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What we (do not) know about research in the strategic management of technological innovation?

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ABSTRACT

This study aims to analyse the different approaches to researching the strategic management of technological innovation through a Systematic Literature Review. The analysis thus focuses on the 59 articles returned from the *ISI Web of Knowledge Social Sciences Citation Index* (SSCI), after our search of publications in the 'Management' domain. This literature divides into two major thematic areas (strategic management and technological innovation) while revealing how performance studies predominate, especially those applied to the development of innovation and its sources. Two areas of lesser interest in the field of technological innovation are diffusion/adoption and commercialisation while these always interlink with strategy formulation. By dividing the analysis into three periods (1987–1996, 1997–2006 and 2007–2016), we may conclude that, in the first period (1987–1996), the study of the three main topics in technological innovation (development, types and sources of innovation) links to strategy formulation while in the following periods essentially move on to performance. Despite the growing interest in recent years on topics such as the internal analysis of innovation types, few studies detail with industry analysis, strategy implementation or the environment and we therefore also set out possible future lines of research.

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Introduction

The strategic management of innovation represents an important component of a firm's strategy (Hamel, 2000) and make a key contribution to a firm's competitive advantage (Porter, 1985). The management of technological innovation in organisations therefore constitutes part of its strategic development as new technologies, product prototypes and the subsequent flow of new products which are developed and explored here (Ansoff, 2004).

Although the current fragmented state of the literature reflects in the usage of many different definitions of innovation (additionally impacting on the technological innovation concept), Keupp, Palmié, and Gassmann (2012) propose a definition of the strategic management of innovation based on definitions of innovation by Damanpour (1991) and strategic management by Nag, Hambrick, and Chen (2007). Combining the two definitions,

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these authors suggest that the strategic management of innovation incorporates the appropriate application of strategic management techniques and measures to increase the impact of the firm's innovation activities on its overall growth and performance. The innovation activities may deal with technological or non-technological aspects.

In addition to the diversity of meanings associated with the term 'innovation', the literature also contains different classifications of types of innovation (Bondarouk, Schilling, & Ruël, 2016) and hence lacking in any congruence as regards just which new products deserve consideration as technological (Garcia & Calantone, 2002). Besides the main classifications of technological innovation existing in the literature, such as product/process (OECD, 2005), radical/incremental (Burgelman, Christensen, & Wheelright, 2006) and exploration/exploitation (Levinthal & March, 1993), new types of innovation recently emerged, for example eco-innovation, reverse innovation, social innovation and design-driven innovation (Cetindamar, Phaal, & Probert, 2016). Hence, the multiple innovation typologies ensure that the same name applies to different types of innovation and with the same innovation classified differently by different typologies (Garcia & Calantone, 2002).

New topics have also emerged in the literature, such as open innovation and knowledge management (Keupp et al., 2012). Regarding the concept of open innovation, Datta, Mukherjee, and Jessup (2014) report that this remains underexplored in the field of commercialising technological innovation before the review by Randhawa, Wilden, and Hohberger (2016) states that researchers have not yet fully explored multiple facets of this concept. On the other hand, the importance of knowledge management reflects in one of the most recent SLRs that cover technological innovation and analyses exchanges of knowledge ongoing among the partners involved in different New Product Development (NPD) networks (Galati & Bigliardi, 2017). Research on technological innovation is furthermore increasingly complex as there are various players involved in such processes, including companies and businesses, higher education institutions and universities, Research and Technology Organisations (RTOs) (Shafia, Shavvalpour, Hosseini, & Hosseini, 2016), Non-Governmental Organisations (NGOs), citizens and users (Cetindamar et al., 2016). Thus, innovation has been undergoing democratisation with active user roles and open innovation processes (Cetindamar et al., 2016).

The exponential growth in the literature on innovation since the 1990s and its consequent fragmentation has led the field on the strategic management of innovation to present many inconsistencies, antagonistic theoretical predictions, and persistent knowledge gaps (Keupp et al., 2012). Datta et al. (2014) report that the most studied subjects in the literature are development and sources of innovation in the field of commercialising technological innovations while, in the field of the strategic management of innovation, Keupp et al. (2012) identify the relationship between innovation and performance, especially in high technology sectors, as the facet receiving greatest attention. Furthermore, environmental contingencies at the political and institutional level raise little interest among the research community (Keupp et al., 2012), especially in adopting technological innovations (Bondarouk et al., 2016). Additionally, there is also a lack of studies on implementing innovation (Crossan & Apaydin, 2010; Keupp et al., 2012; Kim & Chung, 2017) but if implementation is postponed, managed incorrectly or interrupted, the innovation will not entail the results forecast by the organisation. Finally, Crossan and Apaydin (2010)

conclude there is a tension in the literature between the internal and external sources of innovation, which becomes evident only when analysing both sources of innovation simultaneously even though researchers mainly focus on R&D in an isolated fashion.

