recent years by authors such as Chesborough and von Hippel on what has been variously described as ‘open innovation’, ‘distributed innovation’ and even ‘democratic innovation’. However, this work is apparently too recent to have yet been highly cited.

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 formulate this concept, using it to explain Japan’s economic success particularly in high-tech sectors.⁹² 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.⁹³ This builds on earlier work by economic geographers and others,⁹⁴ including several studies by

⁹² 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).

⁹³ The emergence of the term ‘regional innovation system’ around 1992 is described in Cooke (1998).

⁹⁴ This includes such highly cited ‘classics’ as Porter (1990) with his emphasis on geographical clusters, and Krugman (1991) with his work on regional agglomeration. However, the underlying concept of clustering or agglomeration can be traced back to Alfred Marshall’s (1890) work on ‘industrial districts’.

Jaffe (1986, 1989 & 1993) 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 spillovers⁹⁵, and Morgan (1997), who analysed 'the learning region' and the part played in this by institutions and innovation. (See also the related contributions described above in Section 6.3.4.)

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 (particularly Malerba but also others such as Breschi, Orsenigo and McKelvey), none of the publications on this topic appear to have been highly cited, at least not 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 two STS researchers, Bijker & Hughes (1987), with their highly cited book on *The Social Construction of Technological Systems*.⁹⁶ 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 a number of 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*, each highly cited. 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

⁹⁵ 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.

⁹⁶ The chapter by Hughes on 'The evolution of large technological systems', with its discussion of 'reverse salients', was particularly influential in the SPIS community; its total of 180 citations is 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 eroding its citation total.

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,⁹⁷ 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.⁹⁸

The final influential contribution to be considered here is somewhat more difficult to classify since the six authors came from sociology and higher education studies as well as science policy. This is the book by Gibbons et al. (1994) on *The New Production of Knowledge*, which distinguishes between 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'.⁹⁹ 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

⁹⁷ Granovetter (1985), does, however, discuss the work of sociologists such as Rogers, Coleman and Becker on the diffusion of innovations and how that diffusion can be related to social networks and weak ties.

⁹⁸ 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.

⁹⁹ Among the authors, Gibbons is part of the SPIS community, while Nowotony 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.

1950s, and Scherer (1965) were early pioneers in the use of patent statistics.¹⁰⁰ Later, the central figure was Griliches with his book on *R&D, Patents and Productivity* (Griliches, 1984), a paper jointly authored with Hausmann 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 under-utilise 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 indicators¹⁰¹ (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, no indicator¹⁰² or methodological publications by the leading figures involved (e.g. Archibugi, Grupp, Irvine, Martin,¹⁰³ Narin, Pavitt, Soete, van Raan) seem to have been particularly highly cited. 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 the field 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 some 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

¹⁰⁰ They were not, however, the very first to use patent data; for example, in the 1930s Gilfillan and Merton were both analysing patent statistics, as was Stafford in the early 1950s (see Griliches, 1990), 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).

¹⁰¹ 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.

¹⁰² Nor have any of the *Science (and Engineering) Indicators* reports published by the US National Science Board been cited more than 100 times.

¹⁰³ The most highly cited SPRU publication based on bibliometric analysis (Martin & Irvine, 1983) earned 165 citations.

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. Perhaps this is a reflection of the fact that SPIS is still a more fragmented and heterogeneous field than established social science disciplines.

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 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, a confrontational debate between the leading figures in each of these camps, which is set out in the pages of *Rural Sociology* (see Griliches, 1960 & 1962; Rogers & Havens, 1962). One unfortunate consequence of this early rivalry was the limited cross-fertilisation between these two streams of research over subsequent decades (Skinner & Staiger, 2005). For example, although economists and other SPIS scholars cited Rogers (1962, 1971, 1983 & 1995), they almost completely ignored Coleman et al. (1966)’s important work on the diffusion of medical innovation.

Besides economists and sociologists, there were also some early contributions from senior scientists and engineers like Vannevar Bush and from a few management or organisational scientists like Woodward. During the 1960s and 70s, there were growing contribution from economists (e.g. Nelson, Arrow, Mansfield, Schmookler, Scherer) and economic historians (e.g. Gerschenkron, Rosenberg, David), sociologists (in particular, Rogers), and from the fields of organisational studies (e.g. Burns and Stalker), management (e.g. Abernathy, Utterback, Allen) and business history (Chandler) and (to a lesser extent) political science (Walker). 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 from the rest of the embryo field of SPIS. 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 mono-disciplinary university departments. 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 & 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 & Rosenberg, 1986), Dosi’s article (1982) on technological paradigms and trajectories, various contributions in the book edited by Dosi, Freeman et al. (1988) on *Technical Change and Economic Theory*, and the development of the concept of the ‘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 field 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 topic in the field marketing, such as Bass (1969) and Mahajan et al. (1990), seem to have generally had little impact on the SPIS community.¹⁰⁴ 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.¹⁰⁵ A fourth example is psychology, although one complication here is changes in terminology, with part of what was ‘industrial psychology’ morphing into organisational psychology and hence becoming part of

¹⁰⁴ 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 & Stoneman (1992).

