



Exploring the emerging knowledge base of ‘the knowledge society’

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ABSTRACT

Science, technology and innovation have grown in importance over the last 50 years as we have moved towards a more knowledge-intensive society (the ‘knowledge society’). A number of new research fields have emerged in an effort to understand these developments and to offer advice to decision-makers in government, industry and elsewhere. This special issue focuses on studies of three relatively distinct though thematically related research fields (innovation studies, entrepreneurship studies, and science and technology studies). The first three articles use a particular methodology based on analysis of the references cited in the chapters to authoritative ‘handbooks’ to identify the core contributions in the three fields. A fourth article examines the relationship between the core literatures in three fields and how this has evolved over time. Other articles look at the evolution of innovation studies as reflected in highly cited papers, at the development of entrepreneurship as seen by a key ‘insider’, and at the creation of new centres in these fields and the difficulties they face. The last article in this special issue shows how interdisciplinary centres in innovation studies suffer from research assessment systems that are intrinsically biased against interdisciplinary research. This introduction presents a synthesis of the articles in this special issue, discusses similarities and differences between the three fields and their development over time, and considers challenges for policy and governance arising from the research presented here.

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1. Introduction

Concerns with the social and economic aspects of science, innovation, knowledge and entrepreneurship are not new. Already in the 18th Century [Smith \(1776\)](#) highlighted the importance of these phenomena, while [Cantillon \(1755\)](#) discussed the specific role of entrepreneurs in society. Closer to our own time, during the first half of the 20th Century, scholars such as [Schumpeter \(1912/1934, 1942\)](#) and [Knight \(1921\)](#) provided important theoretical building blocks for later work in this area. However, in spite of these pioneering contributions, a broader knowledge base only began to be developed after the Second World War, in particular from the 1960s onwards, reflecting in part the greater societal recognition that such issues enjoyed during the early post-war years. Initiatives to increase the knowledge base in this area were taken by a variety of actors, within and outside academia, and as a result a

sizeable level of research activity has since developed. The papers in this special issue examine the character and interrelationship of these emerging areas of research, identify central contributions and scholars, analyze the evolution of organizations and institutions dedicated to this work, and explore the lessons for science policy and governance.

Despite the growth of the literature about these issues, and the wider societal interest it attracts, very little has been written on the community of scholars who study these phenomena. One of the reasons for this lack of attention may be that these fields are not, or at least not yet, organized as a scientific discipline with departments, undergraduate, graduate and post-graduate teaching, curricula, textbooks and so on. However, as [Whitley \(2000, p. 302\)](#) points out, “scientific fields are no longer coterminous with academic disciplines”. Arguably, what primarily has characterized the development of the academic world in recent decades, apart from its tremendous growth, is the increasing variety with regard to how scientific work is organized and carried out ([Knorr Cetina, 1999](#); [Whitley, 2000](#); [Becher and Trowler, 2001](#)). Thus, the development of new scientific fields such as innovation studies, entrepreneurship studies, and science and technology studies (STS), which are the focus of this special issue, may be seen as part of a broader trend

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towards increased diversification and specialization of knowledge that blurs traditional boundaries and challenges existing patterns of organization within science (including social science). Gaining a better understanding of how these fields have evolved and their relationships with each other, other disciplines and the world outside academia may be of interest not only to researchers in the fields but also to those interested in science policy and how science renews itself.

Although relatively little has been written on these three particular fields, there exists a large literature on the emergence of new scientific fields in general that we may use as a source of inspiration in our research. Thematically focused research communities of the type studied here have been examined from a variety of perspectives: cognitive, organizational or actor (network) oriented, using different labels, such as ‘specialisms’ (Becher and Trowler, 2001), ‘epistemic communities’ (Knorr Cetina, 1999) and ‘scientific fields’ (Whitley, 2000). The latter (more general) notion is preferred here.

From a cognitive perspective, a scientific field may be defined as “all work being done on a particular cognitive problem” (Cole, 1983, p. 130). In this case it is mainly the common focus and the accumulated knowledge shared by researchers in a field that serves to ‘differentiate’ it from other areas of science (Hagstrom, 1965; Merton, 1973). That some degree of shared knowledge or consensus is necessary for a scientific field to thrive – and knowledge to accumulate – is generally acknowledged (Cole, 1983), although the extent of the required ‘consensus’ has been a matter of considerable controversy (Cole, 1983; Whitley, 2000; Becher and Trowler, 2001). Arguably, considerable disagreements should not necessarily be seen as a threat to the survival of a scientific field as long as there is “some agreement about what the fundamental questions or issues are and as long as there are some agreed upon ways of resolving theoretical and methodological disputes” (Pfeffer, 1993, p. 617).

However, for such processes to work, a common communication system, such as conferences and journals, agreed standards (for what is good work and what is not) and a merit-based reward system (that promotes the good work) are required (Whitley, 2000). Without such features, a scientific field is unlikely to survive for long, not only because knowledge accumulation would be difficult under such circumstances (Cole, 1983; Pfeffer, 1993) but also because without such a “reputational system of work organization” (Whitley, 2000, p. 7) – or ‘academic autonomy’ as Merton (1973) puts it – the emerging scientific field would lack the necessary legitimacy in the eyes of the rest of the academic world.

The creation of an adequate infrastructure, including local research units, regular conferences, specialized journals and possibly one or more professional associations, is a resource-intensive task. Thus, successful resource mobilization is essential for an emerging scientific field to prosper (Hambrick and Chen, 2008). However, the advocates of the emerging field – the academic entrepreneurs (Van de Water, 1997) – are often met with considerable scepticism, if not outright resistance, from the academic establishment, particularly from participants in neighbouring scientific fields (or disciplines) that (perhaps rightly) may see this a fight about power and resources (Frickel and Gross, 2005; Braun, 2011). To avoid such conflicts, it may be useful for the new field to position itself as a complement rather than an alternative or rival to its more established counterparts. External recognition and finance may also be important assets in this regard, since these may help to convince colleagues in other fields that the new field is socially desirable and should not necessarily be regarded as threat (Braun, 2011). Academic entrepreneurs in emerging fields will therefore often seek to establish alliances with holders of power and resources outside academia and to use these to support the development of the new field within academia.

Hambrick and Chen (2008), in a study of the emergence of strategic management as a scientific field, have – building on earlier contributions by Merton (1973) and others – emphasized three interrelated processes influencing the development of such new multi- or inter-disciplinary¹ scientific fields: differentiation, legitimation and resource mobilization. First, the new field has to convincingly differentiate itself from other, existing fields. This is not sufficient, however. To succeed, the scholars of the nascent field also need to convince those in other parts of academia that standard academic practices are being adhered to, i.e. the new field needs to build the necessary legitimacy (Merton, 1973). This requires access to organizations and institutions such as (refereed) journals and conferences. It may also imply engaging in teaching and the allocation of degrees, a core activity (or value) in universities. Finally, mobilization of resources is essential not least because, if it fails in this respect, the field will not be able to generate the organizational and institutional frameworks necessary for reproducing itself on a constant or enlarged scale.