In addition to the inconsistencies in the literature on the strategic management of innovation, there are only scarce reviews that focus on narrow domains, whether the level of analysis or the type of innovation (Crossan & Apaydin, 2010). The reviews that do exclusively deal with technological innovation are even scarcer and approach only specific topics such as the association between different New Product Development (NPD) projects and different NPD networks (Galati & Bigliardi, 2017) and the relationship between technological synergies, product characteristics and new product performance (Tsai & Huang, 2012). There is also a lack of reviews about managing technology, such as that of Cetindamar et al. (2016), even if technological management does not only relate to technological innovations.

As our research did not return any review targeting only the strategic management of technological innovation, we proceed here with an SLR based on this theme, which may constitute an important tool in support of both researchers and managers through detailing the state of academic research in this field. Thus, our work seeks to undertake thematic and temporal analysis of the literature on the strategic management of technological innovation, identifying gaps and establishing the relationships prevailing between the different research topics.

The study structure is as follows. After a description of the methodology applied in the literature review, we analysed the 59 articles returned by the *ISI Web of Knowledge Social Sciences Citation Index* (SSCI) database as relating exclusively to the category of 'Management'. Following this analysis, we then identify the most relevant studies by temporal period, thematic areas and future lines of research. Finally, we also set out the limitations of our study and its conclusions.

Methods

To analyse the approaches made to the strategic management of technological innovation, we chose to carry out a Systematic Literature Review (SLR) as, through the application of a transparent and reproducible procedure, systematic reviews improve both the quality of the review process and its results (Tranfield, Denyer, & Smart, 2003). Our research here focuses on articles in the *ISI Web of Knowledge Social Sciences Citation Index (SSCI)*, which has incorporated articles ever since 1956 and ranks as one of the most comprehensive databases of peer-reviewed publications (Crossan & Apaydin, 2010), and has served various SLR studies across different fields of social sciences (Laaksonen & Peltoniemi, 2016). The study took place in 2017 and included articles through to 2016 in accordance with the procedure explained in Figure 1.

Despite search words representing a limitation to the review methodology as it is virtually impossible to embrace the entire topic under analysis with just a couple of keywords (Silva & Teixeira, 2009), we selected documents that include the terms 'strategic-management' and 'technological-innovation' in their title, abstract or keywords as these closely relate to the strategic management of technological innovation. We registered 94 documents following this procedure.

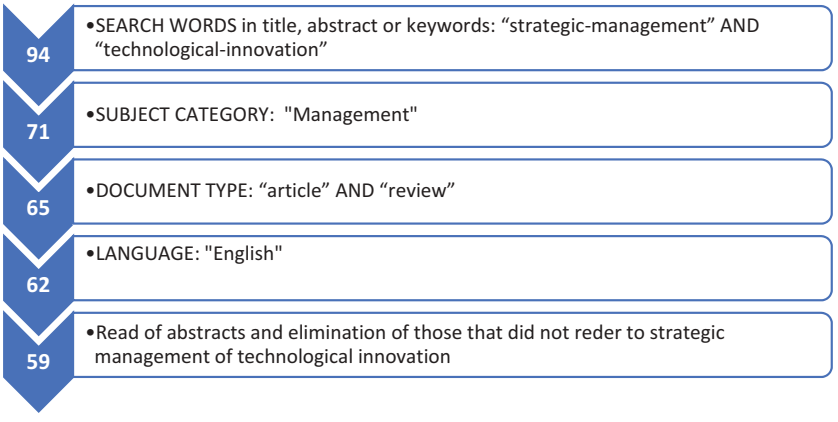

Figure 1. Nº of articles collected in the search process on ISI database.

Furthermore, we only considered journals listed in the ‘Management’ subject category of the ISI Web of Knowledge (Savino, Messeni Petruzzelli, & Albino, 2017), given this category covers the main publications in the field of strategic management, which reduced the total to 71 documents. After selecting ‘Article’ and ‘Review’ documents, as both encapsulate the source of the most up-to-date knowledge (López-Fernández, Serrano-Bedia, & Pérez-Pérez, 2015), we obtained 65 articles. Subsequently, we excluded all articles not in ‘English’ as the dissemination of scientific knowledge fundamentally takes place in this language and furthermore reflects a criterion applied in various reviews (López-Fern ández et al., 2015), resulting in a total of 62 articles. After reading the abstracts and eliminating those that did not refer to the strategic management of technological innovation, 59 articles matched all the already detailed selection criteria.

For a better understanding of some of this data, we chose to divide the analysis into three periods: 1987–1996, 1997–2006 and 2007–2016. The temporal periods each comprise a decade as happens in other literature reviews (Bocconcelli et al., 2016).

To carry out thematic analysis, we divided the literature into topics relating to both technological innovation and strategic management. Regarding the technological innovation topic, we adapted the procedure followed by Datta et al. (2014) and identified five categories in common with the present analysis: Innovation types, Innovation sources, Protection/Diffusion, Development, and Commercialisation. Although these authors dealt jointly with the issues of Diffusion and Protection, we opted to analyse these separately because they reflect different strategies. In relation to the strategic management topic, we selected six categories: Environment, Industry Analysis, Internal Analysis, Strategy Formulation, Strategy Implementation and Performance (Hunger & Wheelen, 2007). Whenever the same article refers to more than one thematic strategic management category and/or technological innovation topic, we then classified the article according to the predominant category of each topic.