¹⁰⁵ [Need to explore this further.]

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.¹⁰⁶

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.¹⁰⁷ There are relatively few instances of interactions between the two fields. For example, the work of Kuhn (1962 & 1970) has been quite frequently cited by SPIS researchers. In particular, his concept of a scientific ‘paradigm’ was picked up by Dosi (1982), who in turn developed the notion of a ‘technological paradigm’. Merton’s work on the sociology of science and that of certain philosophers of science such as Polanyi (in particular, his work on tacit knowledge) and Ziman has also been influential. Other examples include the development of ‘actor-network theory’ by Callon (e.g. 1986 a & b) and others, and the work mentioned earlier by Bijker and Pinch (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 & 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 & Cole, 1981) attracted from other sociologists of science¹⁰⁸ 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 the growing, dominance of US authors. In their study of highly cited economics articles, Kim et al. (2006a, p.7) observed a similarly heavy preponderance of US authors, who, in their case, accounted for 85% of economics HCPs. For SPIS, the picture is broadly similar. 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?

¹⁰⁶ While there certainly has been some work in this area, none of it has been particularly highly cited.

¹⁰⁷ 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).

¹⁰⁸ As the author well remembers from science studies conferences at the time.

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 paper 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 preponderance over the last 20 years.

It was precisely to avoid the need for subjective judgements that I have chosen to adopt an approach based on citation analysis. I certainly recognise that in science, but even more so in social sciences and humanities, it has been asserted that US researchers can be rather 'parochial' in their referencing, tending to cite predominantly US literature, whereas researchers from Europe and other parts of the world are perhaps more 'global' 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 here 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 do correspond 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 that that have had most impact on fellow academics, what factors might explain why US authors account for approximately 85% [check] of the total, with the proportion being even higher over the last 20 years? The first thing to note is that the US represents by some way the largest single 'market' in the academic world.¹⁰⁹ If a publication is to earn over 250 citations (the threshold adopted here), 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

¹⁰⁹ 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.

compared with that of established social science disciplines, an SPIS publication almost certainly has to create a significant impact in one or more adjacent social science disciplines.¹¹⁰ 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),¹¹¹ 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, tend 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 a measurable 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 latter more qualitative and interpretive. Similar observations could be made with some plausibility about science policy and innovation studies. Even so, in the absence of some other method of operationalising the concept of ‘influence’, we are 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 compiled here. As we well know from our studies of the innovation process, it is not sufficient just to come up with a ‘good idea’. 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’, how to provide effective ‘after-sales service’, and so on. At the risk of offending some readers, I might venture to suggest, on the basis of observations

¹¹⁰ 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’.

¹¹¹ 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).

over the last 30 years, that US researchers are, on average, perhaps 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 it to readers to judge.

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

We have seen in this paper how SPIS has 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 & 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 or 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. Eventually, consensus may form around the chosen paradigm, which then starts to exert a growing influence in shaping the research agenda of the emerging discipline.¹¹² However, as with the emergence of a new species in the biological world, it is often not possible to say with any confidence whether a new discipline has formed until some time 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

¹¹² See also Eom (1996): “A review of the major works of Kuhn [41], Kaplan [37], and Cushing [14] 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 [41]; (2) Empirical study of the phenomena to establish a particular fact or a generalization [37]; (3) Articulation of theories to provide a unified explanation of established empirical facts and generalizations [41]; 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) [41].” Vessey et 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.

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,¹¹³ another possible indication of a move towards a more discipline-like nature. Against this, however, there are some signs that a growing proportion of the most highly cited articles in more recent years have appeared in mainstream disciplinary journals rather than dedicated SPIS journals.^{114 115} 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 quality published in SPIS journals. [see also discussion in McGrath, *AMJ*, 2007, on development of management as a field]

In other respects, though, it is clear that SPIS still lacks certain essential characteristics of a ‘discipline’, such as its own permanent, dedicated funding sources, its own professional association to which most researchers belong, and a regular series of major international conference to which *all* ‘wings’ of SPIS bring their best papers to present.¹¹⁷ 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.¹¹⁸ Let us examine SPIS with regard to each of these tests.

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

¹¹³ [Do some analysis on this - cf. Pasadeos et al., 1998; Ramos-Rodriguez & Ruiz-Navarro, 2004]

¹¹⁴ [Need to analyse which journals account for most HCPs, and trends in this – is proportion in high-status disciplinary journals increasing over time?]

¹¹⁵ As we saw in Section 6.6.2, the fact that key methodological papers are not highly cited (as they are in economics) might also be evidence that SPIS still lacks the maturity of established social sciences.

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

¹¹⁷ 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.

