A bibliometric study of the literature on technological innovation: an analysis of 60 international academic journals

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Abstract: This paper aims to contribute to the debate on technological innovation, organization and work. Although technological innovation remained a debated topic in the academic literature during the past years, its implications for organizational processes seem still not sufficiently theorized and empirically investigated. By using two complementary journals' rankings a search in the ISI Web of Science platform from 1985 through 2013 was performed. To analyze the 998 scientific retrieved contributions a bibliometric analysis has been conducted, adopting also Social Network Analysis tools. Our results reveal a significant growth of the technological innovation literature over the investigated period, the multidisciplinarity of the field and, particularly, the relevance of management and business & economics contributions. Overall, this study offers a broad overview of the literature on technological innovation and emphasizes the opportunity to investigate the role of technological innovation within the organizational life.

Keywords: technological innovation, organization, work, literature review, bibliometric analysis

1 Introduction

Over the years theoretical perspectives and empirical research on technological innovation have developed together with theoretical and empirical studies on organization [1]. Moreover, significant changes have led both academics and practitioners to reconsider technology and organization's roles and functions. In response to these changes, scholars started to investigate the implications of technological innovation for the organization [2, 3].

'Innovation' can be defined as the production or adoption, assimilation and exploitation of an idea or behavior that is new for the organization. It can be a new product, a new service, a new process, a new business model, a new technology, or a new administrative practice[4, 5]. With specific reference to 'technological innovation', several authors define it as the development of new products and processes, or of substantial technological improvements in existing products and processes [6, 7]. Particularly, when the innovation is not exclusively related to products, but refers to processes, it implies changes in organizational structures, in the organization of work,

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but also variations in techniques and tools. The latters, in turn, lead to changes of the required skills and the professional roles [8, 9].

Given these premises and regardless of the extent and comprehensiveness of the adopted definition, the importance that technological innovation has for companies dealing with a constantly evolving environment seems undeniable. There appears to be consensus, both in the academic and in the business world, about whether the technological knowledge and the innovative capabilities are key resources for companies, as well as one of the main determinants of their performance [4, 6, 7, 10, 11]. Moreover, the relevance of technological innovation is due to its impact on the economic and social life, both at the macro and at the micro level [4, 12].

Nevertheless and as already noted by some authors[13, 14, 15], although the process of technological innovation [4, 16]and its results increasingly permeate the modern enterprise, the link between technological innovation, organization and work seems still not sufficiently theorized and empirically analyzed. Particularly, the need to investigate the connection between technological innovation, organization and work is emphasized by some recent literature reviews [14, 17]. The outcome of these reviews shows that, after a great deal of attention devoted to technology in organization studies in the 50s of the last century, there has been a decline in the interest to this topic. This trend has become even more marked in the last two decades. Orlikowski and Scott [17], for instance, show that from January 1997 to December 2006 more than 95% of the articles published by the so called top management journals does not take into account the role and impact of technology in the organizational life. Furthermore, the majority of the economic and managerial literature, by Schumpeter onwards [18, 19], appears to be mainly focused on the determinants of innovation [4, 6, 20]while neglecting the effects and the influences that innovation unavoidably exerts on organizational processes and people. This lack of attention turns out to be problematic especially if one considers that the use of new technologies: a) changes both the structural and social aspects within organizations; b) mediates and influences the activities of firms, industries and economies [14].

This paper lies within a wider research aimed at understanding to what extent and how the technological innovation affects the production processes of organizations in different sectors changing their structures, roles, decision-making processes, systems and logics of human resources management. Particularly, the literature review presented here contributes to the debate aforementioned with a twofold purpose:

1. on the one hand, the aim is to offer an overview of the last 30 years' literature concerning technological innovation – both organizational literature and not – and to show how the meaning and importance of this concept evolved;
2. on the other hand, the goal is to identify and categorize - both in time and conceptually - areas of study and research – even future research -about technological innovation, organization and work.

2 Method and Data

The extensive analysis of the existing literature has been articulated in three main steps: (i) identification of the international journals on which carrying out the analysis; (ii) identification of the keywords to use for the scientific contributions' search on the set of journals selected; (iii) use of the social network analysis (SNA)'s tools to perform the bibliometric analysis of the publications retrieved according to the previous stated criteria.