In Section 2 of this introductory article we discuss some of the problems involved in attempts to study the knowledge base of an emerging scientific field, and present a novel methodology for how this might be done. Section 3 gives a concise overview of the evolution of the three strands of research analyzed in this issue, with particular emphasis on the processes of differentiation, resource mobilization and legitimation, while Section 4 addresses the inter-relationship(s) between the three fields. The final section considers some of the challenges arising from the research for science policy and governance.

2. Exploring the knowledge base of new scientific fields – some methodological aspects

There are, in principle, two ways to study a scientific field. One is what may be termed the ‘object-oriented’ approach, in other words, studying the objects (or outputs) that the scientists in the given field produce. The other – the ‘subject-oriented’ approach – is either to use the knowledge of experienced scholars within the field to elicit their subjective view of the evolution of the field or to approach the scholars within the field more directly and ask them about their views. The papers in this issue make use of both these approaches, which in many respects are complementary.

However, both approaches require that the units under study can be identified systematically and comprehensively. In the case of established disciplines such as economics, for example, this may be relatively unproblematic. Economists (mostly) have economics degrees, are members of associations of economists and publish in economics journals. Hence, the label ‘economics’ follows them in whatever they do, and this is something the researcher can exploit in, say, an exploration of the most important contributions to economics (e.g. Kim et al., 2006).

This is not the case to the same extent for new scientific fields that span several disciplines. Although the research presented here indicates that the three fields considered have begun to educate their own researchers, the majority of scholars in these areas still have their backgrounds in other disciplines (see Clausen et al., 2012). Moreover, while some professional associations have developed, most notably within the community of STS researchers (see Martin et al., 2012), these do not always cover the entire field.

¹ By ‘multidisciplinary’ research, we mean work drawing upon knowledge, methods, perspectives, concepts, theories or whatever from two or more disciplines, while ‘interdisciplinary’ research entails an element of linking, blending and integrating those various inputs (Klein, 2010; Martin, 2011).

Furthermore, although some journals have emerged, labels such as ‘innovation studies’, ‘entrepreneurship’ or ‘STS’ are generally not recognized as valid descriptions in international databases on publications. Hence the journals that serve researchers in these fields are classified in other categories. For example, the journal *Research Policy*, which is widely recognized as the leading journal within innovation studies (Fagerberg and Verspagen, 2009) and which is also important within STS and entrepreneurship (Martin et al., 2012; Landström et al., 2012) is classified by the ISI Web of Science in the (rather ill-defined) ‘Planning and Development’ category as well as under ‘Management’.

Another common characteristic of new scientific fields, especially during their early years, is that researchers tend to use books as a publication channel to a much greater extent than those in more established disciplines such as economics or psychology. It follows that the standard procedure used in many contemporary bibliometric exercises (for example, looking at a selection of widely cited journal articles within a specific subject area as defined in the ISI Web of Science) will not suffice in the present case.

Instead, the three studies of innovation studies, entrepreneurship and STS exploit the fact that in these areas – and probably in some other emerging multi- or inter-disciplinary research fields as well – a tradition of publishing surveys of the field (or parts thereof) as chapters in so-called ‘handbooks’ (or other ‘state-of-the-art’ books) has developed. Such handbooks are usually edited by senior academics in the field and targeted at researchers and PhD students. Since the purpose of these handbook chapters is to introduce readers to the most important scholarly work on a topic within the broader area covered by the handbook, it is reasonable to assume that the references in these chapters will include the most important contributions of relevance for the topic, as viewed by the authors of the handbook chapters, who are normally experts on the topics they survey.² Although the topics and orientations of the handbook chapters may vary, as may the references they cite, some contributions will be referred to in many different chapters simply because they are generally considered to be of prime importance by the collective body of authors involved in producing the handbooks. This subset of highly cited contributions is referred to as the ‘the core literature’ in each of the three areas under study here.

An important advantage of this methodology is that it is neutral with respect to publication channel, i.e. books (or book chapters) and journal articles. Interestingly, one important finding from the three studies (and from Martin, 2012) is that books play a very important role in these emerging fields, particularly in earlier years. Hence, any analysis that fails to take this into account is in danger of producing a highly distorted picture. Having identified the core literature in this way, the three field studies then go on to search for citations in scholarly journals to the core literature, with the purpose of identifying the disciplinary background of those authors citing the core literature (as revealed by the subject areas of the journals in which they publish). This also makes it possible to explore the relationships between the emerging field and other established areas of academic research.

Three of the papers in this special issue are based on the methodology outlined above. However, this is not the only methodological approach employed in the special issue. For example, a rather different approach is pursued by Martin (2012) who, starting from a list of established authors and important journals, identifies a number of potentially important works. In a second step, he then searches for citations to these works in

scholarly journals covered in the Web of Science. This leads to the identification of a set of highly cited publications (HCPs) in the area of ‘science policy and innovation studies’³ (i.e. all publications exceeding a certain threshold-level in terms of citations), the character and evolution of which are then scrutinized. However, citations to the literature identified by Martin may come from all areas of science. Thus, while the methodology described previously exploits the views of ‘insiders’ (i.e. the authors of handbook chapters), Martin’s approach is more likely to identify thematically relevant contributions that are highly regarded in other fields as well, in other words, by ‘outsiders’ to that field.

Yet another approach to the ‘identification problem’ inherent in all attempts to study emerging research areas has been adopted by Rafols et al. (2012), who analyze the research performance of three UK research centres working in innovation studies (and also partly in STS) in comparison with that of three leading UK Business or Management Schools. Drawing on information from the institutional websites of these research units, they identify the names of the researchers working in each and the publications they have produced. Based on this and information from the citations to this work in the Web of Science, they then explore how the research performance of the three units can be assessed from different perspectives and with different metrics.

The methodology pursued by Rafols et al. presupposes that the organizational units with which researchers in this area are associated can be readily identified. While this may be relatively straightforward in the case of three well known centres within a single country, it is much less obvious how this can be done systematically on a global scale. In fact, no comprehensive inventory of the organizational units worldwide that take part in research and teaching in the three fields exists. Clausen et al. (2012) address this problem directly through a web-based survey of leading personnel attached to such centres or departments (and expanded using a ‘snow-ball’ approach). Hence, in contrast to the studies described above, they apply a ‘subject-oriented’ approach. Through their search they identified more than four hundred such research units worldwide, of which about one third took part in the survey. Leading personnel in these units were asked detailed questions about the origins, activities, sources of support, challenges encountered and so on, which Clausen et al. then use to discuss the success (or failure) of organizational initiatives in this area. The contribution by Aldrich (2012) – a personal essay from a leading researcher in one of the fields under study here – may also be classified as an example of a ‘subject-oriented’ approach. In this essay the author analyzes a series of initiatives by leading scholars to create fruitful frameworks for the development of entrepreneurship studies as a scientific field, including the creation of social networks, publication opportunities, training programs, research funding, etc.