¹¹⁸ But see also Whitley (1984) on management studies as an ‘adhocracy’, and Goles & H (1999) for a critique of positivistic notion of ‘disciplines’.

assessing this. However, having worked in the field for 30 years, my sense is that a growing proportion of SPIS publications are concerned with studies stimulated by the interests of academic researchers rather than by 'external' policy or management issues. 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 becoming more self-contained and 'self-reflective', and hence more mature or 'discipline-like'.¹¹⁹

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) clearly revealed. In addition, from the list of HCPs produced here, one can begin to identify a core group of leading authors such as Abernathy, Anderson, Christensen, Clark, Cohen, David, Dosi, Eisenhardt, Feldman, Freeman, Griliches, Hall, Henderson, Jaffe, Leonard-Barton, Levinthal, Lundvall, Mowery, Nelson, Mansfield, Pavitt, Powell, Rogers, Rosenberg, Scherer, Teece, Tushman, Utterback, von Hippel and Winter.¹²⁰

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. 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.

[final wrap-up para – to be written]

References

[NB Need to decide how to treat HCP classics from outside SPIS that have heavily influenced SPIS researchers – list here, or put in separate table with no. of cites?]

Acedo et al. (2005)

Alexander & Fabry (1994)

Allen & Sosa (2004) (early history of engineering management)

¹¹⁹ cf. the discussion in Pasadeos et al. (1998) about whether the advertising literature has begun to exhibit more disciplinary rigour, and similar discussions by Pilkington & Liston-Heyes (1999) in connection with operations and production management, and Cornelius et al. (2006) with regard to entrepreneurial studies. See also the debate between Wade et al. (2006) and Grover et al. (2006) over whether information science is yet a discipline.

¹²⁰ In a later paper, I intend to analyse more systematically which individual SPIS researchers have had the greatest influence.

- Almond (1996), Chapter 2 in Goodin & Klingemann (1996a)
- Alavi & Leidner (2001)
- Arnold et al. (2003)
- Ball & Rigby (2006)
- AE Bayer & J Folger (1966), 'Some correlates of citation measure of productivity in science', *Sociology of Education* 39, 381-90.
- AS Bean et al. (1993), 'Introductory note', *Research Policy* 22, 99.
- J Ben-David & R Collins (1966), 'Social factors in the origins of a new science: the case of psychology', *American Sociological Review* 31, 451-65.
- Berndtson (1987),
- Bijker & Hughes (1987), *The Social Construction of Technological Systems*
- Brody (1985)
- Brown & Eisenhardt (1995)
- Casillas & Acedo (2007)
- Coakley (2004),
- RH Coase (1937), 'The nature of the firm', *Economica* ...
- JR Cole & S Cole (1973), *Social Stratification in Science* (University of Chicago Press, Chicago).
- JR Cole & S Cole (1981), *Peer Review in the National Science Foundation: Phase Two of a Study* (Washington, DC: National Academy Press).
- S Cole, L Rubin, & JR Cole (1978), *Peer Review in the National Science Foundation: Phase One of a Study* (Washington, DC: National Academy Press).
- P Cooke, 'Introduction: origins of the concept', Chapter 1 in HJ Braczyk, PN Cooke & M Heidenreich (eds), (1998), *Regional Innovation Systems: the Role of Governances in a Globalized World* (Routledge, London). {book cited 190 times by end of 2006}
- Cornelius et al. (2006)
- Cottrill et al. (1989)
- Coupé (2003)
- Culnan (1986)
- B Dachs, T Roediger-Schluga, C Widhalm & A Zartl (2001), 'Mapping evolutionary economics: a bibliometric analysis' (paper presented at the EMAEE conference, 2001, Vienna).
- Davenport & Prusak (1998)
- Dodgson & Rothwell (eds) (1994), *Handbook of Industrial Innovation*
- Dosi (1988)
- Dosi et al. (2006a) *RP*
- Dosi et al. (2006b) *ICC*
- Drejer (1997) [development of technology management]
- D. Easton, J.G. Gunnell & L. Graziano (eds) (1991), *The Development of Political Science: A Comparative Survey* (Routledge)
- Eom (1996).
- Eom & Lee (1993),
- Erkut (2002)
- Fagerberg (2004)
- Fagerberg et al. (2004), *The Oxford Handbook of Innovation*
- J Fagerberg & B Verspagen (2007), 'Innovation studies – the emergence of a new scientific field' (mimeo, Centre for Advanced Study, Norwegian Academy of Science and Letters, Oslo)
- Farr (1988)
- Freeman (1974)