Descriptive analysis

The first article dealing with this issue dates from 1987 (Shrivastava & Souder, 1987) and strives to set out a model for new product development. In turn, the final article,

published by Li-Ying, Wang, and Ning (2016), concludes that firms should extensively exploit external technologies to promote dynamism in both their internal technological diversity and their internal R&D, which play important roles in transforming and reconfiguring their respective technological resources. This article reflects the growing influence of dynamic capacities (Teece, Pisano, & Shuen, 1997) on the literature on the strategic management of technological innovation in conjunction with articles by Shafia et al. (2016), Paradkar, Knight, and Hansen (2015), and Nieves and Haller (2014).

Table 1 details how 30% of the articles analysed stem from three journals: *Technology Analysis & Strategic Management, Journal of Product Innovation Management* and *Research Policy*. However, there is a diversity of publications containing articles about the strategic management of technological innovation which, in turn, reflects not only the fragmentation of the literature but also the different specialist areas of each journal.

Figure 2 provides an outline of the number of articles and their citations in each respective period while Table 2 identifies the most cited articles per period. The first period (1987–1996) is the least representative in terms of the number of articles published and the number of citations of these same articles. The study by Chiesa, Coughlan, and Voss (1996) ranks as the third most cited article of all the periods examined and deals with the development of a tool for auditing the management of technical innovations. Other relevant studies in this period are from Souder and Moenaert (1992) and Christensen (1995), highlighting analysis of company strategies for integrating either functions or assets. The development of technological innovations generally requires both the integration of several types of assets (Christensen, 1995) and the integration of functions, particularly the R&D and Marketing functions, which acts to reduce the uncertainties related to that development (Souder & Moenaert, 1992).

The next period (1997–2006) reflects a slight rise in the number of articles published, compared to the previous period, but essentially features the greatest number of citations from all the periods studied as it contains the most cited article. It is the article by Subramaniam and Youndt (2005) about the influence of intellectual capital on radical

Table 1. Main journals.

JOURNALS	No.	%
Technology Analysis & Strategic Management	6	10
Journal of Product Innovation Management	6	10
Research Policy	6	10
Journal of Management Studies	4	7
Academy of Management Journal	3	5
Strategic Management Journal	3	5
Technovation	3	5
International Journal of Technology Management	2	3
Journal of International Business Studies	2	3
Management International Review	2	3
Organisation Science	2	3
R & D Management	2	3
Others (only with 1 article)	18	31
TOTAL	**59**	**100**

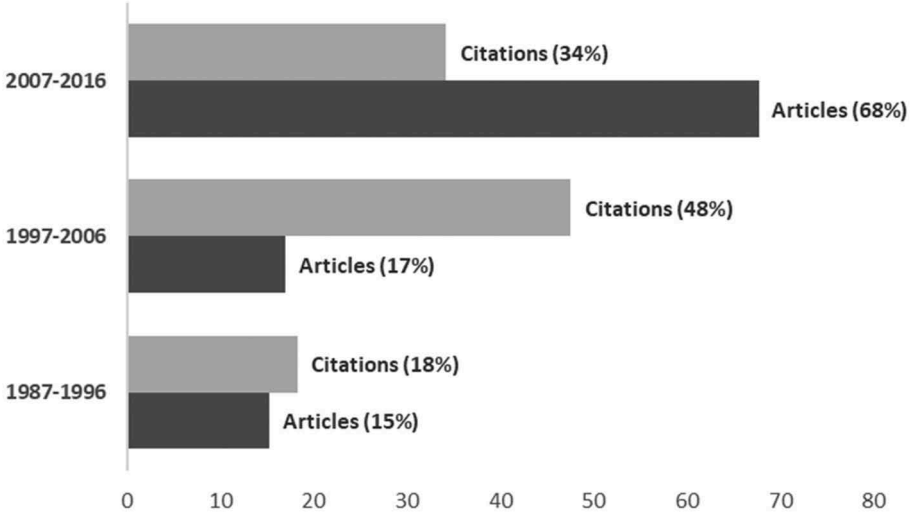

Figure 2. Articles and citations (%), by period.

Table 2. Most cited articles, by period.

	TOTAL CITATIONS		AVERAGE PER YEAR	
PERIOD	Study	Nº	Study	Nº
1987–1996	Chiesa et al. (1996)	192	Chiesa et al. (1996)	8,73
	Souder and Moenaert (1992)	87	Souder and Moenaert (1992)	3,35
	Christensen (1995)	77	Christensen (1995)	3,35
1997–2006	Subramaniam and Youndt (2005)	673	Subramaniam and Youndt (2005)	51,77
	Teece (2006)	153	Teece (2006)	12,75
	Wiggins and Ruefli (2002)	77	Buhalis (2004)	4,93
2007–2016	Crossan and Apaydin (2010)	249	Crossan and Apaydin (2010)	31,12
	Vega-Jurado et al. (2009)	89	Vega-Jurado et al. (2009)	9,89
	O'Connor (2008)	63	Vasudeva and Anand (2011)	8,86

and incremental innovative capabilities, with its 673 citations corresponding to an average of 51.77 citations per year. This study notes the importance of social capital since it significantly influences both capabilities, while human capital only positively influences the radical innovative capacity in association with social capital. In this period, the two other most cited studies were by Teece (2006) and Wiggins and Ruefli (2002).