3. The evolution of the knowledge base on the ‘knowledge society’: the three strands

As mentioned earlier, although there were some early fore-runners, research on science, technology and innovation – or the knowledge base on ‘the knowledge society’, as we are terming it here – only began to emerge on a significant scale some time after the Second World War, related in part to the increasing focus in society on the social and economic importance of science, technology and innovation. As shown in Fig. 1, which illustrates the development of the core literature in the three areas studied over

² To avoid possible biases caused by varying editorial practices, the requirement that a publication should be cited in more than one handbook to merit inclusion in the core literature of an area, was added to the methodological criteria.

³ ‘Science policy and innovation studies’ is broadly equivalent to the field of ‘Innovation studies’ focused on in Fagerberg et al. (2012), the addition of the term ‘science policy’ merely reflecting the name by which such studies tended to be known in the 1960s and 1970s.

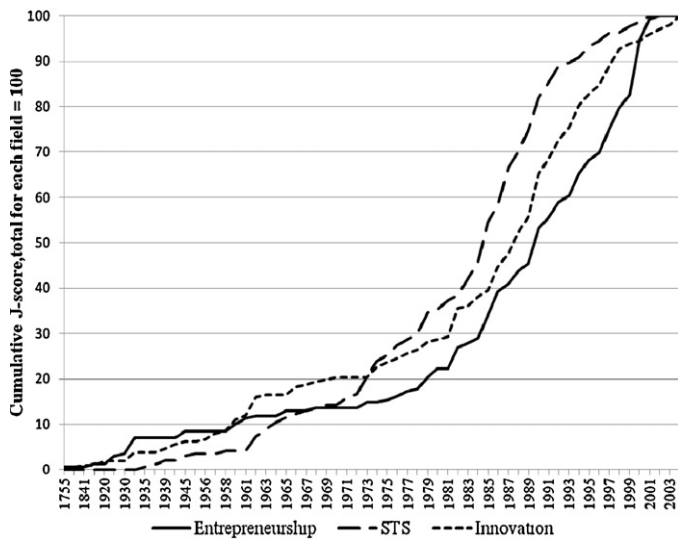


Fig. 1. The evolution of the core literature in innovation studies, entrepreneurship studies and STS.

time (based on the assessments of the handbook authors), the three fields developed at a relatively slow pace, more or less in parallel, until the late 1960s, when the STS field began to take off. A little later in the 1970s, the innovation studies literature also started to grow more rapidly, with particularly fast growth from the end of that decade, when a trend break is clearly noticeable. The entrepreneurship literature developed at a noticeably slower pace than the two other strands until around 1980, when it too took off.

3.1. Innovation studies

Despite earlier contributions by Schumpeter (1912/1934, 1942) and others, innovation studies as we know it today did not really exist as an identifiable research field before the late 1950s (Fagerberg et al., 2012; Martin, 2012). The attempts to develop a knowledge base on R&D and innovation around that time were largely confined to researchers in two leading industrial powers of the time, the US and the UK, and two disciplines, economics and sociology, with little mutual interaction between these. Hence, the research at that early stage is probably better characterized as multidisciplinary rather than interdisciplinary in nature. Actors from outside academia, in particular, the RAND corporation (a think-tank carrying out research and analysis for the US Department of Defense), the Federation of British Industry in the UK and the OECD (based in Paris), played an important role in providing resources and influencing the research agenda of the small community of researchers beginning to show an interest in this area, suggesting that the nascent field was mainly problem-driven in nature at that time.

In the early phase the differentiation of the field related mainly to the topic of the research, with researchers drawing upon cognitive resources from other disciplines to address that topic. Hence, at this stage, the research was essentially multidisciplinary. However, after a while, as researchers not only drew upon concepts, ideas, methods and theories from other disciplines but also began to synthesize and integrate these various inputs to a certain extent, the field became more interdisciplinary in character. The leading British research institute, SPRU, which was set up in 1966 at the recently founded University of Sussex with Christopher Freeman as the Director, was an important catalyst in this process. SPRU's annual report for 1971 (p. 6; emphasis in original) describes the unit's approach as follows:

*“The Unit's central interest is in policy for the professional research and development network and the way in which this social subsystem interacts with society as a whole. This interest includes both technological innovation arising from R&D, and the narrower concept of “science” as fundamental research. It extends to the diffusion process of innovations in social systems. From this it is clear that the work of the unit is **problem-oriented** rather than **discipline-oriented**. Since the object of investigation is a social system, the Unit employs social scientists of various kinds in its research. But since the particular R&D sub-system consists largely of scientists and technologists, the unit takes the view that direct collaboration with natural scientists and technologists is necessary for good work in the field. It also believes that collaboration between natural and social scientists can be fruitful in terms of method and cross-fertilization of ideas.”*

This statement is noteworthy in several respects. First, it contains, in a very condensed form, a system perspective on R&D and innovation, an idea that Freeman and others would come to pursue in various ways during the decades that followed, and which eventually became very central to the development of the field. Second, and related to this, it adopts a relatively broad perspective, recognizing that the analysis cannot be limited to the creation of new ideas, products and so on but also needs to include the adoption and use of these in the social and economic system, in other words, diffusion processes. Third, the need for multi- and interdisciplinarity in researching these issues is strongly emphasized, something that was also followed up in practice. Almost one half of SPRU staff at that time had a background in engineering or natural sciences, with the others being drawn primarily from the social sciences. This broad, systemic perspective combined with a strong emphasis on multi- and inter-disciplinarity came to be a defining characteristic, not only of SPRU, but also of the many other units that emerged around the world and that took inspiration from SPRU and Freeman. It helped to differentiate the emerging field from other strands of research operating at the time.

SPRU quickly developed into a global hub for research in this area, with a large number of visitors and students drawn from all over the world (Fagerberg et al., 2011). From early on, a significant share of its funding (around 80%) came from external sources. Its legitimacy was also strengthened by the engagement in teaching, which from modest beginnings developed into a Masters and doctoral program. What was to become the leading journal in innovation studies, *Research Policy* (Fagerberg and Verspagen, 2009; Fagerberg et al., 2012), was started in 1971 with Freeman as the main editor.

From the mid-1970s onwards, several influential theoretical and empirical contributions emerged that helped to establish a framework for subsequent research in this area. In 1974 Freeman published the first edition of his book, *The Economics of Industrial Innovation*, containing an original synthesis of the available knowledge about innovation, a book which proved very influential over the next two decades or more. In 1982 the Americans Richard Nelson and Sidney Winter published a book entitled *An Evolutionary Theory of Economic Change* (1982), which was to become by far the most influential work in innovation studies (see Fagerberg et al., 2012; Martin, 2012). In this and other works (e.g. Nelson and Winter, 1977), Nelson and Winter developed a radically different theoretical perspective on the micro-foundations of economic growth, emphasizing the heterogeneous character of firms and the ‘organizational knowledge’ that they possess. Influential research was also carried out on issues such as differences in how innovation operates across industries and sectors (Pavitt, 1984), appropriability conditions (Tece, 1986), and the role that firm-level capabilities play in innovation and learning (Cohen and Levinthal, 1990).

