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There has been a considerable increase in the literature devoted to innovation in the past few decades. This research area is characterized by prolific interdisciplinary connections and no single domain is able to embrace all aspects of science, technology and innovation. By analyzing nearly 60,000 references included in the 1442 articles published between 1974 and 2007 in the area's seed journal, *Research Policy* (*RP*), we have uncovered the following patterns: (1) the most important sources of knowledge are associated with "core" economics (mostly mainstream) and management sources, even though the importance of innovation-related sources has been rising; (2) the degree of autonomy of science, technology and innovation research is still weak, revealing its incipience and lack of a unified theoretical framework; (3) the most influential authors and studies follow heterodox approaches, namely the evolutionary approach (e.g. Richard R. Nelson) and the European approach to innovation (e.g. Keith Pavitt and Chris Freeman), although it is rather surprising that one of the most widely recognized founding fathers of innovation-related studies, Joseph Schumpeter, is absent from the top-10 cited authors list; and (4) the ranking of the most influential studies highlights the relevance of the evolutionary paradigm, with its focus on the capabilities and routines of firms, and the policy-driven nature of topics, evidencing the pervasiveness of the literature on the National System of Innovation.

Keywords: state-of-the-art; bibliometrics; innovation

Introduction

Scientific progress is accomplished by local and national researchers, but primarily by researchers integrated in international networks who study research topics stemming from the work of other scientists (Price 1963). By working in an international environment, researchers are informed collectively of the results of their studies. Such findings need to be published – otherwise they would never "exist" – and are thus constantly submitted to continuous peer review (Van Raan and Van Leeuwen 2002).

Through the use of references, the scientific community shows in which ways their work is connected with previous studies (Teixeira 2011; Du and Teixeira 2012). Using such references is the basis of bibliometrics, a mathematical and statistical tool that enlightens the process of written communication as well as the nature and advancement of a scientific field (Pritchard 1969). There have been criticisms of this

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method that mention the lack of a structured use of references by scientists. Thus, the use of bibliometrics has been considered somewhat unwise for research quality assessments (Cozzens 1989). However, Van Raan and Van Leeuwen (2002) empirically support the use of bibliometric analyses, arguing that scientific literature is a portrayal of scientific activity and that the number of times a set of literary ideas is cited worldwide can be seen as a measure of the impact of the research, or its international visibility. Nowadays, bibliometrics is widely used since it provides critical information on research performance and it is viewed as a complement to qualitative literature surveys (Silva and Teixeira 2009).

As is the case of other recent, developing research fields, the rapid development of science, technology and innovation (STI) research has resulted in a wide variety and heterogeneity of concepts, theoretical approaches and empirical findings. However, few efforts have been made as yet to develop a coherent theoretical groundwork that would combine the different research concepts underlying all the literature produced so far. In this respect, there is a need to systematize efforts so as to discuss the state-of-the-art of studies on science, technology and innovation and point out directions for future research. Existing studies within this field of research are mostly based on qualitative reviews of the literature by peer scientists. It is thus important to approach the area of innovation from the "quantitative" point of view, using bibliometric methods that allow for a proper analysis of changes/trends. The present study seeks to fill this gap, complementing available qualitative analyses by providing a different, yet relevant viewpoint concerning the evolution of topics analyzed within this hybrid area.

Given the enormous volume of literature published about STI, whether as books or scientific journals, this study is centered on the analysis of a scientific journal considered to be more specialized and influential (Linton 2006) than others, in which many authors, including the most renowned in this field of research, are keen to publish. Thus for the bibliometric analysis we selected the *Research Policy* (*RP*) journal, which stands out among the top journals in STI research, according to reasoned criticism by various authors (e.g. Linton and Thongpapanl 2004) and the analysis of its impact factor (Figure 1). Thus, by thoroughly analyzing abstracts of 1442 articles published in *RP* between 1974 and 2007, and proceeding with a statistical analysis of almost 60,000 citations, this study provides an innovating overview of the state-of-the-art in innovation research.

The article is divided into four sections. The following section presents a brief qualitative overview of the literature on science, technology and innovation, detailing a few key concepts as well as characterizing and documenting the growing importance of this area. The next section analyzes the state-of-the-art of science, technology and innovation research using *RP* as a reference and performing an analysis of the in-flows of knowledge within the STI area based on the citations made in *RP*'s articles. Finally, the conclusion summarizes the main research findings.

Qualitative overview of the literature on science, technology and innovation

In a classic source (Schmookler 1966), technology is defined as "social pool of knowledge of the industrial arts" and technological change as changes to that pool of knowledge. Meanwhile the concept of "technology" has undergone both stricter and broader definitions, from technical information only (contained in a patent) to a more generic meaning that combines the artifact dimension (machine) with the