The final period (2007–2016) presents the largest number of articles published in addition to recording more citations than the first period (1987–1996), which conveys the growing interest in recent years in themes related to the strategic management of technological innovation. Correspondingly, the 2007–2016 period registers the second most cited study of all the periods analysed. This belongs to Crossan and Apaydin (2010) who produced an SLR on organisational innovation. One reason that may justify this number of citations for such a recent article derives from the nature of an SLR focus on an area as fragmented as innovation, where reviews are scarce and might provide an important support tool for researchers. The other most cited works in this period are from Vega-

Jurado, Gutiérrez-Gracia, and Fernández-De-Lucio (2009) and O'Connor (2008), that reflect the recent interest of the scientific community in better understanding the different classifications of innovation, such as product/process or major innovations (radical and really new innovations).

In order to reduce any bias from the article life cycles, we also examined the articles with the highest number of average annual citations in each period before concluding that these articles generally coincide with the most cited documents, although with the exceptions of the studies by Buhalis (2004) and Vasudeva and Anand (2011) in the periods 1997–2006 and 2007–2016 respectively. The latter two studies analyse particular organisations, such as airline companies, in which process innovations, such as Information Communication Technologies (ICTs), are critical to their strategic and operational management (Buhalis, 2004), and firms facing technological discontinuities, which underlines the relevance of their portfolio strategies for knowledge acquisition (Vasudeva & Anand, 2011).

In the literature on the strategic management of technological innovation, empirical studies prevail but, while qualitative methods were the most common in the 1987–-1996 period, quantitative methods prevailed in number in the following periods (Table 3). The works of Kfir (2000), Cattani (2008) and Di Minin and Bianchi (2011) are the only studies simultaneously applying quantitative and qualitative methods. Furthermore, not only are conceptual articles not very well represented but there is only one literature review (Crossan & Apaydin, 2010), which accounts for the second most cited article of all the articles analysed.

As the empirical studies adopt several sectoral classifications, we choose here to divide the analysis into three sectors in order to facilitate their comparison: Agriculture, Industry and Services (Mishra, Mall, & Pradhan, 2017). The industrial sector, with 26 articles, constitutes the leading sector in all periods while focusing especially on high-technology firms (Table 4). There are seven articles on the service sector, where Research and Technology Organisations are highlighted (Kfir, 2000; Shafia et al., 2016), although the service sector is jointly analysed with industry in a total of 11 articles.

Table 3. Methods, by period.

PERIOD	METHOD		No.	%
1987–1996	CONCEPTUAL	Theoretical articles	2	22
	EMPIRICAL	Qualitative	4	44
		Quantitative	3	33
	Total 1987–1996		**9**	**100**
1997–2006	CONCEPTUAL	Theoretical articles	1	10
	EMPIRICAL	Qualitative	2	20
		Quantitative	6	60
		Mixed	1	10
	Total 1997–2006		**10**	**100**
2007–2016	CONCEPTUAL	SRL	1	3
		Theoretical articles	7	18
	EMPIRICAL	Qualitative	4	10
		Quantitative	26	65
		Mixed	2	5
	Total 2007–2016		**40**	**100**

Table 4. Empirical studies, by sectors.

SECTOR	No.	%
Industry	26	54
Industry & Services	11	23
Services	7	15
Agriculture	1	2
No specified	3	6
Total	**48**	**100**

Only one article deals with the agricultural sector, approaching the adoption of technological innovations among the purchasers of agricultural tractors (Cavallo, Ferrari, Bollani, & Coccia, 2014). Furthermore, these authors point out that, given the currently significant application of high technology in agriculture, it is fundamental to grasp the preferences, expectations and needs of tractor operators in order to improve the allocation of human resources, the budgets of innovation projects and as well as the financing of agricultural subsidies. On the other hand, conclusions drawn from empirical studies applied to the industry and services sectors may not be verified in the agricultural sector and thus the literature needs further studies on this sector.

The empirical studies focus mainly on the most developed countries, especially the USA even while Spain attains relevance in the 2007–2016 period with four studies, including the second most cited article of this period (Vega-Jurado et al., 2009) (Table 5). The study by Musteen, Datta, and Francis (2014), on the early internationalisation of firms, reinforces this conclusion in reporting how most studies approach the context of high technology firms in developed economies and hence requiring further studies to address emerging and developing economies. Additionally, there are only a handful of articles focusing on more than one country, making comparison difficult and especially between countries in different stages of development.