Another important contributor to the innovation literature during these years was the economic historian, Nathan Rosenberg (Rosenberg, 1976, 1982; Kline and Rosenberg, 1986), whose analyses of technological, institutional and economic change pointed to the need for a more systemic perspective on innovation. A new approach, centered on “national systems of innovation” (NSI), emerged around the late 1980s (Freeman, 1987; Lundvall, 1992; Nelson, 1993). Rather than focusing on various aspects of innovation in isolation, the NSI approach favours a more holistic perspective, emphasizing the role of interaction between different actors and how this interaction is influenced by broader social, institutional and political factors. This quickly attracted the attention of policy makers, who were in need of a framework for developing and assessing policies in this area (Lundvall and Borrás, 2004).

The field grew rapidly during the 1980s and 1990s, with a large number of researchers from various disciplinary and geographical backgrounds joining the field. Several new journals focusing on innovation and related issues were established, and professional associations were formed, among the most important being the International Joseph Schumpeter Society (ISS, formed in 1986), the Technology and Innovation Management Division (TIM) of the (American) Academy of Management (1987), DRUID (1995) and Globelics (2002).

Compared with the early years, the field today is much larger, more international and diverse in terms of research interests and disciplinary backgrounds. While initially the leading researchers came from the social sciences (and economics and sociology in particular), scholars in the area of business and management, and more generally the academic communities associated with business and management schools, have increased their roles as producers and – not least – as users of the knowledge base of innovation studies. Hence, leading innovation scholars such as Nelson and Freeman have generally found a much more fertile ground for their ideas among the rapidly expanding faculty in business and management schools than in their own native discipline of economics.

To sum up, the field relatively early in its development successfully differentiated itself from other strands within the social sciences through its specific thematic focus and strong emphasis on multi- and inter-disciplinarily. This was associated with entrepreneurship from leading scholars, with Christopher Freeman perhaps the most influential figure. Legitimation and mobilization of resources for the field’s development was partly sought externally, from important political actors at the national or international scene, and partly internally from the academic system through engagement in teaching, particularly at the graduate and postgraduate level, and the creation of an academic infrastructure of refereed journals and professional associations. According to the analysis of Fagerberg et al. (2012), there are now two large components of the field, one oriented towards economic, social and political issues and the other associated with the rapidly growing field of business and management, each to some extent with their own publication channels and meeting places. For example, there is no professional association that covers the entire field. The greatest challenge to the field in the years to come may be how to prevent these two components from drifting apart, with progressively less mutual interaction between them.

3.2. Entrepreneurship studies

Entrepreneurship is in some respects the youngest of the three fields included in this comparison. Although, as noted above, early contributions can be found as far back as the 18th and 19th Centuries, more systematic research on entrepreneurship did not emerge much before the 1980s. That emergence was mainly driven by economic and political changes in society during the 1960s

and 1970s. This might be characterized as a period in which new technologies were gaining ground, changes were taking place in industrial structure, questions were being raised about the efficiency of larger companies, and attitudes toward entrepreneurship were evolving, supported by politicians such as Ronald Reagan in the US and Margaret Thatcher in the UK. Against this background, entrepreneurship and industrial dynamics gained more attention in society. As a consequence, many scholars from a number of fields gravitated towards this promising area of research, and since the 1990s entrepreneurship studies has grown significantly in scale, establishing itself as a distinct field in its own right.

The study by Landström et al. (2012) focusing on the cognitive evolution of the field suggests that the emergence of entrepreneurship as a field of research can be regarded as an entrepreneurial achievement in itself, with some individuals being particularly instrumental in contributing to the wide-ranging knowledge of entrepreneurship as a phenomenon. Even though entrepreneurship studies are still based on fairly old theoretical frameworks imported from established fields such as ‘management studies’ and ‘economics’, over time, the field has become more formalized with its own core knowledge and with an increased number of influential works by ‘insiders’ to the field.⁴

However, the evolution of entrepreneurship studies cannot be explained solely in terms of individual (entrepreneurial) actions to create new knowledge about entrepreneurship; also important are the social processes based on the collective action taken by a number of people through which these ideas are created and subsequently institutionalized. In this respect, Aldrich (2012) explores six forces that have created an institutional infrastructure within the field, including: (1) social networking (through professional associations and conferences); (2) publication opportunities; (3) training and mentoring, for example, through the introduction of PhD programs; (4) foundations and funding sources; (5) recognition and awards; and (6) a globalization of the field.

If we take a closer look at the evolution of entrepreneurship studies since the 1980s, we can divide the development into three main phases: the take-off phase; the growth phase; and the search for maturity. The ‘take-off phase’ of entrepreneurship studies in the 1980s was characterized by a focus on discovering and making entrepreneurship more visible not only to researchers from a number of different fields of research but also, and not least, to policy-makers and politicians. At this stage, the research community was relatively small, individualistic and fragmented. Accordingly, there was a need to create a range of means for stimulating communication between scholars, and during the 1980s several ‘entrepreneurial’ initiatives were taken to create an infrastructure within the field – most notably the creation of various conferences (e.g. the Babson College Entrepreneurship Research Conference, and the RENT Conference), journals (e.g. *Journal of Business Venturing*, *Entrepreneurship and Regional Development*, and *Small Business Economics*) and professional organizations (the Entrepreneurship Division within the (American) Academy of Management, and the European Council for Small Business).

As we noted earlier, Hambrick and Chen (2008) argued that the evolution of new research fields could be described in terms of ‘differentiation’, ‘mobilization’ and ‘legitimacy’. Using this terminology, the 1980s can be characterized by a focus on ‘differentiating’ entrepreneurship – in other words, showing that entrepreneurship was an important phenomenon that could not be adequately addressed by existing disciplines like economics with its focus on notions such as equilibrium and economies of scale. In fact these arguments had already been raised by early

⁴ ‘Insiders’ are mainly appreciated by scholars within a given field (in contrast to ‘outsiders’).

proponents such as Schumpeter (1934). Later Baumol (1968) pointed to entrepreneurship as an important phenomenon to be studied but one that at that stage was only marginally considered by established disciplines. In the 1980s, interest in entrepreneurship started to grow among actors outside academia, not the least policy-makers and politicians. New fields need to mobilize resources, and organizations such as the National Federation of Independent Business (NFIB) and the Kauffman Foundation in the US promoted efforts to improve the databases available to entrepreneurship researchers, while OECD provided funding for the Observatory Reports that described the evolution of the small business sector in OECD countries over time. Entrepreneurship research was exploratory and in many cases based on anecdotal evidence, and at best it used rather simple and unsophisticated methods. Many scholars within as well as outside the field were critical of the research conducted, and the level of legitimacy of these early efforts within the academic community was in general quite low. Instead, legitimacy was gradually created more by external forces. Entrepreneurship captured the public's attention, not least because of the efforts of politicians and policy-makers, but also due to an increased interest in the media. Also of importance was the part played by the education system. Students started to request courses on entrepreneurship and small business, and the introduction by prestigious academic institutions like Wharton, Harvard and Stanford of entrepreneurship courses at an early stage conferred on entrepreneurship a measure of legitimacy in the academic system.