Concerning the first step, we focused not only on top management (or business) journals – as previous literature reviews have done [14, 17] – but we identified 60 journals taking into account two different and complementary rankings:

- 45 journals of the 'Financial Times' ranking (FT45)[3] : this is a rating whose importance is widely recognized in the academic world and especially by management scholars [21];
- 15 journals of the 'Technology Innovation Management Journals' ranking (TIM): this is a ranking developed by Thongpapanl and published, in its last version, on the journal 'Technovation' [22]. This rating has attracted interest and attention, especially in the last two decades [23, 24, 25].

[3]http://www.ft.com/intl/cms/s/2/3405a512-5cbb-11e1-8f1f-00144feabdc0.html#axzz2YYYxf4nd

We chose the ISI (Institute for Scientific Information) Web of Science (ISI-WoS)[4] platform to search and retrieve publications, since we had checked the presence of all the 60 selected journals in its databases and following previous scientific works (for example see Knoben and Oerlemans[26]). Afterwards, we identified "technolog* innovation*" as the keyword to use in the "TOPIC" field of the query. On ISI-WoS, the words specified in the "TOPIC" field are searched in the title, abstract and keywords of each contribution published in one of the sixty journals. The asterisk in the keyword indicates zero or more characters (e.g. technology, technologies or technological). The search of the selected keyword in all the 60 journals from 1985 to now[5] returned 998results.

Finally, a bibliometric analysis has been conducted on the 998 scientific retrieved contributions, adopting also Social Network Analysis (SNA) tools. As a matter of fact, the use of SNA tools for the literature review, especially within the social sciences [27, 28], allows to examine the behavior of a scientific community (or more than one community) based on the data of the related publications [29].

3 Analysis and results

During the observed period, a total of 998 scientific contributions were published, consisting of 806 (81%) articles, 43 (4%) proceeding papers, 51 (5%) book reviews, 69 (7%) reviews and 26 (3%) editorials, (the dataset also includes one note, one correction and one meeting abstract). All the document types were kept in the dataset since our purpose is to provide a broad overview of the literature on technological innovation and because all of them make a substantial contribution to the literature. Concerning the distribution of the 998 publications in the selected journals, 78% of them have been published on journals belonging to the TIM ranking – particularly, 144 (14%) appear on Research Policy, 121 (12%) on Technovation, 101 (10%) on International Journal of Technology Management –, whereas the remaining 22% on the FT45 ranking's journals – for example, 29 (3%) have been published on Organization Science, 26 (3%) on Strategic Management Journal and 15 (1,5%) on Management Science.

The examination of the 998 publications involves two steps: (i) the analysis of some descriptive indicators (e.g. the trend of the number of publications and citations per year), and (ii) the use of SNA tools with the aim to discover some interesting insight about the content of the selected contributions.

3.1 Descriptive Analysis

Figure 1(a) reports the number of publications per year from 1985 to 2013. As shown in this figure the number of publications increases through the years, especially during the period 2006-2012 (reaching 84 publications in 2012).

More in general, three distinct time periods could be identified:

- "*emerging*" stage (from 1985 to 1991): this first time period is characterized by a very moderate production (between 4 and 7 publications per year);
- "*growing interest*" stage (from 1992 to 2005): on average, the number of publications is higher than in the previous phase and fairly constant;
- "*strengthening*" stage (from 2006 to 2012): after 2005, a jump is evident in the number of publications. The consistent growth of scientific contributions during this phase shows that – in the last years - there is a strong and consolidated interest in the scientific community on this topic.

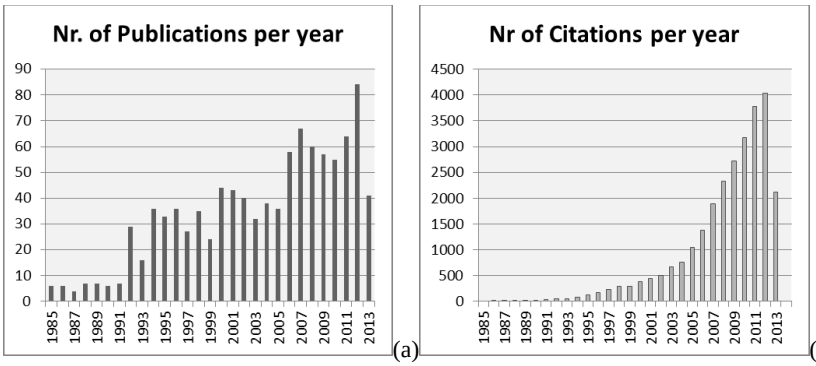
The data obtained for the current year (2013) are partial, since we conducted the search on August 7th, 2013.