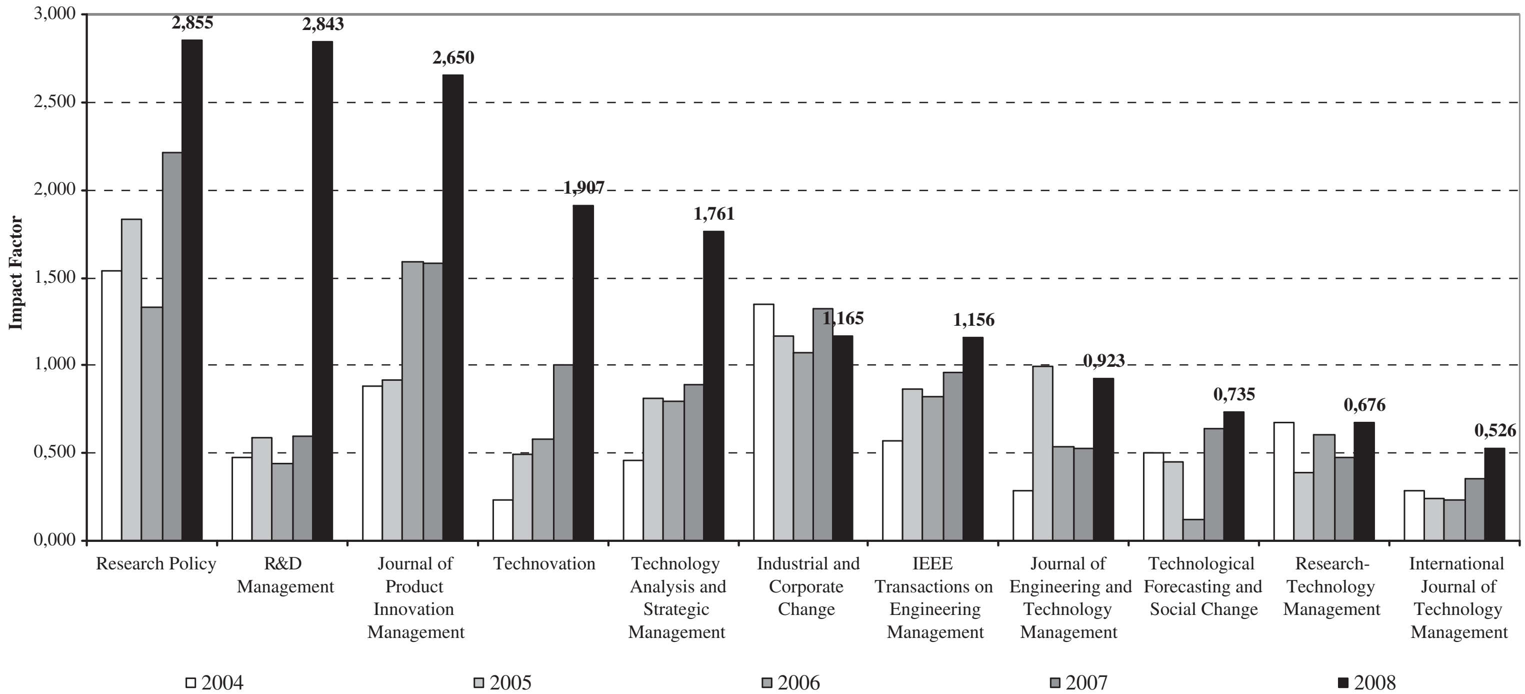

Figure 1. Top journals in science, technology and innovation research by impact factor, 2004–2008.
Source: ISI Web of Knowledge[SM], 2008 JCR Social Science Edition.

technical know-how of human beings (engineers, managers, machine operators, etc.). Broader definitions also include institutions that facilitate the use of technical know-how (including companies and the way they are organized), as well as the social–political and legal settings that influence the direction and transfer rate of technical know-how and its associated artifacts.

Hence, depending on the context and definition, technological change may relate not only to changes to knowledge that, *a priori*, all potential users could easily access, but also to the experience associated with people's work and learning, as well as developments in the machines they work with (Hall 1994). It may also apply to organizational and social–cultural changes. When such changes involve some type of improvement in terms of a given criterion, it is called technological progress or advance.

Technical or technological change requires innovation. Like "technology", innovation can also be given a narrow or a broad meaning. The overall innovation process involves a number of activities contributing toward the production of new products and services, or using entirely new forms/methods. In the strictest sense, innovation occurs when a new product, service or production method is marketed for the first time. This usually means the first time in a given economy, but sometimes it can be in a certain company or at the global level (Tidd et al. 2005). Whenever a given product is produced by a new method, there is process innovation. When a product is modified or a new product introduced, then there is product innovation. It is important to note that some product innovations are also process innovations (Steil et al. 2002).

Generally speaking, STI research covers topics in the economics of innovation (Freeman 1990) and economics of technological change (Mansfield and Mansfield 1993). The former is usually associated with the evolutionary thought movement and the latter with the neoclassical school. Although this "division" of nomenclatures and schools may be evident in the work edited by Chris Freeman (the economics of innovation) and Edwin and Elizabeth Mansfield (the economics of technical change), a not insignificant number of authors (mainly scholars) in the area do not distinguish between them (at least not explicitly).

In the work edited by Freeman, the main topics are as follows: "innovation and evolutionary models of economic growth and development", "sources and effects of innovation", "innovative business strategies", "the selective context that innovative companies are facing" and "patterns of innovation, cycles and paradigms". In the work by Mansfield and Mansfield, the "preferred" topics are: "technological change and economic growth", "the social and private returns to research and development", "market structure and technological change", "intellectual property rights", "diffusion of innovations", "international technology transfer" and "technology management".

The stress on interdisciplinarity that characterizes most of the work in the innovation policy area reflects the fact that no single domain is able to encompass all aspects of innovation. Therefore, in order to obtain a wider picture, it is necessary to combine contributions from several disciplines. Economics, for instance, has traditionally worked with the issue of allocating resources to innovation activities in competition with other purposes and their respective economic impacts; here the process of innovation has been more or less treated as a "black box". What happens in this "box" has been left for other domains to figure out. Most of what happens in the innovation area obviously has to do with learning, a central topic in cognitive science. Such learning takes place in organized milieus, for example, groups, teams, companies and networks, and the ways in which they operate are studied in fields such as sociology, science of organizations, management and business studies. In addition, as argued by economic geographers, learning processes tend to relate to specific contexts and locations. The way innovation is organized, as well as its location, has also undergone major changes over time, as outlined in studies within the scope of economic history. STI thus invaded the territory that had already been subdivided among industrial economics, business theory and management, regional economics, as well as international economics, public economics or engineering.

Despite the fact that all schools of thought have systematically acknowledged the central importance of innovation for the competitiveness of companies and nations, as well as for the long-term growth of the world economy (Freeman 1990), up until the second half of the twentieth century, most economists dedicated little or no attention to the study of technological change (Godinho 2000).