- Freeman (1982)
- Freeman (1997)
- Freeman (2004)
- Gallivan & Benbunan-Fich (2007)
- E Garfield (1975), 'The obliteration phenomenon', *Current Contents*, No. 51/52, 5-7 (22 December).
- E Garfield (1979), *Citation Indexing – Its Theory and Application in Science, Technology, and Humanities* (Institute for Scientific Information, Philadelphia).
- Gavetti & Levinthal (2004)
- B Godin (2006), 'The linear model of innovation: the historical construction of a analytical framework', *Science, Technology, & Human Values* 31, 631-67.
- B. Godin (2008), 'The knowledge economy: Fritz Machlup's construction of a synthetic concept', Project on the History of and Sociology of S&T Statistics, Working Paper No. 37.
- Goodin & Klingemann (1996a), *A New Handbook of Political Science*
- Goodin & Klingemann (1996b), Chapter 1 in Goodin & Klingemann (1996a)
- O Granstrand (1994), 'Economics of technology – an introduction and overview of a developing field', Chapter 1 in O Granstrand (ed.), *Economics of Technology* (North Holland/Elsevier, Amsterdam & New York)
- Z Griliches (1960), 'Congruence versus profitability: a False dichotomy', *Rural Sociology* 25, 354-56.
- Z Griliches (1962), 'Profitability versus interaction: another false dichotomy', *Rural Sociology* 27, 325-330.
- Griliches (1990)
- H Grupp, U Schmoch & S Hinze (2001), 'International alignment and scientific regard as macro-indicators for international publications of publications', *Scientometrics* 51, 359-80.
- Gu (2004)
- Hahn & Mathews (1964)
- Halsey & Donovan (2004)
- Harnad (1985)
- Harzing & van der Waal (2007)
- Henrekson & Waldenström (2007)
- DA Hounshell (????), 'The medium is the message, or how context matters: the RAND Corporations builds an economics of innovation, 1946-1962', in AC & TP Hughes (eds), *Systems, Experts, and Computers*, pp.255-310)
- IITRI (1968), *Technology in Retrospect and Critical Events in Science*, report to the National Science Foundation (Illinois Institute of Technology Research Institute, Chicago).
- Jascó (2005)
- R Kärki (1996), 'Searching for bridges between disciplines: an author cocitation analysis on the research into scholarly communication', *Journal of Information Science* 22, 323-34.
- M Karshenas & P Stoneman (1992), 'A flexible model of technological diffusion incorporating economic factors with an application to the spread of colour television ownership in the UK', *Journal of Forecasting* 11, 577-601.
- Kim et al. (2006)
- MED Koenig (1983), 'Bibliometric indicators versus expert opinion in assessing research performance', *Journal of the American Society for Information Science* 34 (March), 136-45.
- RE Kohler (1982), *From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline* (Cambridge University Press, Cambridge)
- Kousha & Thelwall (2007), 'Google Scholar citations and Google web/URL citations: a multi-discipline exploratory analysis' (mimeo, University of Wolverhampton) [check download site?]
- PR Krugman (1979), 'Increasing returns: monopolistic competition, and international trade', *Journal of International Economics* 9, 469-479.

- P? Krugman (1991), *Geography and Trade ...*
- Kuhn (1962)
- Kuhn (1970)
- Linton (2004)
- Linton (2006)
- Linton & Embrechts (2006)
- List (1841)
- B-Å Lundvall (2004)
- B-Å Lundvall (2007), 'Innovation system research and policy; where it came from and where it might go' (paper presented at CAS Seminar, Oslo, 4 December 2007).
- A Marshall (1890), *The Principles of Economics*.
- BR Martin & J Irvine (1983), 'Assessing basic research: some partial indicators of scientific progress in radio astronomy', *Research Policy* 12, 61-90.
- Marshall (1890)
- Medoff (1996)
- RK Merton (1968), *Social Theory and Social Structure* (Free Press, New York).
- RK Merton (1979), 'Foreword' to Garfield (1979).
- Meyer (2001)
- Meyer et al. (2004), 'The scientometric world of Keith Pavitt'
- Mintzberg (1973), *The Nature of Managerial Work*
- F Moavenzadeh (2006), 'The Center for Technology, Policy, and Industrial Development' (MIT); downloaded from http://web.mit.edu/ctpid/www/report_final.pdf?tttype=2&tid=11008 (22 November 2007).
- HF Moed, WJM Burger, JG Frankfort & AFJ van Raan (1985), 'The use of bibliometric data for the measurement of university research performance', *Research Policy* 14, 131-49.
- Mowery & Rosenberg (1979)
- RR Nelson (1974), 'Demand and discovery in technological innovation', *Minerva* 12, 277-280.
- R Nelson & S Winter (1972), 'Neoclassical vs. evolutionary theories of economic growth: critique and prospectus', *Economics Journal* 84, 886.
- Nelson & Winter (1977)
- R.R. Nelson (2003), 'Origins and factors shaping our joint work developing an evolutionary theory of economic change', remarks at the Sid Winter-fest, 16 October, 2003.
- Pasadeos et al. (1998)
- Pilkington & Teichert (2006)
- ET Penrose (1959), *The Theory of the Growth of the Firm ...*
- Pilkington & Fitzgerald (2006)
- Pilkington & Liston-Heyes (1999)
- Ponzi (2002)
- M Porter (1990) ...
- Ramos-Rodriguez & Ruiz-Navarro (2004)
- Ratnatunga & Romano (1997)
- A Rip, TJ Misa & J Schot (1995), *Managing Technology in Society: The Approach of Constructive Technology Assessment* (Pinter)
- EM Rogers & AE Havens (1962), 'Rejoinder to Griliches' 'Another false dichotomy' ', *Rural Sociology* 27, 330-332.
- Shane & Ulrich (2004)
- CW Sherwin & RS Isenson (1966), *First Interim Report on Project Hindsight – Summary*, Report No. AD 642-400 (Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.).