Past and future paths for the strategic management of technological innovation

Development, the types and sources of technological innovation account for the best covered topics in the literature, essentially focusing on performance-related issues and the formulation of strategies (Table 6). This finding is in line with the conclusions of Datta et al. (2014) but only in terms of the development and sources of innovation as,

Table 5. Empirical studies, by countries.

COUNTRY	No.	%
USA	17	35
Spain	4	8
Germany	3	6
England	2	4
Others (only with 1 study)	14	29
Divers	5	10
No specified	3	6
Total	**48**	**100**

Table 6. Thematic classification, by period (Technological Innovation/Strategic Management).

PERIOD	TI/SM THEMES	Industry Analysis	Internal Analysis	Performance	Strategy Formulation	Strategy Implementation	Environment	All (RSL)
1987–1996	**Innovation Development**				Christensen (1995); Shrivastava and Souder (1987); Souder and Moenaert (1992)	Chiesa et al. (1996)		
	Innovation Sources				Bowonder and Miyake (1994); Mathe and Dagi (1996)			
	Innovation Types	Segars and Grover (1995), Webb (1996)			Dowling and Ruefli (1992)			
1997–2006	**Innovation Commercialisation**				Teece (2006)			
	Innovation Development	Gallagher and Park (2002)		Persaud (2005); Pike, Roos, and Marr (2005); Wiggins and Ruefli (2002)				
	Innovation Sources			Irwin, Hoffman, and Lamont (1998); Wang and Chien (2006)				
	Protection				Kfir (2000)			
	Innovation Types			Buhalis (2004); Subramaniam and Youndt (2005)				

(*Continued*)

Table 6. (Continued).

PERIOD	TI/SM THEMES	Industry Analysis	Internal Analysis	Performance	Strategy Formulation	Strategy Implementation	Environment	All (RSL)
2007–2016	**Adoption/Diffusion**				Aarstad (2014); Cavallo et al. (2014)			
2007–2016	**Innovation Commercialisation**				Loya and Rawani (2016)			
	Innovation Development		Ellis, Henke, and Kull (2012)	Ernst and Fischer (2014); Madsen and Leiblein (2015); Musteen et al. (2014); Shafia et al. (2016); Yuan et al. (2016)	Al-Aali and Teece (2013); Di Minin and Bianchi (2011); Salomon and Jin (2010)	Choomon and Leeprechanon (2011)		
	Innovation Sources		Li-Ying et al. (2016)	Demirkan and Demirkan (2012); Inkinen et al. (2015); King, Slotegraaf, and Kesner (2008); Nieves and Haller (2014); Paradkar et al. (2015); Pitelis (2009); Wang and Chen (2010)	Bogers and West (2012); Vasudeva and Anand (2011)		Veliyath and Sambharya (2011)	
	Innovation Sources/ Innovation Types			Vega-Jurado et al. (2009)				
	Protection			Kim (2016)		Kim (2013)		
	Innovation Types		Hervas-Oliver et al. (2016); Kraiczy et al. (2015); Mihalache et al. (2012); O'Connor (2008); Seifried and Katz (2015); Su and McNamara (2012); Veider and Matzler (2016)	Ansari and Krop (2012); Cattani (2008); Keupp and Gassmann (2013); Yannopoulos et al. (2012)	Nadkarni and Chen (2014)			
	All (RSL)							Crossan and Apaydin (2010)

SM: Strategic Management; TI: Technological Innovation

in their literature review on the commercialisation of technological innovations, the types of innovation places less importance. The integration of functions/assets/resources is the preferred topic for researchers analysing the development of innovation, while product/process innovations are the most studied innovation types. The external sources of innovation, whether through acquisition or collaboration processes, represent the most studied facet, which contradicts the conclusions of Crossan and Apaydin (2010) who refer to researchers prioritising the study of internal sources. This may mean that the conclusions drawn from the more general field of innovation do not apply to the specific case of technological innovations.

Despite the types and sources of innovation receiving the greatest attention in the literature, there are issues related to those topics that gain less coverage. For example, the literature overlooks the associations between the various types of innovation classifications as only the studies of Su and McNamara (2012), and Yannopoulos, Auh, and Menguc (2012) approach both types of innovation classification: product and exploration/exploitation. On the other hand, only the works of Bowonder and Miyake (1994) and Wang and Chien (2006) simultaneously analyse internal and external sources of innovation, although Crossan and Apaydin (2010) point out that there is a tension in the literature between the internal and external sources of innovation that only emerges when jointly considering both sources of innovation.

Following the thematic analysis by temporal period, we may confirm that there have been evolutions in the preferred themes of researchers over the last three decades. While in the two first periods studied, the articles focused only on a limited number of topics, a greater diversification of themes emerges in the last period (2007–2016). This scenario confirms the growing fragmentation of the literature deepened by the inclusion of new research topics. In the first period (1987–1996), the study of the three main technological innovation topics (development, types and sources of innovation) interlinks with strategy formulation while becoming essentially subordinate to performance in the following periods. Nevertheless, there are a few studies related to industry analysis, strategy implementation and environment.