> Schumpeter was almost alone among the leading economists in placing innovation at the centre of his theoretical system from his first classic work on the Theory of Economic Development (1931) until his death in 1950. (Freeman 1990)

Traditionally, studies on long-term economic change were focused on factors such as capital accumulation or how markets operate, but not innovation. Today, this seems to be changing. Research on the role of economic and social changes associated with technology and innovation has proliferated over the past few years, particularly within the scope of the social sciences, with a markedly multidisciplinary nature.

In fact, as illustrated in Figure 2, in recent years, the number of articles published in scientific journals (indexed in Econlit) that focused on innovation and technology topics increased much more rapidly than the total number of articles published in all areas of Economics, respectively 14 and 7% per year on average between 1990 and 2006. It is worth noting that the proportion of articles that focused on innovation or

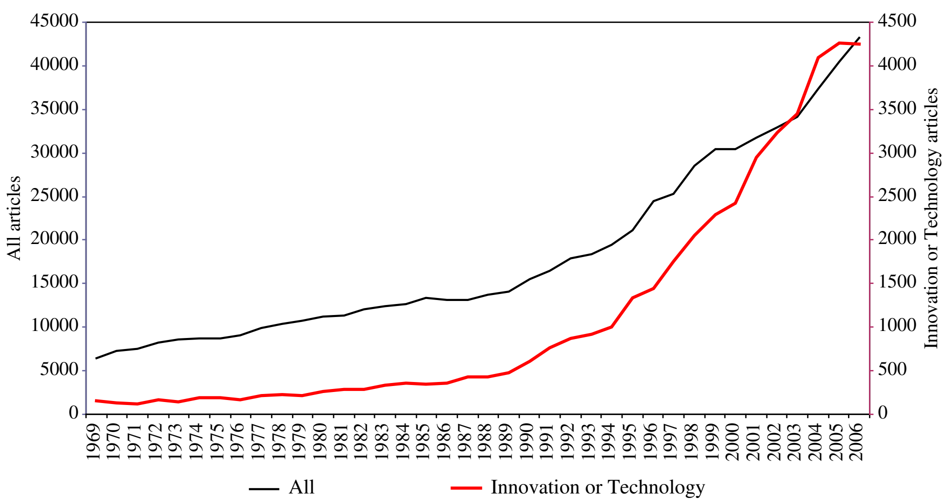

Figure 2. Number of articles published per year in journals indexed in Econlit, 1969–2006.
Source: Calculations based on information extracted from Econlit.

technology issues did not exceed 2% of the total number of articles published in journals indexed in Econlit in the 1970s, and this proportion more than doubled (to almost 6%) in the 1990s, reaching approximately 10% of the total between 2000 and 2006. As a result, there has been a considerable increase in knowledge on the innovation process as well as its determinants, and its economic and social impacts.

Early contributions in innovation research were shaped by the works of Schumpeter (1940s and 1950s), who emphasized the dynamic character of innovation. Thus, a substantial part of the studies was dedicated to the issue of whether the power of the market would be a prerequisite to carry out R&D and whether political authorities should censure static market power even in circumstances in which this would encourage innovation.

The birth and rise of innovation as a specific area of academic study and empirical research – applied to concrete problems of industrial dynamics, business strategy and economic policy – occurred at the same time as the boundaries of economic theory expanded horizontally during the 1950s and 1960s (Antonelli et al. 2006).

The efforts by Chris Freeman greatly contributed to the autonomy of innovation. In 1965, he founded the Science Policy Research Unit (SPRU) at the University of Sussex (Fagerberg 2005). The research conducted at SPRU gave rise to a great number of projects, conferences and publications: *RP*, one of the most influential journals in the field, was created in 1972 with Chris Freeman as founding-editor (and after him another "giant" of innovation studies, Keith Pavitt, also from SPRU); the first edition of *The Economics of Industrial Innovation*, a seminal book by Chris Freeman, was published in 1974, and edited and reviewed twice after that. Freeman was also a key player in the establishment of a vast collaboration project (International Federation of Institutes for Advanced Study) which resulted in the publication of another seminal book in the field of innovation, *Technical Change and Economic Theory*, edited by Dosi, Freeman, Nelson, Silverberg and Soete (Dosi and Soete were Ph.D. students at SPRU) in 1988. SPRU was a model for the establishment of many research institutions in the field of innovation, essentially from the mid-1980s, in Europe and especially in Asia, combining multidisciplinary Master's and Ph.D. programes with externally funded research.

In a complementary line, although within a different, neoclassical paradigm, since the late 1950s several researchers (e.g. Arrow, Griliches, Mansfield and Solow) in the USA have contributed to the development of the field of economics (mostly), of technology and, (to a lesser extent) of innovation. Thus, econometric and applied works by Griliches and Mansfield, theoretical works by Arrow and Nelson, or Rosenberg's work, with its distinctive, historical perspective, brought decisive advances which were for the most part integrated in this new field of knowledge. What distinguishes the research of some of these American economists from that carried out in Europe is the fact that, at least initially, it is part of a theoretical matrix closer to the neoclassical school. Progressively, however, many of these economists, unsatisfied with the limitations imposed by the paradigm of the representative agent, or with the assumptions of rationality and perfect information, produced contributions that were significant improvements on neoclassical thought or that became progressively more closely linked to alternative theoretical frameworks, such as the evolutionary one (Godinho 2000).

The evolutionary approach is a relatively recent economic methodology based on biology that emphasizes the complexity of the interdependencies between economic agents, competition, growth and resource restrictions (Hodgson 1998; Dopfer 2006). One of the most important contributions to evolutionary economics was the publication of *An Evolutionary Theory of Economic Change* by Richard Nelson and Sidney Winter in 1982. These authors focused essentially on the issue of technological changes and routines, suggesting a framework for their analysis. In this line of thought, if there is constant change in economics, then some type of evolutionary process will have to be in operation, proposing that the nature of the process was "Darwinian". Thus, it is necessary to identify mechanisms that facilitate selection, generate variation and establish self-propagation. In the evolutionary approach, markets are the main vehicle of selection. As companies compete against each other, unsuccessful rivals fail to obtain a suitable market share, start to decline and are forced to leave the market. The variety of competing companies stems from both their products and their practices when confronted with the market. Products and practices are determined by the routines used in companies: standardized patterns of actions implemented in a continuum. Through the imitation of such routines, companies propagate themselves and thus establish a legacy of successful practices.