- CW Sherwin & RS Isenson (1967), 'Project Hindsight: a Defense Department study of the utility of research', *Science* 156, 1571-77.
- Schildt et al. (2006),
- J Skinner & D Staiger (2005), 'Technology adoption from hybrid corn to beta blockers', NBER Working Paper No. 11251.
- Skyrme (1998) – see <http://www.skyrme.com/updates/u20.htm>
- Solow (1956),
- Tol (2007)
- van Ours & Vermeulen (2007)
- B Verspagen & C Werker (2003), 'The invisible college of the economics of innovation and technological change', *Estudios de Economía Aplicada* 21 (3), 393-419.
- B Verspagen & C Werker (2004), 'Keith Pavitt and the invisible college of the economics of technology and innovation', *Research Policy* 33, 1419-31.
- Walstrom & Leonard (2000),
- Whitley & Galliers (2007)
- OE Williamson (1975), *Markets and Hierarchies ...*
- OE Williamson (1979), 'Transaction cost economics', *Journal of Law & Economics ...*
- OE Williamson (1985), *The Economic Institutions of Capitalism ...*
- Zimmermann (2007)

Table 1. High-impact publications in SPIS

Publications with ≥ 250 citations in the *Web of Science – Citation Index*; figures are for the total to the end of 2006 from the *SCI*, *SSCI* and *A&HCI*.

‘Pre-history’	
JA Schumpeter (1934), <i>Theory of Economic Development</i>	1505
JA Schumpeter (1939), <i>Business Cycles: Theoretical, Historical and Statistical Analysis</i>	930
JA Schumpeter (1942), <i>Capitalism, Socialism and Democracy</i>	1585
V Bush (1945), <i>Science the Endless Frontier</i>	385
JA Schumpeter (1947), <i>Capitalism, Socialism and Democracy</i> (2 nd ed)	335
JA Schumpeter (1950), <i>Capitalism, Socialism and Democracy</i> (3 rd ed)	1155
The pioneers	
Z Griliches (1957), ‘Hybrid corn ... economics of tech change’, <i>Econometrica</i>	675
RM Solow (1957), ‘Tech change and aggregate production function’, <i>Rev Ec and Stat’s</i>	1375
J Woodward (1958), <i>Management and Technology</i>	250
RR Nelson (1959), ‘The simple economics of basic research’, <i>J Pol Econ</i>	310
T Burns, GM Stalker (1961), <i>The Management of Innovation</i>	2125
E Mansfield (1961), ‘Technical change and the rate of imitation’, <i>Econometrica</i>	465
KJ Arrow (1962a), ‘Econ welfare and alloc of resources for invention’ in Nelson (ed.)	960
KJ Arrow (1962b), ‘Economic implications of learning by doing’, <i>Rev Econ Stat’s</i>	1135
[AD Chandler (1962), <i>Strategy and Structure</i>	2325]
[F Machlup (1962), <i>The Production & Distribution of Knowledge in the United States</i>	545]
EM Rogers (1962), <i>Diffusion of Innovations</i>	1360
DJD Price (1963), <i>Little Science, Big Science</i>	950
FM Scherer (1965), ‘Firm size ... and output of patented innovations’, <i>Am Econ Rev</i>	250
JS Coleman et al. (1966), <i>Medical Innovation</i>	680
DC Pelz, FM Andrews (1966), <i>Scientists in Organizations: Productive Climates for R&D</i>	575
J Schmookler (1966), <i>Invention and Economic Growth</i>	720
R Vernon (1966), ‘Internat invest’t and internat trade in the product cycle’, <i>Q J Econ</i>	1220
E Mansfield (1968), <i>Industrial Research and Technological Innovation</i>	580
FM Bass (1969), ‘New product growth model for consumer durables’, <i>Mngt Sc</i>	665
JL Walker (1969), ‘Diffusion of innovations among American states’, <i>Am Pol Sc Rev</i>	520
FM Scherer (1970), <i>Industrial Market Structure and Economic Performance</i>	900
EM Rogers, FF Shoemaker (1971), <i>Communication of Innovations</i>	1615
[R Vernon (1971), <i>Sovereignty at Bay: the Multinational Spread of US Enterprises</i>	670]
[H Mintzberg (1973), <i>The Nature of Managerial Work</i>	1370]
G Zaltman, R Duncan, J Holbek (1973), <i>Innovations and Organizations</i>	705
ER Berndt, DO Wood (1975), ‘Tech’y, prices & derived demand for energy’, <i>Rev Ec Stat</i>	510
PA David (1975), <i>Technical Choice, Innovation and Economic Growth</i>	275
JM Utterback, WJ Abernathy (1975), ‘Dynamic model of innovation’, <i>Omega</i>	345