The second descriptive indicator used in our analysis is the number of citations per year. As shown in figure 1(b), the number of citations increases almost exponentially during the years. Also in this case we considered the

[4] http://apps.webofknowledge.com

[5] 1985 was selected as the starting point because the chronological coverage of ISI dates from this year. The search has been conducted for the last time on August 7th, 2013 in order to have a sample updated as much as possible to the latest contributions available on the database ISI.

data obtained for the current year (2013) as partial. The trend of the number of citations per year could be considered a proxy of the impact of these contributions on the whole research community.



(a) (b)

Fig.1.- Number of publications(a) and citations (b) per year

Particularly, citation patterns are relevant to see which publications, and what type of research, has been influential on the literature (a sort of building blocks). On this regard, Table 1 indicates which publications are most often cited within our dataset. The table reports the publications that are cited at least 50 times by the contributions belonging to the dataset. We arbitrarily chose this cutoff point, resulting in this core set of 18 contributions, namely the most influential publications in the specific field of technological innovation.

Table 1.–The most cited references

Author(s)	Year	Article/Book Title	Source[6]	Cit.
Cohen, W.M. and Levinthal, D.A.	1990	Absorptive Capacity: A New Perspective on Learning and Innovation	ASQ	147
Teece, D.J.	1986	Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy	RP	141
Nelson, R.R. and Winter, S.G.	1982	An evolutionary theory of economic change	HUP	141
Henderson, R.M. and Clark, K.B.	1990	Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms	ASQ	101
Tushman, M.L. and Anderson, P.	1986	Technological Discontinuities and Organizational Environments	ASQ	99
Teece, D.J., Pisano, G. and Shuen, A.	1997	Dynamic capabilities and strategic management	SMJ	82
Dosi, G.	1982	Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change	RP	77
Barney, J.	1991	Firm Resources and Sustained Competitive Advantage	JoM	72
Von Hippel, E.	1988	The Sources of Innovation	OUP	71
March, J.G.	1991	Exploration and Exploitation in Organizational Learning	OS	67
Pavitt K.	1984	Sectoral patterns of technical change: Towards a taxonomy and a theory	RP	63
Schumpeter, J.	1934	The Theory of Economic Development	HUP	53
Kogut, B.	1992	Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology	OS	53
Wernerfelt, B.,	1984	A resource-based view of the firm	SMJ	53
Rogers, E.M.	1995	Diffusion of innovation	FP	52
Damanpour, F.	1991	Organizational innovation: a meta-analysis of effects of determinants and moderators	AoMJ	51
Garcia, R. and Calantone, R.	2002	A critical look at technological innovation typology and innovativeness terminology: a literature review	JPIM	50
Abernathy, W. J. and Clark, K.B.	1985	Innovation: Mapping the winds of creative destruction	RP	50

[6]ASQ: Administrative Science Quarterly; RP: Research Policy; HUP: Harvard University Press; SMJ: Strategic Management Journal; JoM: Journal of Management; OUP: Oxford University Press; OS: Organization Science; FP: The Free Press; AoMJ: Academy of Management Journal; JPIM: Journal of Product Innovation Management

The most cited contribution, with 147 citations, is the article of Cohen and Levinthal, published in 1990 in Administrative Science Quarterly; three additional publications (two articles and one book) have more than 100 citations. Moreover, two of the most cited articles (the grey rows in the table) belong to our dataset of 998 publications: the article of Teece (1986) with 141 citations and the work of Garcia and Catalone (2002) which obtained 50 citations. Referring to the sources of the most cited references, the table highlights that four articles are published in Research Policy (TIM ranking); three are published in Administrative Science Quarterly (FT45 ranking); two most cited publications belong to Organization Science (FT45 ranking) and other two papers are published in Strategic Management Journal (FT45 ranking). These results validate the value of combining the two rankings that we have chosen for our analysis.