Modern economic evolutionism is also particularly influenced by "Schumpeterian" techno-economic dynamics and by behavioral approaches, as developed by Herbert Simon and others (Witt 1993). Evolutionary economics is characterized by an interest in economic change and its causes, in the motivations and rationales of intervening agents, in the process in which the change takes place, and its consequences. Evolutionary authors have sought to contribute to an understanding of competing and cooperative behaviors that typify the action of economic agents and are the basis of much of the technological, organizational and institutional dynamics that characterize the contemporary world. In spite of the antagonistic nature of these two types of behavior, since they simultaneously contribute to the selection and cohesion of the economic system, the said authors have also underlined their complementary nature. This complementarity can thus be seen alongside the impulses of change and rupture (innovation), and the interaction between competition and cooperation also creates the basis (diffusion) for the preservation and reproduction of the economic system (Godinho 2000).

Metcalfe (1995) unequivocally shows the close relation between the evolutionary theory of innovation and the literature on "systems of innovation". The influential book edited by Bengt-Ake Lundvall, *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (published in 1992), marks the beginning of a long series of studies on this matter. In this literature, the production and dissemination of economically relevant knowledge emerges as strongly conditioned by the "historical tradition, culture and institutions" of the countries/regions where innovation systems are located. Additionally, innovation is considered a "systemic" phenomenon, associated with the density and quality of interactions between the different parts of the system, including companies, their suppliers and clients, science and technology infrastructures, financial entities and other intervening organizations and agencies, namely governmental. The studies on innovation systems also highlight the importance of "tacit knowledge existing locally and the cumulative processes of skills development" which have, in the course of time, proven critical in the production of innovation. Alongside these singular aspects, research on systems of innovation, in particular "regional systems of innovation" (Braczyk et al. 1998), has sought to demonstrate that regions with more intensive systemic dynamics are those that also present a higher capacity to incorporate national and international networks and assimilate inputs from external sources.

More recently, developments in innovation research have been centered on other aspects, such as the impact of spillovers on productivity, the role of cooperation in R&D and the importance of patents in promoting innovation when it is cumulative – Sena (2004) provides an extensive and meticulous overview of the literature on these topics. Audretsch et al. (2002), in a summary article on innovation and technological change, point out important advances in this area in the last two decades:

> In some instances, the areas of study we examined . . . were essentially unknown as formal research topics just a few short years ago.

The studies on patents and intellectual property serve as clear examples, since until very recently, according to the above-mentioned authors, they included very few contributions of relevance. Although the availability of patent databases and of quantification techniques greatly facilitated research in this field, the influence of public policy was equally instrumental in the proliferation of studies in the area. With changes to laws and statutes relative to patents, and particularly to the detention of intellectual property by universities and public researchers, the matter has clearly gained greater importance in more recent years.

Similarly, the study of internal technological transfer could not, to all intents and purposes, be considered a field of research 20 years ago. However, the convergence of research techniques and political initiative has led to an increase in research on this topic.

There are several aspects that still require additional exploration (Audretsch et al. 2002; Sena 2004; Antonelli et al. 2006). The first of these is the relation between globalization and the property of science and technology. Although there is a well-established literature on international technology transfer, the typical model used in these studies is centered on understanding the relations between technology or knowledge of the "granting" nation and that of the "receiving" nation. This type of model is not sufficient for understanding the complexities of the current state of technology transfer. This stems from the fact that nowadays there are numerous situations in which the figure of "business-nation" is practically inconsequential, in which capital flows through a wide range of different channels, institutions and multinational forums, and in which technology is simultaneously transacted by different channels with different companies in a large number of countries. The complexity of this process is not easily rendered in the existing models.

Another area that requires more attention from the research community is the intersection between economics of innovation and technological change and issues related to social and redistributed equity (in addition to the question of how much new technology affects the labor force). In fact, one of the most interesting questions in the economics of innovation and technological change is who "wins" and who "loses" with innovation and the introduction of new technologies. The "digital divide" (Crenshaw and Robison 2006) is often heard of, but there are also disparities, for instance, in healthcare technologies. If we can understand the economic forces that enable the efficient production and transaction of technologies associated with health and pharmaceuticals, but fail to understand the problem of (re)distribution related to access to technology, we are likely to encourage more and more innovation while aggravating inequalities in society (Went 2005).

Flows of knowledge in science, technology and innovation. A bibliometric analysis based on citations from *RP* articles

Methodological underpinnings

The citations found in *RP* articles were obtained through Thomson Reuters' Web of Knowledge[SM] database. A set of references was exported to an Excel® spreadsheet for each of the 1442 articles published between 1974 and 2007. For each article, the database includes information relative to the citations under study, namely first author, year and publication. Organizing the article database by citations resulted in 57,552 entries. This high number of entries required the use of Access® software, which enabled the creation of relations between data and consequently between the tables presented below. In this section, the analysis – based on the citations found in *RP* articles – is of a static statistical nature, that is, types of publication, authors and most-cited articles are detailed for the overall time period (1974–2007).

Most important cited sources

A total of 57,552 citations were found in the 1442 articles published in the *RP* journal between 1974 and 2007. Approximately 45% (26,110) refer to scientific journals and the remainder to other sources, such as books, published and unpublished theses, working papers, notes, reports or newspapers. Within this set of citations, the number of scientific journals cited is 3706. It is interesting to note that *RP* chiefly cites studies published in *RP* itself (representing about 7.2% of all the citations or 15.8% of all the citations and journals), followed by, although lagging relatively far behind, the *Strategic Management Journal* (1.3%; see Table 1).