[OE Williamson (1975), <i>Markets and Hierarchies</i>	4845]
[GW Downs, LB Mohr (1976), 'Conceptual issues in study of innov'n', <i>Admin Sc Q</i>	245]
N Rosenberg (1976), <i>Perspectives on Technology</i>	560
JA Schumpeter (1976), <i>Capitalism, Socialism and Democracy</i> (6 th ed)	360
TJ Allen (1977), <i>Managing the Flow of Technology</i>	765
[AD Chandler (1977), <i>The Visible Hand: Managerial Rev'n in American Business</i>	2145]
RR Nelson, SG Winter (1977), 'In search of useful theory of innovation', <i>Res Policy</i>	370
WJ Abernathy, JM Utterback (1978), 'Patterns of ind innov'n', <i>Tech'y Rev</i>	395
RG Cooper (1979), 'Dimensions of industrial new product success & failure', <i>J Mktg</i>	280
GC Loury (1979), 'Market structure and innovation', <i>Q J Econ</i>	260

SPRU contributions

R Rothwell et al. (1974), 'Project SAPPHO Phase II', <i>Res Policy</i>	285
C Freeman (1974), <i>Economics of Industrial Innovation</i>	255
C Freeman (1982), <i>Economics of Industrial Innovation</i> (2 nd ed)	435
C Freeman et al. (1982), <i>Unemployment and Tech Innov'n: long waves and econ develpt</i>	270
G Dosi (1982), 'Technological paradigms and trajectories', <i>Res Policy</i>	595
M Jahoda (1982), <i>Employment and Unemployment</i>	370
K Pavitt (1984), 'Sectoral patterns of tech change', <i>Res Policy</i>	435
C Freeman (1987), <i>Technol Policy and Econ Perf: Lessons from Japan</i>	355
G Dosi (1988), 'Sources and microeconomic effects of innovation', <i>J Econ Lit</i>	535
G Dosi, C Freeman et al. (1988), <i>Technical Change and Economic Theory</i>	535
C Freeman, C Perez (1988), 'Structural crises of adjustment', in Dosi et al., <i>Tech Change</i>	310

The field matures

FM Scherer (1980), <i>Industrial Market Structure and Economic Performance</i> (2 nd ed.)	1835
JR Kimberly, MJ Evanisko (1981), 'Organizational innovation ...', <i>Acad Mngt J</i>	320
MI Kamien, NL Schwartz (1982), <i>Market Structure & Innovation</i>	465
RR Nelson and SG Winter (1982), <i>An Evolutionary Theory of Economic Change</i>	3550
N Rosenberg (1982), <i>Inside the Black Box: Technology and Economics</i>	720
LG Tornatzky, KJ Klein (1982), 'Innov'n characteristics ...', <i>IEEE Trans Eng Mngt</i>	255
RM Kanter (1983), <i>The Change Masters: Innov'ns for Productivity in the Amer Corp'n</i>	1075
EM Rogers (1983), <i>Diffusion of Innovations</i> (3 rd ed.)	2635
J Hausman et al. (1984), 'Econ models ... patents-R&D relationship', <i>Econometrica</i>	500
RH Hayes, SC Wheelwright (1984), <i>Restoring Our Competitive Edge</i>	735
DA Hounshell (1984), <i>From American System to Mass Production ... Devlpt of Mfg Tech</i>	280
Z Griliches (ed.) (1984), <i>R&D, Patents and Productivity</i>	275
[MJ Piore, CF Sabel (1984), <i>The Second Industrial Divide</i>	2330]
[B Wernerfelt (1984), 'A resource-based view of the firm', <i>Strat Mngt Rev</i>	1155]
WJ Abernathy, KB Clark (1985), 'Innov'n: mapping winds of creative destr'n', <i>Res Pol</i>	265
PA David (1985), 'Clio and economics of QWERTY', <i>Am Econ Rev</i>	680
P Drucker (1985), <i>Innovation and Entrepreneurship</i>	415
J Farrell, G Saloner (1985), 'Standardization, compatibility and innovation', <i>RAND J Ec</i>	390