Since the end of the 1980s there has been an enormous growth of entrepreneurship studies. The cognitive development of the field was characterized by a strong empirical focus in which scholars tried to understand the entire phenomenon of entrepreneurship, pursuing a number of different directions. The 1990s were also characterized by the emergence of a research infrastructure within the field; many new chairs were established, new journals and conferences were launched, and there was an increase in the number of courses and education programs in entrepreneurship and related topics.

Following the terminology of Hambrick and Chen (2008) mentioned above, we can observe that entrepreneurship studies continued to differentiate itself from the mainstream field of management, and there was a tendency among scholars to regard themselves increasingly as belonging to this new field and as 'entrepreneurship scholars'. It can also be argued that the stronger infrastructure in entrepreneurship was important in order to achieve a level of 'academic autonomy' (Merton, 1973) that serves to distinguish it from other fields, but also helps to legitimate the field in the eyes of others. Legitimacy also increased with the enhanced quality of entrepreneurship research, at least at the 'top-end' of research, with an increased number of entrepreneurship articles appearing in leading management journals (Busenitz et al., 2003). 'Resource mobilization' was arguably the key issue for entrepreneurship research during the 1990s, and in Europe a considerable amount of research on policy-related issues was funded by governmental agencies, whereas in the US the Kauffman Foundation was instrumental in making available substantial grants for research projects in entrepreneurship. In addition, a number of entrepreneurship centres were created based on external funding, mainly from individual donors.

Entrepreneurship studies in the 2000s could be characterized in terms of a search for maturity. The article by Shane and Venkataraman (2000) in *Academy of Management Review* could be regarded as the trigger for an intense debate regarding the domain of entrepreneurship research, initiating increased interest in research on opportunity recognition, and creating renewed interest among entrepreneurship researchers in the Austrian School of Economics (cf. Kirzner, 1973, 1997). Over time, the research issues and the research community involved in

entrepreneurship have become more heterogeneous in character, and various different subgroups of scholars have emerged.

In terms of 'differentiation', it would appear that entrepreneurship researchers continue to search for an identity of their own, founded on the development of concepts and theories that can play a 'boundary-defining' role (in the 2000s several new field-specific concepts and theories have been put forward in an effort to gain a better understanding of entrepreneurship), as well as a distinct 'social culture' within the field based on regular and intensive discussions. Entrepreneurship studies have also 'mobilized' progressively more research funding, not least from policy agencies and individual donors, but the field still has difficulty in attracting larger funding from 'traditional' scientific foundations and funds. In addition, entrepreneurship research continues to struggle to be seen as a legitimate field in the eyes of many other scholars. On the one hand, the field of entrepreneurship studies does not seem to be evolving into a coherent entity but is instead developing in a number of new directions. On the other hand, there are signs that the field is finally gaining a measure of academic respectability. For example, over time entrepreneurship has established a relatively strong infrastructure within the academic system, such that today entrepreneurship is regarded as an essential component of regular courses and education programs offered at many universities around the world. In addition, entrepreneurship studies has in many ways begun to conform to the research norms and standards of established fields, often adopting a 'normal science' approach, and today articles on entrepreneurship are readily accepted in mainstream management journals.

3.3. Science and technology studies

Like innovation studies and entrepreneurship, science and technology studies did not exist as a distinct research field before the 1960s. Instead, there were relatively separate streams of work focusing on history of science, philosophy of science, and sociology of science. A few of the contributions from this earlier period were later to form part of the intellectual foundations of STS, appearing among the core contributions identified by Martin et al. (2012), for example, the work by Fleck (1935), Bernal (1939), Barber (1952), Merton (1957) and Polanyi (1958). While there were some early efforts to begin building bridges between these three research traditions, it was the publication of Kuhn's (1962) book, *The Structure of Scientific Revolutions*, and his demonstration that developments in science cannot be explained solely in terms of 'internal' factors, which set in motion a much closer integration of these three research fields, thereby helping to give birth to STS. (Hence Kuhn's position at #3 in the core contributions identified in Martin et al. (2012), as well as being the oldest publication in the top 20 – see Table 2 in *ibid.*)

However, it would be erroneous (as well as ironic) to portray the emergence of STS as being driven entirely by 'internal' forces. As Martin et al. (*ibid.*) note, there were broader societal influences at work, including the concerns of scientists and others about the role played by science in such developments as the atom bomb and technologies deployed during the Vietnam War. This gave rise to various efforts by 'concerned' or 'radical' scientists (including social scientists) and by those seeking 'social responsibility in science' (for example, in the UK) to demonstrate how science was shaped by political, economic and social forces, as well as being used to reinforce the power of established actors and the legitimacy of their policies. In the Netherlands and elsewhere in Europe, there were social and political movements seeking to 'open up' science to the wider public (for example, through the Dutch 'science shops'). As Martin et al. (*ibid.*) note, STS emerged from social networks such as these which were opposed to the traditional view of science with

its apolitical internalist history and its epistemologically focused philosophy of science.

Reflecting this mix of internal and external factors, a number of STS groups began to form in the 1960s and 70s, differentiating themselves from established departments of sociology, history, or philosophy – in other words, the first element in Hambrick and Chen's (2008) scheme. Examples include the groups established at Columbia, Yale and Cornell in the US, at Edinburgh, York and Bath in the UK, at Starnberg and later Bielefeld in Germany, and at Paris and (somewhat later) at Amsterdam and elsewhere in Europe. Despite the fact that the different 'schools' associated with these centres pursued different approaches, often in fierce rivalry with one another, STS began to coalesce as a field in the early part of 1970s as it embarked on the process of resource mobilization (Hambrick and Chen, 2008), in particular following the setting up of its own dedicated journal, *Social Studies of Science (SSS)* in 1971. A second journal, *Science, Technology & Human Values (ST&HV)* followed a few years later in 1976.