As shown in Table 1, journals in areas such as economics, management or innovation are among the 20 most-cited sources in *RP*. This list includes a high percentage of journals in the area of economics (33.2%), where the highest number of references covers publications in the area of STI, thus confirming the analysis by Linton and Thongpapanl (2004). Therefore, if a researcher intends to approach the STI research area from an economic perspective, then *RP* is clearly the best and most prestigious journal to begin work on (Linton and Thongpapanl 2004).

Interestingly, the twentieth most-cited publication (ex quo with *Econometrics*) is a book entitled *Technical Change and Economic Theory*, edited in 1988 by a group of renowned authors – Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg and Luc Soete – resulting from a large collaboration project (IFIAS) aimed at rethinking the economic theory of innovation. The fact that this work is included in the 20 most-cited publications proves its seminal nature in the field of innovation research.

In terms of the "quality" of citations, it is clear that, since it is the leading journal in the area of STI, *RP* cites a number of high-quality journals from different areas. Over 60% of the 19 journals mentioned in Table 1 (other than *RP*) are classified (according to the Tinbergen Institute) as AAs and As, and the remainder as Bs.

Among the most important sources of knowledge that have "fed" *RP* (see Figure 3), literature in the field of innovation stands out, representing about 29% of all the citations, even though *RP* alone accounts for 7.2%. The journal thus emerges as having relatively little autonomy as its representativeness in the citations' total is fairly low. At the same time, the number of contributions from the economics and

Table 1. The 20 most-cited sources in *RP*'s articles, 1974–2007

Rank	Journal/book	Scientific area	Number of citations	Percentage of total ($n = 57{,}552$)	Impact Factor (2006)	Tinbergen classification
1	***Research Policy***	**Innovation (EMI)**	**4138**	**7.2**	**1.328**	**B**
2	*Strategic Management Journal*	Management	772	1.3	2.632	A
3	*American Economic Review*	Economics	745	1.3	1.876	AA
4	*Management Science*	Management	545	1.0	1.687	A
5	*Administration Science Quarterly*	Management	526	0.9	2.455	A
6	*Scientometrics*	Science	439	0.8	1.363	B
7	***Industrial Corporate Change***	**Innovation**	**437**	**0.8**	**1.076**	**B**
8	*Economic Journal*	Economics	398	0.7	1.629	A
9	***R&D Management***	**Innovation (EMI)**	**349**	**0.6**	**0.443**	**B**
10	*Science*	Science	335	0.6	30.028	AA
11	*The RAND Journal of Economics*	Economics	307	0.5	1.077	B
12	*The Review of Economics and Statistics*	Economics	305	0.5	1.085	B
13	*Organisation Science*	Management	298	0.5	2.815	AA
14	*Quarterly Journal of Economics*	Economics	292	0.5	3.938	AA
15	*The Journal of Industrial Economics*	Economics	281	0.5	1.152	B
16	*Journal of Economic Literature*	Economics	276	0.5	4.667	AA
17	*Journal of Political Economy*	Economics	252	0.4	3.194	AA
18	***Technovation***	**Innovation (EMI)**	**214**	**0.4**	**0.582**	**B**
19	*Academic Management Journal*	Management	213	0.4	3.353	AA
20	*Econometrica*	Economics	211	0.4	2.402	A
20	***Technical Change and Economic Theory***	**Innovation**	**211**	**0.4**	**—**	**—**

Source: Calculations based on information extracted from the ISI Web of Knowledge[SM].
Legend: AA, generally accepted as leading journals; A, very good journals covering economics in general and leading journals in each field of research; B, good journals in all fields of research (see Tinbergen Institute Journal Ranking); bold shows innovation-related sources.

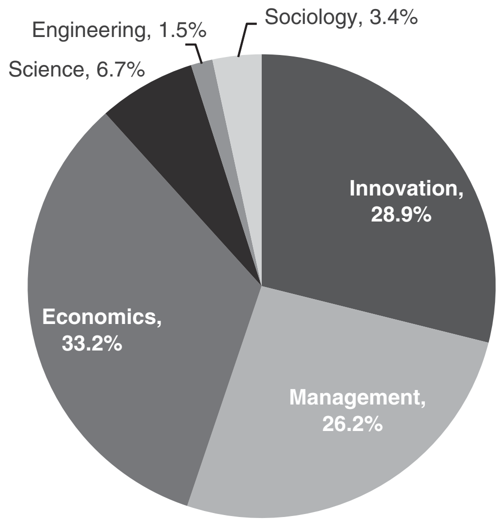

Figure 3. Distribution (%) of the areas of the most-cited publications by articles published in *RP*, 1974–2007.
Source: Calculations based on information extracted from the ISI Web of Knowledge[SM].

management areas is high (approximately 60%), which supports, in line with Vieira and Teixeira (2010), the claim that innovation research is dependent on more wide-ranging, "core" areas of study.

Analyzing the other side of the "coin", by looking at the top-20 list of journals that cites *RP* in their articles, we conclude that *RP* does not have a great impact on core economics journals (no economics-related journals are included in the top-20 citing journals), albeit its influence on core, high-quality, management journals is somehow emerging, with *Journal of Management Studies* and *Strategic Management Journal* appearing as the most important *RP* citing sources. On the whole, the range of influence of *RP* is, in contrast with its roots/scientific basis, relatively narrow; *RP*'s greatest influence is on (high-quality) journals belonging to the STI field, which represent 60% of the top-20 listed journals citing *RP*.