[M Granovetter (1985), 'Econ action & social structure', <i>Amer J of Sociology</i>	2690]
[OE Williamson (1985), <i>The Economic Institutions of Capitalism</i>	4415]
M Abramovitz (1986), 'Catching up, forging ahead and falling behind', <i>J Amer Hist</i>	335
J Farrell, G Saloner (1986), 'Installed base and compatability – innov'n ...', <i>Am Ec Rev</i>	285
RN Foster (1986), <i>Innovation: The Attacker's Advantage</i>	305
AB Jaffe (1986), 'Tech opportunity and spillovers of R&D', <i>Am Ec Rev</i>	365
ML Katz, C Shapiro (1986), 'Technology adoption ... network externalities', <i>J Pol Econ</i>	345
SJ Kline, N Rosenberg (1986), 'Overview of innovation', in <i>Positive Sum Strategy</i>	255
[PM Romer (1986), 'Increasing returns and long-run growth', <i>J Pol Economy</i>	1685]
DJ Teece (1986), 'Profiting from technological innovation', <i>Res Policy</i>	795
ML Tushman, P Anderson (1986), 'Tech discontinuities and org envts', <i>Admin Sc Qu</i>	780
AH Van de Ven (1986), 'Central problems in management of innovation ...', <i>Mngt Sc</i>	335
[WE Bijker, T Hughes (1987), <i>The Social Construction of Technological Systems</i>	605]
RS Burt (1987), 'Social contagion and innovation ...', <i>Am J Sociology</i>	345
RC Levin et al. (1987), 'Appropriating the returns from ind R&D', <i>Brookings Papers</i>	510
SG Winter (1987), 'Knowledge and competence as strat assets', <i>Competitive Challenge</i>	380
[B Levitt, JG March (1988), 'Organizational learning', <i>An Rev Sociology</i>	825]
[RE Lucas (1988), 'On the mechanisms of econ devlpt', <i>J of Monetary Economics</i>	1840]
BA Lundvall (1988), 'Innov'n as interactive process', in Dosi et al. (eds), <i>Tech Change</i>	275
E von Hippel (1988), <i>Sources of Innovation</i>	800
WB Arthur (1989), 'Competing technologies, increasing returns ...', <i>Econ J</i>	700
KA Bantel, SE Jackson (1989), 'Top mngt and innov'ns in banking', <i>Strat Mngt J</i>	295
WM Cohen, DA Levinthal (1989), 'Innov'n and learning: 2 faces of R&D', <i>Econ J</i>	605
FD Davis et al. (1989), 'User acceptance of computer technology', <i>Mngt Sc</i>	670
AB Jaffe (1989), 'Real effects of academic research', <i>Am Econ Rev</i>	290
D Mowery, N Rosenberg (1989), <i>Technology and the Pursuit of Economic Growth</i>	250
M Storper (1989), <i>Capitalist Imperative: territory, tech'y and ind growth</i>	510
P Anderson, ML Tushman (1990), 'Tech discontinuities and dom designs', <i>Admin Sc Qu</i>	275
[AD Chandler (1990), <i>Scale and Scope: the Dynamics of Industrial Capitalism</i>	875]
WM Cohen, DA Levinthal (1990), 'Absorptive capacity', <i>Admin Sc Qu</i>	1585
Z Griliches (1990), 'Patent statistics as economic indicators', <i>J Econ Lit</i>	440
RM Henderson, KB Clark (1990), 'Architectural innovation', <i>Admin Sc Qu</i>	690
V Mahajan et al. (1990), 'New product diffusion models in marketing – review', <i>J Mktg</i>	280
P Milgrom, J Roberts (1990), 'Econ's of mod mfg: tech'y, strategy and org'n', <i>Am Ec Rev</i>	360
[DC North (1990), <i>Institutions, Instit'nal Change & Econ Performance</i>	2580]
[ME Porter (1990), <i>The Competitive Advantage of Nations</i>	2570]
[CK Prahalad, G Hamel (1990), <i>The Core Competence of the Company</i>	1375]
[CK Prahalad, G Hamel (1990), 'The core competence of the corp'n', <i>Harv Bus Rev</i>	1135]
PM Romer (1990), 'Endogenous Technical Change', <i>J Pol Econ</i>	1385
FM Scherer (1990), <i>Industrial Market Structure and Economic Performance</i> (3 rd ed.)	945
[PM Senge (1990), <i>The Fifth Discipline ... the learning organization</i>	3030]
JP Womack et al. (1990), <i>The Machine that Changed the World</i>	1550