The emergence of the new field was signalled by the establishment of the Society for Social Studies of Science (4S) in 1975, and (a few years later) the European Association for Studies of Science and Technology (EASST, founded in 1981). Each of these professional associations organized regular conferences, bringing together large numbers of the growing STS community. This can be viewed as part of the process of legitimation set out in Hambrick and Chen's (2008) scheme. Another key event in that process was the publication of the first STS handbook in 1977, edited by two central figures (de Solla Price and Spiegel-Rösing) and bringing together contributions from other leading researchers in the emerging field. The 1970s also saw the publication of various books that began to form the intellectual 'core' of the new field, particularly Latour and Woolgar's (1979) *Laboratory Life: the Social Construction of Scientific Facts* (#2 in Table 2 in Martin et al., *ibid.*).

However, it was the following decade that, stimulated in part by Latour and Woolgar's (1979) emphasis on the social construction of scientific facts, saw the publication of the largest number of STS core contributions, with no less than nine of the top 20 (see Table 2, Martin et al., *ibid.*) appearing in the 1980s, mostly in the second half of the decade. The list was headed by Latour (1987), with his book on *Science in Action: How to Follow Scientists and Engineers through Society*. Other prominent contributions to the intellectual foundations of STS from this period included work by Pinch and Bijker (1984), Collins (1985), Shapin and Schaffer (1985), Bijker et al., 1987, Traweek (1988) and Star and Griesemer (1989). At the same time, the 1980s also witnessed the drifting apart of quantitative studies of science, previously an important part of the field, from the main body of STS, in which many researchers were increasingly critical of bibliometric approaches. Conversely, quantitative researchers often found it difficult to deal with the increasing conceptual and terminological complexity of mainstream STS. By the 1980s, bibliometric researchers were beginning to publish in their own journals (particularly *Scientometrics*, set up in 1978) and were increasingly attending their own conferences (for example, the 'Leiden' conferences on S&T indicators, first held in 1988) rather than the 4S or EASST conferences. In other words, quantitative science studies was going through its own process of first differentiation, and then resource mobilization and legitimation (Hambrick and Chen, 2008).

This process continued in the 1990s. One of the publications appearing highest in the list of core contributions for the decade was that by Narin et al. (1997) (#10 in Table 2, Martin et al., *ibid.*), which was highly regarded by authors in the second quantitative science studies handbook. By then, this would probably have been perceived less as a contribution to STS and more as one to science policy and innovation studies. Likewise, two other prominent core contributions from the period, those by Jasanoff (1990)

and Gibbons et al. (1994), both relate to science policy as well as STS. More central contributions to STS during the decade included Haraway (1991), Pickering (1995), and Knorr Cetina (1999). However, by then, the internal divisions were growing deeper and STS was becoming more fragmented, a process aggravated by its embroilment in the 'Science Wars' about scientific objectivity, scientific method and scientific knowledge, in which STS was subject to harsh criticism from leading scientists and others. One sign of these deepening divisions was the disbandment at the end of the decade of what had been one of Europe's leading STS centres, the Science Dynamics group at Amsterdam University (Clausen et al., 2012).

Comparison of STS with innovation studies and entrepreneurship suggests that in the latter two a number of leading researchers, besides publishing core contributions to the field, also took it upon themselves to construct the institutions and infrastructure necessary for the establishment of a new field. Such academic entrepreneurs are as crucial to the successful development of a field as the intellectual advances embodied in published core contributions. STS was unfortunately deprived of the services of two institution-builders by the untimely deaths of Derek de Solla Price and Nicholas Mullins. However, another explanation for the greater fragmentation in STS may be linked to the emphasis in STS on deconstructing claims to hierarchical knowledge, which, combined with a strong group identification, gives it more of an 'egalitarian' flavour and makes building consensus difficult, leaving the field more prone to fragmentation (cf. Hood, 1998, e.g. pp. 129 and 132). As Martin et al. (2012) note, in a field in which researchers often seem to have an almost theological concern with reflexivity and critique, institution-building is never going to be easy.

Whatever the case, STS gives the appearance of being more fragmented into competing 'schools'. In innovation studies, there have been some fierce debates in the past (for example, between economists such as Griliches and sociologists like Rogers in the early 1960s, or between advocates of the science-push and demand-pull models of innovation in the late 60s and early 70s, or over whether SMEs are more or less innovative than large firms), but these debates seem to be far less common than in STS. To some extent, this may be a consequence of the deliberate efforts of pioneers such as Nelson and Freeman to work cooperatively with others and to bring the field together. It may also partly reflect the role of S&T indicators in 'binding together' the field of innovation studies. This has not been a factor in STS, where, although science indicators had been prominent during the first decade or so, many STS researchers became rather sceptical or even hostile towards bibliometric indicators as time went on.

4. One or several fields?

One of the questions that motivated the research presented here is to what extent the three research areas can be said to be part of a single broader scientific field. In this section we will discuss what the various contributions in this special issue have to say in this regard.

Even if the three fields are relatively distinct research communities, with their own meeting places and communication channels, the possibility cannot be excluded that, to some extent at least, they share – and contribute to – broadly the same knowledge base. However, if so, one would expect the core literature of the three strands to overlap to some extent. In Table 1 the extent of overlap between the three sets of core literature is shown. Since the samples differ in size, and we wanted to limit the comparison to the more important publications, we chose to limit the analysis to the top 100 publications in each of the three fields (i.e. a maximum of 300 publications in total, if there was no overlap).

Table 1
Overlap between the three fields (among the top 100 contributions in each field).

	Rank in the core literature		
	Entrepreneur	STS	Innovation
<i>(a) Overlap between Innovation and Entrepreneurship</i>			
Marshall (1890): Principles of Economics	47		26
Schumpeter (1934): The Theory of Economic Development	1		4
Schumpeter (1942): Capitalism, Socialism, and Democracy	5		19
Penrose (1959): The Theory of the Growth of the Firm	17		69
Nelson and Winter (1982): An Evolutionary Theory of Economic Change	18		1
Williamson (1985): The Economic Institutions of Capitalism	89		88
Cohen and Levinthal (1990): Absorptive capacity: a new perspective on learning and innovation	35		8
Krugman (1991): Geography and Trade	99		94
Saxenian (1994): Regional Advantage: Culture and Competition in Silicon Valley and Route 128	14		11
Audretsch and Feldman (1996): R&D Spillovers and the Geography of Innovation and Production	67		78
Teece et al. (1997): Dynamic capabilities and strategic management	64		98
Aldrich (1999): Organizations Evolving	20		80
<i>(b) Overlap between Innovation and STS</i>			
Kuhn (1962): The Structure of Scientific Revolution		3	43
Rogers (1962): Diffusion of Innovations		82	5
Schmookler (1966): Invention and Economic Growth		34	44
Griliches (1990): Patent Statistics as Economic Indicators		31	50
Gibbons et al. (1994): The New Production of Knowledge, the Dynamics of Science and Research in Contemporary Societies		13	77

Sources: Analysis based on Appendix 1 in Fagerberg et al. (2012), Landström et al. (2012) and Martin et al. (2012).