Figure 4 reflects the evolution of the distribution of sources' citations by articles published in *RP* over the years of its existence. Specifically it presents in relative values the 10 most-frequently cited publications (in each sub-period of the period under study, 1974–2007). As shown, the citations of more generalist journals, such as *Science* or *Nature*, have fallen into decline as more recent authors of *RP* have been citing another genre of journals more closely linked to economics and management. *Industrial Corporate Change* and the *Strategic Management Journal* have gained relevance in the distribution of the most-cited publications by *RP*. The former journal is dedicated to the analysis of businesses and industry through an interdisciplinary approach centered on issues related to economics, sociology of organizations and organizational theory, and the latter is more focused on aspects of strategic management. Also the *American Economic Review* (generalist journal of economics) has seen its representativeness grow over time as *RP*'s source of knowledge, thus explaining the greater expressivity of economics topics (Linton and Thongpapanl 2004).

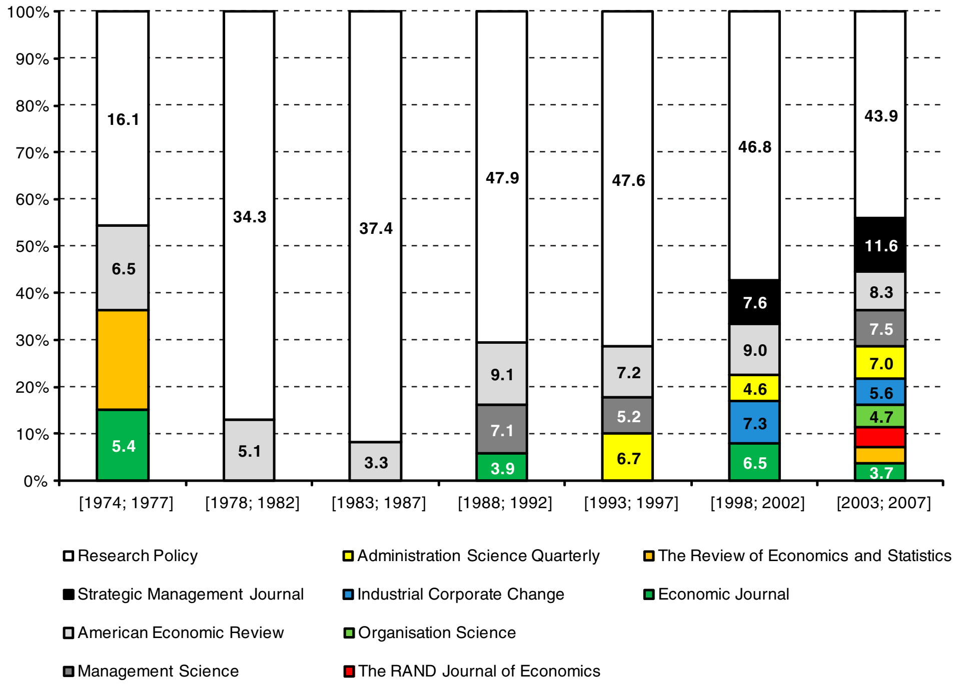

Figure 4. Distribution (%) of the 10 most-cited sources in *RP*, 1974–2007.
Source: Calculations based on information extracted from the ISI Web of Knowledge[SM].

Most important cited (first) authors

The analysis of the top-cited authors in *RP* (see Table 2) is important and potentially revealing of the schools of thought that have most served as the journal's knowledge base – the evolutionary school (Nelson, Winter, Freeman, Dosi, among others) and the neoclassical school (for example, Mansfield, von Hippel and Griliches). The analysis presented on the most-cited authors is relatively limited and partial since it is restricted to the first author of each publication. The database used – ISI Web of Knowledge[SM] – only provides information on the first author of each cited work but not on all published authors (co-authors).

The 20 most-cited authors represent about 11% of all the authors cited in *RP* (19,843 different authors). Nelson and Pavitt are in the leading position, as the two most extensively published authors in *RP* between 1974 and 2007 (Teixeira and Silva 2010).

The education and research institution corresponding to the author's affiliation with the highest representation (20%) in Table 2 is the University of Sussex (SPRU). Next on the list is Harvard University (Cambridge, MA), representing 15% of the sample. Even though the institute with the highest representation is located in the UK, education and research institutions in the USA are those with the highest representativeness (65% of the total) on the list of most-cited author affiliations.

When analyzing the most-cited authors over the period studied, we can observe that, as a general rule, authors whose relative importance has grown – among the 10 most-cited (Figure 5) – have also experienced a rise in their (absolute) importance in the field of innovation. The most obvious exceptions are Dosi and Rosenberg who,

Table 2. The 20 most-cited authors in articles published in *RP*, 1974–2007

Rank	Author	Affiliation	Number of cites	Percentage of total (n = 57,552)
1	**Richard R. Nelson**	**Columbia University, New York, USA**	**748**	**1.30**
2	**Keith Pavitt**	**Science Policy Research Unit, University of Sussex, UK**	**507**	**0.88**
3	Chris Freeman	University of Sussex, Science Policy Research Unit, UK	469	0.81
4	Edwin Mansfield	University of Pennsylvania, Philadelphia, USA	469	0.81
5	Wesley M. Cohen	Carnegie Mellon University, Pittsburgh, USA	415	0.72
6	Nathan Rosenberg	Columbia University, New York, USA	396	0.69
7	**David C. Mowery**	**University of California, Berkeley, USA**	**345**	**0.60**
8	Giovanni Dosi	Scuola Super Sant Anna, Pisa, Italy	341	0.59
9	David J. Teece	University of California, Berkeley, USA	329	0.57
10	**Eric von Hippel**	**MIT, Cambridge, USA**	**286**	**0.50**
11	Zvi Griliches	Harvard University, Cambridge, USA	281	0.49
12	Bengt Åke Lundvall	University of Aalborg, Aalborg, Denmark	242	0.42
13	Paul A. David	University of Oxford, Oxford, UK	221	0.38
14	Michael E. Porter	Harvard University, Cambridge, USA	220	0.38
15	Pari Patel	University of Sussex, Science Policy Research Unit, UK	217	0.38
16	F.M. (Mike) Scherer	Harvard University, Cambridge, USA	210	0.36
17	Joseph Schumpeter	Harvard University, Cambridge, USA	194	0.34
18	Roy G. Rothwell	University of Sussex, Science Policy Research Unit, UK	188	0.33
19	**Francis Narin**	**CHI Research, USA**	**177**	**0.31**
20	Adam B. Jaffe	Brandeis University, Waltham, USA	172	0.30