[J Barney (1991), 'Firm resources & sustained comparative advantage', <i>J of Mngt</i>	1915]
[J Seely Brown, P Duguid (1991), 'Organis'l learning and comm's of practice', <i>Org Sc</i>	500]
KB Clark, T Fujimoto (1991), <i>Product Development Performance</i>	780
[KR Conner (1991), 'Historical comparison of resource-based theory ...', <i>J Mngt</i>	330]
[F Damanpour (1991), 'Organizational innovation – a meta-analysis ...', <i>Acad Mngt J</i>	410]
[RM Grant (1991), 'Resource-based theory of competitive advantage', <i>Calif Mngt Rev</i>	400]
GM Grossman, E Helpman (1991), <i>Innovation and Growth in the Global Economy</i>	1100
[G Hamel (1991), 'Compet'n for competence and inter-partner learning', <i>Strat Mngt J</i>	450]
[G Huber (1991), 'Organizational learning: contributing processes & literatures', <i>Org Sc</i>	720]
P Aghion, P Howitt (1992), 'Model of growth thro creative destruction', <i>Econometrica</i>	490
RS Burt (1992), <i>Structural Holes: The Social Structure of Competition</i>	1095
D Dougherty (1992), 'Interpretive barriers to successful product innov'n ...', <i>Org Sc</i>	300
PM Haas (1992), 'Epistemic communities and internat policy coordin'n', <i>Int Org</i>	475
B Kogut, U Zander (1992), 'Knowledge of firm ... and replic'n of technology', <i>Org Sc</i>	725
D Leonard-Barton (1992), 'Core capabilities and core rigidities', <i>Strat Mngt J</i>	480
BÅ Lundvall (1992), <i>National Systems of Innovation</i>	705
SC Wheelwright, KB Clark (1992), <i>Revolutionizing Product Development</i>	405
[P Drucker (1993), <i>Post-Capitalist Society</i>	515]
TH Davenport (1993), <i>Process Innovation: Reengineering Work thro Info Technology</i>	605
AB Jaffe et al. (1993), 'Geographic localization of knowledge spillovers', <i>Qu J Econ</i>	550
DA Levinthal, JG March (1993), 'The myopia of learning', <i>Strategic Management J</i>	385
RR Nelson (ed.) (1993), <i>National Innovation Systems</i>	455
G DeSanctis, MS Poole (1994), 'Capturing the complexity in adv tech'y use', <i>Org Sc</i>	260
M Gibbons et al (1994), <i>The New Production of Knowledge</i>	745
RM Henderson, I Cockburn (1994), 'Measuring competence ... firm effects', <i>Str Mngt J</i>	260
I Nonaka (1994), 'Dynamic theory of organizational knowledge creation', <i>Org Sc</i>	855
AL Saxenian (1994), <i>Regional Advantage: Culture and Competition in Silicon Valley</i>	930
JM Utterback (1994), <i>Mastering the dynamics of innovation</i>	340
E von Hippel (1994), 'Sticky info and locus of problem-solving ...', <i>Mngt Sc</i>	270
SL Brown, KM Eisenhardt (1995), 'Product development ...', <i>Acad Mngt Rev</i>	345
DT Coe, E Helpman (1995), 'International R&D spillovers', <i>Europ Ec Rev</i>	330
K Eisenhardt, BN Tabrizi (1995), 'Accelerating adaptive processes', <i>Ad Sc Q</i>	290
D Leonard-Barton (1995), <i>Wellsprings of Knowledge</i>	490
[I Nonaka, H Takeuchi (1995), <i>The Knowledge Creating Company</i>	1640]
EM Rogers (1995), <i>Diffusion of Innovations</i> (4 th ed.)	2320
[KE Weick (1995), <i>Sensemaking in Organizations</i>	1100]
DB Audretsch, MP Feldman (1996), 'R&D spillovers', <i>Amer Econ Rev</i>	320
[KR Conner, CK Prahalad (1996), 'Resource-based theory of the firm', <i>Org Sc</i>	240]
[RM Grant (1996), 'Towards a knowledge-based theory of the firm', <i>Strat Mngt J</i>	450]
WW Powell et al. (1996), 'Interorganizational collab'n and locus of innov'n', <i>Ad Sc Q</i>	480
G Szulanski (1996), 'Exploring internal stickiness ... transfer of best pract', <i>Strat Mngt J</i>	365
SL Brown, KM Eisenhardt (1997), 'The art of continuous change', <i>Ad Sc Q</i>	270
CM Christensen (1997), <i>The Innovator's Dilemma</i>	565

K Morgan (1997), 'The learning region: instit'ns, innov'n ...', <i>Regional Studies</i>	255
DJ Teece et al. (1997), 'Dynamic capabilities and strategic management', <i>Strat Mngt J</i>	850
P Aghion, P Howitt (1998), <i>Endogenous Growth Theory</i>	405
[T Davenport, L Prusak (1998), <i>Working Knowledge: How Org's Manage What They Know</i>]	660]
MA Heller, RS Eisenberg (1998), 'Can patents deter innovation? Anticommons', <i>Science</i>	320
GM Hodgson (1998), <i>Economics and Evolution</i>	260
J Nahapiet, S Ghoshal (1998), 'Soc capital, intell capital & org advantage', <i>Ac Mngt Rev</i>	425
[J Seely Brown, P Duguid (2000), <i>The Social Life of Information</i>	280]
KM Eisenhardt, JA Martin (2000), 'Dynamic capabilities: what are they?', <i>Strat Mngt J</i>	285
[V Venkatesh, FD Davis (2000), 'Theoretical ext'n of tech'y acceptance model', <i>Mngt Sc</i>	215]

Post-2000 ≥100 citations

M Alavi, DE Leidner (2001), 'Knowledge mngt ... conceptual found'ns', <i>MIS Q</i>	170
SA Zahra, G George (2002), 'Absorptive capacity: review ...', <i>Acad Mngt Rev</i>	130
M Zollo, SG Winter (2002), 'Deliberate learning and evol'n of dyn capabilities', <i>Org Sc</i>	100
EM Rogers (2003), <i>Diffusion of Innovations</i> (5 th ed.)	225

References in [] relate to work by researchers who would perhaps be regarded as 'outside' the SPIS field, but which drew extensively upon, and/or contributed substantially to, SPIS research.