The analysis summarized in Table 1 suggests that, for this sample at least, there is no overlap between STS and entrepreneurship and only a very limited overlap between STS and innovation studies. With regard to the latter, two of the five overlapping publications, Schmookler (1966) and Griliches (1990), are contributions on the use of patent statistics in economic analyses, and are probably only of relevance for that part of the STS community that focuses on measurement (which nowadays tends to regard itself as a somewhat separate subfield – see discussion above). The remaining ones are Kuhn's (1962) classic study on scientific revolutions and the book by Gibbons et al. (1994) on the two 'modes' of knowledge production, both of which are central in STS but much less so in innovation studies, and the study by Rogers (1962 with several later editions) on the diffusion of innovation, for which the opposite applies. Thus, as far as the literature is concerned, STS appears on this evidence to be a field that has little in common with the two other fields under study here.

However, innovation studies and entrepreneurship appear to be more closely related. The lists of the top 100 most important publications in the two areas have twelve entries in common, of which four are in the top twenty in both cases, including the two best known books by Schumpeter (1912/1934, 1942), Nelson and Winter's (1982) book on *An Evolutionary Theory of Economic Change* and the more recent analysis by Saxenian (1994) on the dynamics in Silicon Valley.⁵ Hence, central theoretical contributions with an evolutionary leaning seem to be an important element in the overlap. This characterization also applies to the contributions by Aldrich (1999) and Cohen and Levinthal (1990). Moreover, Lazonick (2004), in a review of the theory of the innovative firm for the Oxford Handbook of Innovation, includes both Marshall (1890) and Penrose (1959), also part of the overlap, as forerunners for later evolutionary theorizing in this area. The emphasis on firm-level knowledge and learning that characterizes much of this literature is also evident in the more recent management literature on 'dynamic capabilities' (Teece et al., 1997) which again figures among the top 100 contributions in both areas.⁶

⁵ The two least central contributors among the 12 are Williamson (1985) and Krugman (1991), who arguably are 'outsiders' to both fields.

⁶ Teece was one of the participants in the collaboration initiated by Freeman, Nelson and others in the 1980s (with the purpose of reviving evolutionary economics)

The relationships between the literature of the three fields are analyzed in more detail by Bhupatiraju et al. (2012), who examine the citations between the various publications included in the three sets of core literature. Their analysis confirms that there is very little interaction, as measured by cross-citation, between STS and entrepreneurship. There is somewhat more interaction between innovation studies and STS, and between innovation studies and entrepreneurship. However, most of the cross-citations are internal to the three fields, indicating that the division between them is relatively clear-cut. Bhupatiraju et al. (ibid.) explore, using different techniques, how this interaction pattern has evolved over time. The results indicate that the boundaries between STS, innovation studies and entrepreneurship were appreciably less clear a few decades ago than they are now. In particular, the development of a separate 'entrepreneurship' cluster, clearly distinguishable from innovation studies, appears, according to Bhupatiraju et al. (ibid.), to be a relatively recent phenomenon.

A different take on this issue is offered by the article of Clausen et al. (2012). In contrast to the studies referred above, which focus on the outputs of the scholarly activity (i.e. an 'object-oriented approach'), they research the organizational settings within which this scholarly activity takes place through a web-survey directed at leaders of research units in innovation studies, entrepreneurship studies and related fields (i.e. a 'subject-oriented approach'). They find (see Fig. 2) that less than one third of the research units surveyed focus on a single field only (i.e. on innovation, entrepreneurship, science/research policy or STS), with innovation studies or entrepreneurship being the most common. Among those centres that combine two or more areas, combinations including innovation studies and entrepreneurship are particularly common. In fact, nearly half the units combine research on innovation with research on entrepreneurship, sometimes extending to one or two of the other research areas included in their study. This indicates that, at the level of the research-performing units, there is considerable overlap between research on innovation and on entrepreneurship.

Science or research policy, which is included as a separate category in their survey, is also mentioned relatively frequently by

that led to the (previously mentioned) collective work by Dosi et al. (1988), in which Teece has a chapter.

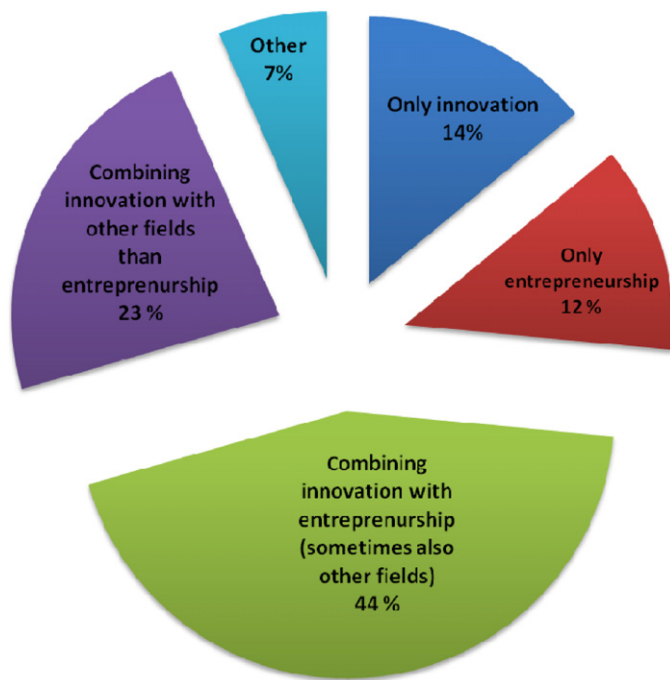


Fig. 2. One field or several? The focus of research units in these areas.

the respondents, but in nine out of ten cases in combination with innovation, and the same holds for STS (see Clausen et al., 2012). As pointed out by Martin (2012), the term ‘innovation studies’, as used today, often includes science/research policy as a subfield, so in that case this result may not seem very surprising. However, as mentioned earlier, the same observation holds to some extent for STS, which can hardly be considered as a subfield of innovation studies (Martin et al., 2012). In contrast, no research unit reports combining only STS and entrepreneurship, and only one unit (0.7%) combines research/science policy, STS and entrepreneurship (see Clausen et al., 2012, for further details). One possible explanation could be that innovation studies and STS have more in common thematically, although this is not obvious; indeed, one might have expected the relatively micro-oriented approach that characterizes much STS research to fit well with entrepreneurship studies. Another possible explanation might be that both STS and innovation studies are characterized by a high degree of interdisciplinarity and hence have more in common in that regard (in contrast to entrepreneurship studies, where an interdisciplinary approach is rather less common – see Landström and Persson, 2010; also Landström et al., 2012).