Furthermore, on the basis of the three time periods identified before, it is possible to highlight the impact of each cited reference on one (or more) specific time interval. Particularly, the first three references listed in table 1 are also the most cited references in the "strengthening" stage, and among them Nelson and Winter (1982) and Cohen and Levinthal(1990) are also the first and the third most cited ones in the "growing interest" stage. While the citations of all the references shown in the table are quite homogeneously distributed among the two more recent stages, only three of them result quite relevant for all the three time periods: Dosi (1982), Nelson and Winter (1982), and Schumpeter (1934).

3.2 Investigation based on SNA

Additional insights emerged from the Social Network Analysis of the publications' distribution by Web of Science categories (Figure 2) and research areas (Figure 3).

Overall, the sample under examination appears characterized by a balanced representativeness. Particularly, our resulting dataset of 998 publications could be classified into 14 Web of Science subject categories which reflect the way in which journals are grouped. These categories are assigned by the ISI staff on the basis of a number of criteria including the journal's title and its citation patterns. The three most common categories are 'management' (854 contributions; 85.6% of the total), 'business' (431; 43.2%) and 'engineering industrial' (293; 29.4%), followed by 'planning development' (250; 25.1%), 'operations research & management sciences' (245; 24.5%). The size of the nodes represented in figure 2 reflects this information. As 'management' and 'business' subjects are at the top of this ranking, this implies a more managerial rather than technical tradition in technological innovation. This result supports the decision of combining the two selected journal rankings. Moreover, the figure shows the linkages among the categories and the thickness of the ties indicates how many publications are classified in both categories. We can observe that 308 contributions are assigned to both 'management' and 'business' categories; other two categories pairs are connected by more than 200 publications - 'management' and 'engineering industrial' (293) and 'management' and 'operations research & management sciences' (245). The distribution of the publications by a variety of categories – including also 'Multidisciplinary Sciences', 'Ethics', 'Business Finance', 'Applied Psychology' - gives us an idea of the multidisciplinarity of the technological innovation field. This diversity of subject categories should suggest researchers, seeking information on technological innovation, to expand their search to different and even general purpose journals.

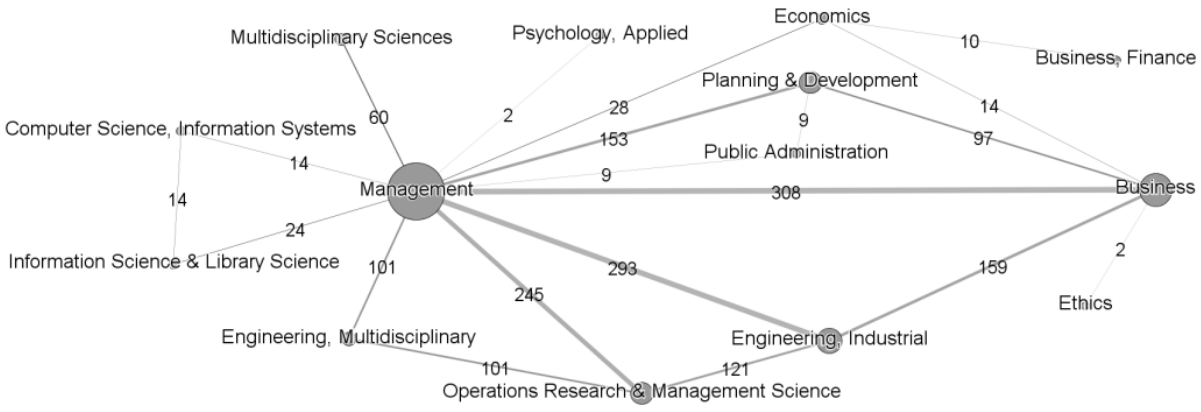


Fig.2.– ISI subject categories network

Whereas subject categories are assigned to each scientific contribution on the base of the journal of publication's characteristics, ISI-WoS attributes to each publication also one or more research areas, namely article-based parameters reflecting the specific field of the study.

Figure 3 shows the linkages among the nine research areas (the total number of the possible research areas is 151) in which the contributions of our sample have been classified. The most recurrent research areas are: 'business & economics' (998 publications; 100% of the total), 'engineering' (394; 39.5%), 'public administration' (250; 25,1%). The figure also points out that 'business & economics' presents a huge linkage with 'engineering' (394 publications are common to the two areas), 'public administration' (250) and 'operations research and management science' (245). There are very few common publications (only 2) between 'business & economics' and both 'psychology' and 'social science-other topics'.