To better understand the literature about the strategic management of technological innovation, Table 7 includes the main findings and future lines of research.

Performance

Except for the 1987–1996 period, performance studies predominate in the research on the strategic management of technological innovation and relate primarily to the sources and development of innovation, focusing on the industry and service sectors of the USA and European countries.

The number of articles in recent years on the relationships between the internal and/or external sources of innovation and performance outcomes reveal the researcher interest in this subject. The external sources of innovation generate important impacts on performance, essentially through collaboration processes, although the partner type depends on the context. Paradkar et al. (2015) note that start-ups demonstrate an ability to form alliances with local but not with international partners, limiting their growth potential, while firms in the biotechnology industry depend heavily on the social network of academic scientists for the exchange and production of knowledge and to the corresponding number

Table 7. Main findings and future lines of research.

SM THEME		TI theme/Period	Findings	Future lines of research
MORE STUDIES	**Performance**	Innovation Development, Sources and Types (1997–2006, 2007–2016), and Protection (2007–2016)	Empirical studies about industry and services sectors, examining essentially sources and development of innovation in EUA and European countries.	Analyse of what causes high or low levels of integration between R&D and the patent functions, since those integration determines new product performance.
			Management of knowledge in an organisation is fundamental for innovation performance not only internally but also externally, requiring the ability to form alliances with partners.	Understand how networking capabilities and the management of collaborative networks influence firm performance.
			The positive impact of innovation capabilities in performance is highlighted.	
			In the highly competitive environment of technology-based industries, the capability of a firm to integrate the R&D and the patent functions, during new product development (NPD), is increasingly relevant for performance.	
	Strategy Formulation	Innovation Development, Sources and Types (1987–1996, 2007–2016), Innovation Commercialisation (1997–2006, 2007–2016), Protection (1997–2006), and Adoption/Diffusion (2007–2016)	Empirical studies examining mainly innovation development on industry sector of USA, as the formulation of strategies to integrate firm functions, namely R&D, Marketing and Intellectual Propriety functions.	More studies about adoption/diffusion and commercialisation strategies.
			Conceptual studies related essentially to innovation development and commercialisation.	Further studies concerning to the environmental aspect, namely strategies related to the environmental attitude of adopters of technological innovations and to the utilisation of various waste utilising innovations.
			Two of the least studied areas in the field of technological innovation are diffusion/adoption and commercialisation but are always linked to strategies formulation.	Development of strategies that includes different types of non-profit innovation intermediaries.
				Strategies for the adoption of technological innovations in the agricultural sector could be further studied.

(*Continued*)

Table 7. (Continued).

SM THEME		TI theme/Period	Findings	Future lines of research
	Internal Analysis	Innovation Development, Sources and Types (2007–2016)	Despite the focus on innovation types, empirical studies analyse essentially product innovations, while conceptual studies focus rather on two other innovation types: major innovation and exploration/ exploitation.	Further studies in the context of family firms, essentially the influence of individual preferences and dispositions of the TMT on the decisions for new product projects and on organisational ambidexterity.
			Empirical studies about industry and services sectors, examining essentially EUA and European countries.	More studies about the role of single process innovators, especially comparing SMEs from European Union countries.
			Analysis of specific organisations such as SMEs, family firms and armed forces	
			The role of TMT is crucial to product innovations, although it is important to engage non-family externals to the TMT to provide the diversity in knowledge and backgrounds that is needed for organisational ambidexterity.	
LESS STUDIES	**Industry Analysis**	Innovation Types (1987–1996) and Innovation Development (1997–2006)	Empirical studies focusing on high-technology industries in USA, namely videogame and fibre optic components industries.	Lack of studies related to industry analysis
			The development of technological innovations is crucial in network-based industries.	More studies about the specific nature and competitive rules for each industry technology-based, analysing unique features of competing in these industries.
			Structural characteristics of the industries are dramatically altered after the introduction of specific process innovations, as Information Technologies (IT).	
	Strategy Implementation	Innovation Development (1987–1996, 2007–2016), and Protection (2007–2016)	Empirical studies focusing in the industry sector.	Lack of studies related to strategy implementation.
			Frameworks for assessing technological innovation management allows firms to continually improve, examining the processes where technological innovations are developed.	More studies about the improvement of tools for developing technological innovations, not only in the industry sector but also in the services sector.
			Firms with different sets of resources and capabilities can implement different types of isolating strategies, to sustain their competitive advantage.	
	Environment	Innovation Sources (2007–2016)	The environment topic is represented only by an article, focusing on the factors that determine R&D investments by multinational corporations.	Lack of studies related to environment.
			The most important factors in attracting R&D investments made by MNCs are the country's capacity for the creation of technology, technology infrastructure and the development of human skills.	Further studies must analyse as developing countries become part of the international R&D networks of MNCs, and as relative comparative advantages of countries shift because of the dynamic forces of globalisation.