To sum up the discussion in this section, from a cognitive perspective the three fields appear relatively different and increasingly so (Bhupatiraju et al., 2012). In particular there is very little overlap between STS and the two other fields, while innovation studies and entrepreneurship have somewhat more in common. This overlap, however, appears to have more to do with the basic theoretical foundations or ‘roots’ of the two fields than with the more recent contributions to the core literature in the two fields. From a network perspective, the three fields also seem to some extent to develop in different directions, with their own specialized meeting places (conferences, professional associations) and publication channels.⁷ In fact, the research undertaken in the three central contributions to this special issue (Fagerberg et al., 2012; Landström et al., 2012; Martin et al., 2012) shows that, among the top ten journals citing

the core literature in the three fields, only one journal appears in all three cases, namely *Research Policy*. STS, in particular, appears to differ in this respect, while the two other fields again have rather more in common.⁸ Finally, an organizational perspective reveals that innovation and entrepreneurship scholars tend to be attached to the same local research units, while this is not the case for researchers associated with entrepreneurship and STS. Thus, one possible conclusion might be that the potential for exploiting synergies is largest for scholars in entrepreneurship and innovation studies. They tend to work in the same units, and they have some overlap with respect to the knowledge base and publication channels, but they have few common meeting places, which perhaps may be the greatest hurdle when it comes to exploiting this potential.

5. Challenges

In this section we discuss some of the challenges for science policy and governance arising from the research published in this special issue. As pointed out earlier, science is best seen as an evolving structure. New challenges, insights and opportunities regularly result in the creation of new scientific fields forming within or across existing disciplines. This is not the exception but rather the normal state of affairs (Whitley, 2000). From the viewpoint of society, this may be seen as a desirable outcome, as it may yield new, socially useful knowledge that the holders of this knowledge may then exploit to tackle societal challenges as they arise. A relevant question, therefore, is how science policy and governance may be shaped to support such renewal processes in science, particularly given that these processes often encounter strong resistance. While such resistance may be understandable in some instances, in others it may have less to do with the pursuit of truth and society’s need for knowledge than with attempts by elites to preserve the status quo with respect to the distribution of power, status and resources.

Much depends, of course, on the ability of academic entrepreneurs behind such renewal attempts to make a persuasive case for their initiatives, perhaps by putting forward what Hagstrom (1965, p. 215) called “utopias to legitimize their claims and to form the basis for identification”. However, good ideas and strong arguments are not enough. One clear lesson from the research in this area is, as we noted earlier, that renewal processes in science are highly dependent on resources, and that it is difficult to attract resources on the required scale by reallocating existing funding within universities. The reason is simple; someone’s gain is someone else’s loss, which understandably may provoke strong resistance. Therefore, as Clausen et al. (2012) point out, change agents (or ‘academic entrepreneurs’) within the world of science will usually have to assemble resources from several sources. Here, support from sources external to universities such as governments and research councils – but also private sources – are often important (ibid.). To some extent, this may be seen as good news with respect to policy effectiveness, because it shows that external financial support may have a large impact on the type of knowledge that is being produced in the system. The research reported in Clausen et al. also indicates that leaders of universities are often willing to support such renewal processes (provided they feel that there are good possibilities for attracting substantial external support), and that such support can be crucial for the success of the initiative.

While all countries support their scientific systems to some degree, the extent to which the support schemes are shaped with respect to renewal processes in science differs. In recent years,

⁷ For evidence, see Aldrich (2012), Fagerberg and Verspagen (2009), Fagerberg et al. (2012), Landström et al. (2012) and Martin et al. (2012).

⁸ This seems to some extent to reflect the fact that business and management scholars – and hence the journals in which they publish – are eager users of the core literature in the two fields (see Fagerberg et al., 2012; Landström et al., 2012).

there has been a drive in many countries towards performance-based criteria playing a larger role in such support schemes, and nowhere has this tendency been more manifest than in the UK system (Geuna and Martin, 2003). In the UK periodic evaluations of the entire university system have been undertaken, with future funding depending on the results of the research evaluation. This evaluation is conducted by largely disciplinary panels, which in turn have based their assessments to a significant extent on the publication records with particular emphasis on articles in 'top journals' (Martin and Whitley, 2010). While such a system may be effective in supporting high quality research within existing, well established disciplines, particularly in areas where publication in journals is the rule, it may also have certain side effects that are not necessarily desirable, such as introducing a bias against renewal processes, particularly across or outside existing disciplines (ibid.). For example, Rafols et al. (2012), show how the use of journal rankings in research evaluations may substantially disadvantage interdisciplinary research. Comparison with UK Management Schools shows, not surprisingly, that innovation studies units are consistently more interdisciplinary in their research. However, the top journals in the widely used Association of Business Schools' ranking scheme tend to span a relatively narrow set of disciplines, and this results in a more favourable assessment of the performance of disciplinary-focused units such as Management Schools compared with innovation research centres. The study thus challenges research assessment exercises based on journal ranking schemes, illustrating how, although ostensibly 'excellence-based', such rankings tend to exhibit a systematic intrinsic bias in favour of mono-disciplinary research. Such a bias is likely to adversely affect the financial resourcing of interdisciplinary research organizations, and may also result in researchers becoming more compliant with disciplinary authority over time (Martin and Whitley, 2010). Clearly, research assessment in one form or another is essential, and published output must feature centrally in such assessments. But there is no reason why a publication by an innovation scholar, say, in *Nature* should be less "valuable" in such an assessment than one in a top management or economics journal. On the contrary, the ability of a research unit to publish widely in high quality channels should be regarded as strength and not be discouraged, as happens when narrow discipline-based lists of journals are used as the basis for the assessment. It should surely be an objective of science policy to combat such disciplinary narrow-mindedness when designing the criteria for research assessments. Moreover, focusing only on journals and ignoring books, which are important in many scientific fields (and particularly in emerging ones), may also discriminate against interdisciplinary research endeavours in general, and socially relevant research and policy research in particular.

An evolving society requires a continuous renewal of its knowledge base and the scientific system supporting it. While the established institutions in science may be good at promoting high quality research within existing boundaries, they are often less effective in supporting new knowledge that challenges those very boundaries. Supporting such renewal, therefore, should be a key goal for science policy. To some extent the need for new knowledge, for example in helping to deal with global warming, may be foreseen by politicians and other actors who may design targeted schemes supporting the production of that new knowledge. The evidence presented in this paper suggests that such support, to be effective, needs to be long term and to include support for academic entrepreneurship and the creation of new research units among academics specializing in the targeted area. Such 'top-down' initiatives are not sufficient, however, to guarantee a dynamic scientific system adapted to the changing needs of society. Not all new needs for knowledge can be easily predicted in advance, and this applies even more so for the social carriers of that knowledge. A dynamic system therefore must have room for 'bottom-up'

renewal processes as well (e.g. supporting academic excellence and academic entrepreneurship independent of scientific field), and this may require separate schemes supporting such initiatives not only within, but also across, existing disciplines and fields of specialization.⁹

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⁹ Several funding sources, such as the European Research Council (ERC) and the Netherlands Organisation for Scientific Research (NOW) and the Royal Netherlands Academy for Arts and Sciences (KNAW), have designed specific procedures for such interdisciplinary initiatives.

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