Source: Calculations based on information extracted from the ISI Web of Knowledge^{SM}.Notes: bold shows authors with the highest number of articles published in *RP*, 1974–2007 (see Teixeira and Silva 2010); the top-20 most cited (first) authors represent around 11% of total citations.

despite having lost some relevance among the highest ranking authors, present a growing pattern of citations overall. We can see that authors mentioned previously – Freeman, Mansfield, Nelson and Pavitt – are fairly persistent in the periodic list of the 10 most cited. Rosenberg, albeit not on the list of the 10 top-cited authors in the first period (1974–1977), has since then always been included in that restricted set of authors. His works, presenting a historical perspective, brought about decisive

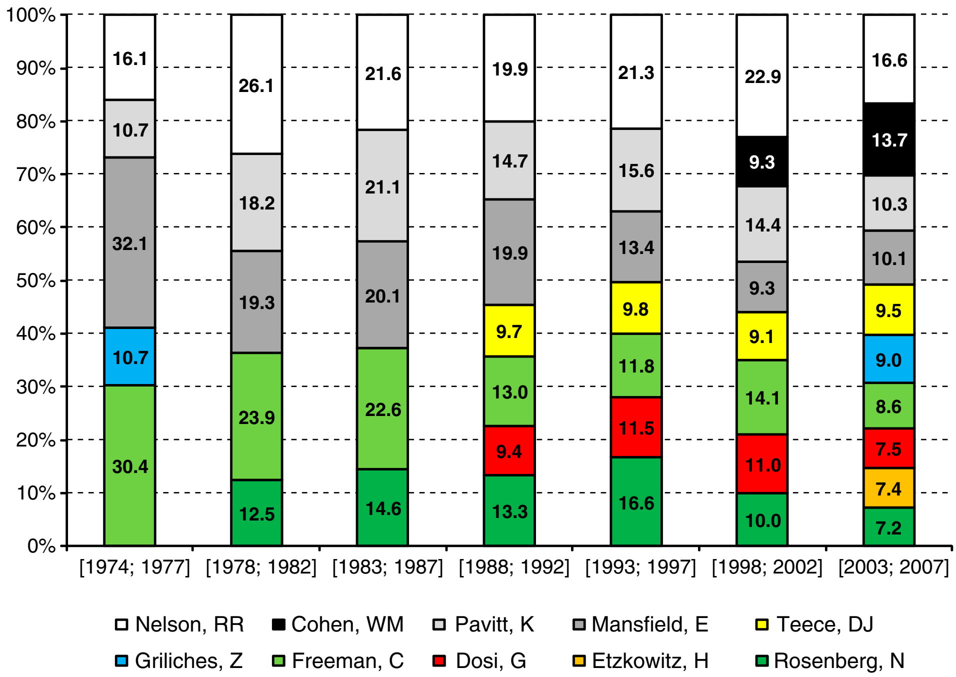

Figure 5. The 10 most frequently cited authors in relative terms, 1974–2007.
Source: Calculations based on information extracted from the ISI Web of Knowledge[SM].

advances that were largely integrated in this new area of study. Most surprising is the absence of the founding father of innovation studies, Joseph Schumpeter, among the top-10 most cited in each period (and for the period as a whole).

Teece, Dosi and Cohen may be considered emerging authors, having seen their citations rise since 1988 (Dosi and Teece) and 1998 (Cohen). Among the authors who only occasionally appear on the 10 top-cited list, we can point out Griliches, who appears in the first and last periods (in the latter with many citations, probably indicating a rebirth of his growth model associated with more technological and innovation matters), Porter (1993–1997), Scherer (1988–1992), Schmookler (1978–1982) and Williamson (1988–1992). Hence, as with companies, there is an interesting demographic dynamic at work among the most renowned and cited authors.

Most important cited studies

The most-cited articles and other studies throughout the period under analysis are presented in Table 3. Among the 10 top-cited publications by *RP* over the 37 years of the journal's existence, we can see that half are books published by renowned authors (who also published in *RP*), namely *Technical Change and Economic Theory* (by Giovanni Dosi et al.) and *An Evolutionary Theory of Economic Change* (by Richard R. Nelson and Sidney Winter). The first work, *Technical Change and Economic Theory*, by Dosi et al., has already been mentioned (see Section 1 and Table 1). The second most referenced publication, *An Evolutionary Theory of Economic Change*, by Richard R. Nelson and Sidney Winter, published in 1982, is one of the most important contributions to evolutionary economics, in which the authors basically

Table 3. The 10 most-cited works in articles published in *RP*, 1974–2007

Rank	Number of cites	Study	Journal/book	Authors	Year
1	211	*Technical Change and Economic Theory*	Book	Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg and Luc Soete	1988
2	186	*An Evolutionary Theory of Economic Change*	Book	Richard R. Nelson and Sidney Winter	1982
3	169	*National Innovation Systems: A Comparative Analysis*	Book	Richard R. Nelson *et al.*	1993
4	158	*National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*	Book	Bengt Äke Lundvall *et al.*	1992
5	121	"Sectoral patterns of technical change: toward a taxonomy and a theory"	Article (*RP*)	Keith Pavitt	1984
6	111	"Profiting from technological innovation: implications for integration, collaboration, licensing and public policy"	Article (*RP*)	David J. Teece	1986
7	101	"Innovation and learning: the two faces of R&D"	Article (*Economic Journal*)	Wesley Cohen and Daniel Levinthal	1989
8	96	*The Sources of Innovation*	Book	Eric von Hippel	1988
9	93	"Absorptive capacity: a new perspective on learning and innovation"	Article (*Administrative Science Quarterly*)	Wesley Cohen and Daniel Levinthal	1990
10	89	"Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change"	Article (*RP*)	G. Dosi	1982

Source: Calculations based on information extracted from the ISI Web of Knowledge[SM].

focus on the issue of technological changes and routines, proposing a framework for their analysis.