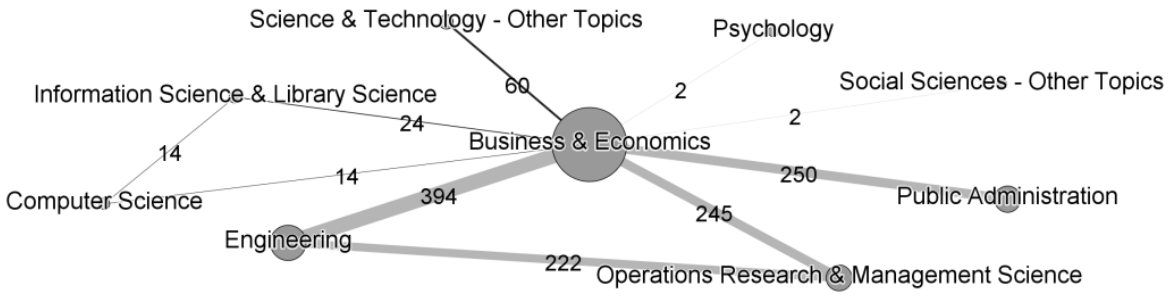


Fig.3.– Research Areas network

On the basis of what emerges by Figure 2 and 3, the multidisciplinary of the research on technological innovation is confirmed, avoiding the risk to mostly (or exclusively) consider the Information Technology (IT) perspective.

Since both subject categories and research areas are defined by ISI-WoS, we decided to perform a third analysis, similar to the previous ones, but based on the keywords defined for each contribution by the authors. The keywords analysis provided an overview of the research trends, since keywords reflect the focus of individual contributions. For this purpose we extracted the most popular keywords used in the dataset and we showed them in a graph (figure 4) in which they represent the nodes.

The tie between two of them indicates that they are mentioned in the same publication; whereas the thickness is related to the number of contributions in which the pair appears. In figure 4 we present the 32 most frequently used keywords. The size of each node (and its label) represents the occurrence of keywords within the dataset. It arises that 'performance' (139), 'technological innovation' (116), 'research and development' (119) are the three most recurrent keywords. Furthermore, there is also 'technological-innovation' keyword (87 occurrences) that can be viewed as synonym of 'technological innovation'. Considering the occurrences of both keywords (203), they reach the greatest value compared to the other ones. The most popular keywords pairs are 'performance/technological innovation' that recurs 37 times; both the pairs 'performance/research and development' and 'technological-innovation/research and development' recur 32 times. In particular, the keyword 'performance' is often matched with 'firms' (26 times); it recurs 23 times also with the keywords 'management', 'industry' and 'knowledge'. Topics related to 'technological innovation', instead, are: product development (the pair recurs 20 times), firms (22 times) and knowledge (21 times). Finally, the keyword 'research and development' is also linked to 'absorptive capacity' 21 times.