SM: Strategic Management; TI: Technological Innovation

of patents granted (Demirkan & Demirkan, 2012). Knowledge management is also important in the association between internal sources of innovation and performance. Firms are able to sustain innovation performance levels through the strategic management of knowledge and competence, knowledge-based compensation practices, and information technology practices (Inkinen, Kianto, & Vanhala, 2015) and, still furthermore, when experiencing highly dynamic environments, firms should increase the diversity of their knowledge composition in order to mitigate the risk of value erosion arising from firm-specific innovations (Wang & Chen, 2010).

The article by Vega-Jurado et al. (2009) stands out as it the only one that analyses types and sources of innovation, concluding that the effects of knowledge-sourcing strategies differ significantly depending on the type of innovation (product or process). Although internal R&D activities are associated with a greater use to external scientific knowledge sources (through cooperation), the authors find that they do not have synergistic effects.

The studies focusing on the relationship between innovation development and performance highlight the positive impact of innovation capabilities. In addition to innovation and marketing capabilities positively influencing the performance of technology-based firms (Yuan, Shin, He, & Yong Kim, 2016), technological innovation capabilities and dynamic capabilities increase competitiveness in Research and Technology Organisations (Shafia et al., 2016). Additionally, the capabilities of firms to integrate the R&D and the patent functions, during new product development (NPD), is increasingly relevant to performance in the highly competitive environment of technology-based industries (Ernst & Fischer, 2014). This reflects how the NPD process incorporates important strategic and legal inputs from the patent department. In the case of multinational corporations (MNCs), the synergistic innovative capabilities, evaluated in the context of four constructs (autonomy, formalisation, socialisation, and communication), are improved through intrafirm collaborative relationships among the globally dispersed R&D units of MNCs (Persaud, 2005).

In terms of the relationship between the sources of technological innovation and performance, there is a need for more studies examining different contexts, in particular different industries (Inkinen et al., 2015; Nieves & Haller, 2014) and countries at different stages of development (Inkinen et al., 2015; Paradkar et al., 2015). As the integration of the R&D and patent functions holds importance to new product performance, there is great research interest in understanding more about just what causes high or low levels of integration between those functions, especially corporate culture, incentive systems and organisational structures (Ernst & Fischer, 2014). It would also be worthwhile to understand what kind of collaborative management networks yield superior outcomes, examining the role of managing both network relationships and the knowledge flows ongoing in these networks (Paradkar et al., 2015). Besides networking capabilities, the influence of production capabilities on firm performance also requires analysis (Yuan et al., 2016).

Strategy formulation

Studies on strategy formulation constitute the second most covered topic in the literature, behind studies of performance outcomes, and relate mainly to innovation

development as integrating functions. In the 1987–1996 period, firm strategies for the integration between R&D and Marketing functions are analysed (Souder & Moenaert, 1992), while the 2007–2016 period highlights strategies for integrating R&D and Intellectual Propriety (Al-Aali & Teece, 2013; Di Minin & Bianchi, 2011).

R&D and Intellectual Property (IP) management should work together, so senior managers should ensure the integration of the various forms of IP (patents, trade secrets, trademarks and copyrights) into the corporate strategy with the guidance provided by R&D/Technology managers (Al-Aali & Teece, 2013). Strategy formulation addressing the integration of these two functions is also crucial to the internationalisation of R&D activities, as the interlinking of core R&D projects to domestic locations not only relate to organisational inertia and the immaturity of subsidiaries, as the literature identifies, but above all with the headquarters centralisation of intellectual property (Di Minin & Bianchi, 2011).

Two of the least studied areas in the field of technological innovation are diffusion/adoption and commercialisation but always emerge interlinked with strategy formulation. The field of diffusion/adoption examines different contexts that determine the formulation of different strategies. Aarstad (2014) analyses scale-free firm networks in which one or a few central actors connect to numerous peripheral actors, concluding that a firm's strategy must consider how peripheral actors may restrict the central actor's propensity to adopt innovations and thus prevent their diffusion. The work of Cavallo et al. (2014) on the agricultural sector notes that the adoption of tractors with more advanced technological innovations mainly takes place on large-scale farms under professional management, although this sector also reports specific character given that the older the tractor driver and the longer they have been working in agriculture, then the greater their commitment to environment protection and safe working conditions. Hence, company strategies must improve environmental and safety training among young and new tractor drivers.

In the field of commercialisation, the Loya and Rawani (2016) study addresses the less studied aspects of the open innovation paradigm, through a strategy formulation framework able to assist a particular category of non-profit innovation intermediary, that is, fly ash innovation intermediaries. However, as this underlines, there are various types of innovation intermediaries eligible for classification according to their ownership (central government, local authorities, universities, private consultancies, NGOs, industry associations, etc.), their funding (public and private funding sources) and their profit intentions (profit-making and non-profit) (Klewitz, Zeyen, & Hansen, 2012).