It is worth noting that the books *National Innovation Systems*: *A Comparative Analysis* by Richard R. Nelson et al. and *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* by Bengt Äke Lundvall, both collections of studies by different authors regarding National Systems of Innovation, are also among the most-cited and therefore most important studies in the STI area.

Among the most-cited articles published in *RP*, three stand out. The first article on the list, "Sectoral patterns of technical change: toward a taxonomy and a theory" by Keith Pavitt, provides a description and explanation of the sectoral patterns of technical change related to significant innovations in the UK since 1945, and achieved 121 citations. Next on the list comes "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy" by David Teece with 111 citations. In this article, Teece seeks to explain the reason why innovative companies sometimes fail to achieve a significant financial return on innovation, while clients, copycats and other industries benefit from it. Giovanni Dosi, in his article "Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change" (with a total of 89 citations), discusses the implications of paradigms and trajectories in the light of technical advances, as well as the potential impact of such relations in the face of transformation or change in existing economic theories and public policies.

Overall, the most-cited articles (as presented in Table 3) are mainly dedicated to the topic of "business competences/capacities (including trajectories, routines; tacit knowledge)", generally approaching issues related to financial return on innovations, R&D within companies or a company's ability to acknowledge new external information. It is interesting to note that the top-cited articles and works in *RP* are already fairly old, having been published between 1982 and 1993. Hence, one can assume that, although they were published over 15 years ago, they contain valuable, timeless contents.

Conclusion

The present article analyzes the scientific basis of the STI research field through the study and characterization of the citations made inside articles published in Research Policy (*RP*), the "seed" journal in this field of research, and among the best and most renowned.

In scientific terms, the study contributes to gaining further insights into STI research, thus shedding light on the boundaries of the field and complementing more qualitative literature surveys existing in the area. By analyzing the genesis and evolution of STI, we found that it covers the following topics: economics of innovation (Freeman 1990) and economics of technological change (Mansfield and Mansfield 1993). The interdisciplinarity that characterizes the bulk of the studies carried out in this field reflects the fact that no single domain is able to encompass all aspects of innovation. The boundaries of this area of study are thus relatively unclear and open to new sources of information.

The number of citations of articles published in *RP* has grown exponentially throughout the period under analysis. Such exponential growth is related to several factors, namely the journal's increased visibility and, partially, the increase in the number of issues per year and the number of articles per issue. Moreover, the average number of citations per article has risen but not as markedly as the number of citations per year. Such dynamics can partly be explained by the growing online accessibility of articles in electronic format. Lawrence (2001) has demonstrated that there is a strong and positive statistical correlation between the number of times an article is cited and the probability of the article being available online.

Based on a detailed analysis of the flow of knowledge that "enters" *RP*, in other words, by characterizing the information used by authors throughout the almost 60,000 citations found in the journal's articles, we uncovered the following (and at times surprising) patterns.

With regard to *RP*'s most important sources of knowledge, the relevance of "core" economics (mostly mainstream) and management sources is apparent, even though the importance of innovation-related sources (namely, *RP* itself) has been rising. However it is disappointing, but at the same time instructive, to observe that *RP*'s influence outside the innovation and technology-related field is limited: it is negligible as regards the citing patterns of economics journals but is, nevertheless, reasonably noticeable in regional studies, as well as in planning and management. This in part reflects the policy-driven scope of *RP* but also its quite extraordinary scientific achievement of bridging previously rather unconnected areas: innovation and management. The seminal works of Nelson and Winter, who propose an evolutionary theory of the capabilities and behavior of business firms operating in a certain market environment, but also those of Pavitt and Teece, constitute critical cornerstones in this regard.

Despite the achievement, STI's degree of autonomy is still weak, revealing not only its incipience, but also the lack of an unified theoretical framework. Although the diversity of theoretical frameworks is not in itself a bad thing, in the sense that it can generate novelty and dynamism within a scientific field, Silva (2009) insightfully points out that within the "tribe" of evolutionary technological change, which is closely related to *RP*, there are perhaps too many "families". This may endanger the quest for "the outlines of scientific paradigm" (Andersen et al. 1996, 1) and block the falsification of evolutionary theorizing and the idea of eclecticism associated with the "synthetic character of the evolutionary mechanism which forces evolutionary-economic theories to transgress the borders of different social-sciences disciplines" (Andersen 1997, 2).

We further show that, in spite of the relevance of mainstream economics, as far as sources of knowledge are concerned, the most influential authors and studies follow heterodox approaches, namely the evolutionary approach (Richard Nelson, Keith Pavitt and Chris Freeman). Notwithstanding, it was rather surprising and puzzling that one of the most widely recognized founding fathers of innovation-related studies, Joseph Schumpeter, failed to enter the list of top-10 cited authors. Schumpeter's main books also failed to appear among the most-cited studies. The most influential studies reveal both the importance of the evolutionary paradigm, as highlighted by the prominence of the seminal work in this "tribe", *An Evolutionary Theory of Economic Change* (Nelson and Winter 1982), which proposes an evolutionary theory of the capabilities and behavior of business firms operating in a certain market environment (Silva 2009) and brings management contributions (Teece 1986; Cohen and Levinthal 1989, 1990) into the realm of innovation studies, and the policy-driven nature of topics covered by *RP*, with a clear prevalence of literature on the National System of Innovation (Lundvall et al. 1992; Nelson 1993).

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