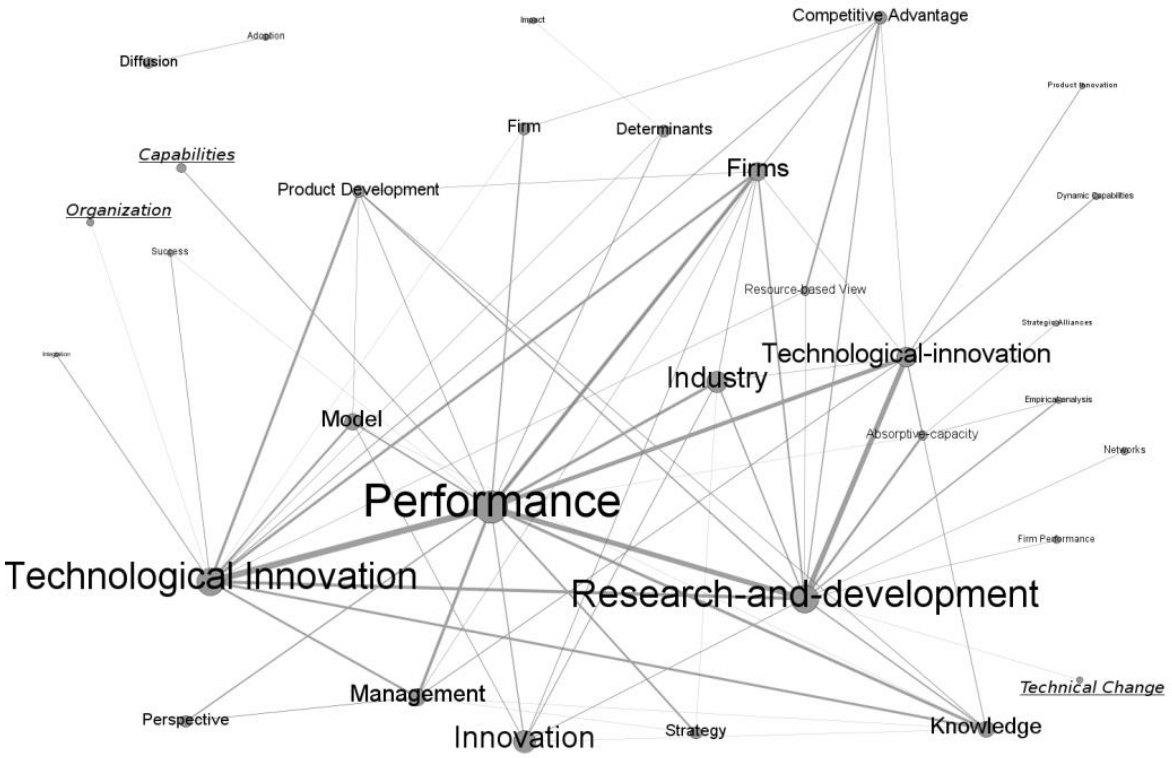


Fig.4.– Keywords occurrence network

Overall, the results obtained by the keywords occurrence analysis show that some relevant issues about the research on technological innovation should be addressed. On the basis of our analysis, the linkages between technological innovation and 'organization', 'capabilities' and 'technical change', have hitherto received relatively little attention in the literature. It is surprising also to note the absence of some topics traditionally linked to technological innovation in organizational studies, such as design, employment, task or, more in general, job[30, 31, 32].

4 Conclusion and next steps

We started this article by highlighting that there is not much clarity about the actual level of progress that has been made in studying the link between technological innovation, organization and work. Our analysis was motivated by two observations: first, technological innovation and its determinants have remained a debated topic in the academic literature during the past years and, second, the same literature has neglected the role and impact of technological innovation on the organizational processes. Accordingly, we approached our analysis with a twofold objective: to provide an overview of the existing literature on technological innovation and to identify extant or potential areas of study and research on technological innovation, organization and work.

Although earlier studies have already explored the technological innovation literature's state of the art, our analysis extends and complements these findings by using a more comprehensive set of journals, as well as bibliometric methods of analysis. Particularly, the descriptive and social network analysis conducted in this study show a significant growth of the technological innovation literature during the years, the multidisciplinarity of the field and, particularly, the relevance of management and business & economics contributions. The central point of the paper is to highlight the need for more theoretical and empirical exploration of technological innovation within the organizational life.This is highlighted by the analysis conducted on the dataset of 998 contributions selected from 60 international academic journals and particularly emphasized by the keywords occurrence analysis. Even if at this stage of the research, it is difficult to draw any strong conclusions concerning the possi-

ble developments in this field, we are pretty sure that the exploration of the relationship between technological innovation, organization and work will be an interesting and promising future area of research.

The next steps of analysis should include the refining of the keywords used for selecting the dataset. Furthermore, the use of additional Social Network Analysis tools both for recognizing clusters of articles in the sample depending on whether they have common references or not (co-reference analysis - [33, 34]), and for identifying the theoretical building blocks using the recurring quotes (co-citation analysis - [35]) also conducting a longitudinal study on the three different stages identified before. Moreover, the bibliometric analysis could be used to examine the evolution in time of the knowledge creation process within the sample of the selected articles (cross-citation analysis - [36][37]). Future works could thus identify newly emerging topics and observe the temporal evolution of the already emerged insights. Finally, a qualitative-interpretative analysis of a limited subset of articles, identified during the phase of bibliometric analysis as core theories or cluster's representatives, should be conducted.

Overall, this paper offers a broad overview of the literature on technological innovation and highlights a lack of attention on the relationship between technological innovation, organization and work. It suggests promising future research paths which could have both theoretical and practical implications.

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