As for future lines of research, the adoption/diffusion and commercialisation of technological innovations account for areas that require further study from the strategic management point of view, particularly the formulation of strategies. The environmental aspect requires greater study not only in the field of innovation commercialisation, as this needs the implementation of more frameworks for real-life cases within the context of deploying various waste utilisation innovations (Loya & Rawani, 2016), but also in the field of strategies for adoption/diffusion, for example the environmental attitudes of agricultural tractor drivers adopting technological innovations (Cavallo et al., 2014). Additionally, studying technological innovation in the agriculture sector from the strategic management perspective is another overlooked facet, for example studying technological innovations not only in agricultural tractors but also in other

equipment types (Cavallo et al., 2014). In addition, the literature needs more studies analysing different types of non-profit innovation intermediaries, as the context of open innovation intermediaries represents a recent phenomenon (Loya & Rawani, 2016).

Internal analysis

The 2007–2016 period reflects a great interest in the internal analysis of innovation types, not only through empirical but also through conceptual studies. Empirical studies highlight specific organisations such as SMEs, family firms and the armed forces, essentially examining product/process innovations in the USA and in European countries. In contrast, the conceptual papers focus on two other types of innovation: major innovations (O'Connor, 2008) and exploration/exploitation (Veider & Matzler, 2016). In the first case, O'Connor (2008) states that dynamic capabilities required for phenomena as complex as major innovations must be considered in a management system rather than as operating routines and repeatable processes, while Veider and Matzler (2016) underline the importance of engaging non-family externals for top management teams (TMTs) to provide the diversity in knowledge and backgrounds necessary for organisational ambidexterity.

Empirical articles also examine the role of TMT, although they focus on the analysis of product innovations on European firms across different dimensions (Kraiczy, Hack, & Kellermanns, 2015; Mihalache, Jansen, Van den Bosch, & Volberda, 2012). In family SMEs, the risk-taking propensity of their chief executive officers (CEOs) returns a positive effect on new product portfolio innovativeness but with a weaker effect when TMT family member levels of ownership are high, while stronger in family firms in the earlier generational stages (Kraiczy et al., 2015). In firms with more than 25 employees, offshoring business functions (production, R&D, and engineering) returns an inverted U-shaped influence on firm innovativeness but this relationship is steeper in firms with high TMT information diversity and in firms with low levels of TMT shared vision (Mihalache et al., 2012).

However, only one study addresses process innovation and argues that SMEs might follow a specific pattern of innovation focused mainly on developing new technological processes, rather than products (Hervas-Oliver, Boronat-Moll, & Sempere-Ripoll, 2016). There are two distinct patterns to this type of innovation in accordance with their innovation capabilities: one characterised mainly by the acquisition of embodied knowledge and external support from suppliers, and another centred on R&D development and high absorptive capacity, accompanied by organisational innovation. The work of Seifried and Katz (2015) jointly analyses product and process innovations and report how the U.S. Armed Forces, through the dynamic capabilities of its top officers and officials, organised bowl games as product innovation and used football as process innovation, managing the mass mobilisation and training of men for the various military campaigns ongoing between 1942 and 1967.

Further studies should analyse technological innovation within the context of family firms, essentially individual preferences and dispositions of the TMT not only as regards decision making on new product projects (Kraiczy et al., 2015) but also on organisational ambidexterity (Veider & Matzler, 2016), attending to the differences in terms of firm size, family composition or its legal structure (Kraiczy et al., 2015).

Considering the lack of studies related to process innovation, the role of single process innovators should be more deeply examined, especially through comparing SMEs from different European Union member states (Hervas-Oliver et al., 2016).

Industry analysis

There are few studies approaching industry analysis but focus on the specific characteristics of high-technology industries in the USA, especially the videogame (Gallagher & Park, 2002) and fibre optic component (Webb, 1996) industries. In the videogame industry, where complementarity exists between software and hardware, business networks are crucial to lowering transaction costs and increasing buyer-switching costs. However, attracting independent software vendors into the network of a platform requires superior technology, early entry through innovation, proper pricing, brand name, channel management and entry barriers (Gallagher & Park, 2002). Fibre optic components represents another important high-technology industry, characterised by a rapid series of technological changes throughout the 1980s with the development of products able to compete in various markets previously dominated by electrical systems. The factors determining the development of fibre optics include system price and performance, market acceptance, market size, the rate of technological innovation and economic conditions (Webb, 1996).

While the two works above focus on one industry, the study of Segars and Grover (1995) examines the particularities of three industries in order to demonstrate how the introduction of specific process innovations, such as information technologies (ITs), brings about substantial impacts on the structural characteristics of the airline, industrial chemical and wholesale drug industries. In the airlines and industrial chemicals industries, early adopters broke away from other industry participants while, in the drug wholesaler industry, previously distinct bases of competition underwent consolidation to result in a more competitive industrial structure than that which existed prior to the introduction of ITs.

Due to industry analysis constituting the theme of only a few studies, detailing innovation types and innovation development, we need further studies to understand the specific nature and competitive rules for each technology-based industry, while also exploring unique features of the competition prevailing in such sectors (Gallagher & Park, 2002).

Strategy implementation

Strategy implementation is one of the issues receiving the lowest level of attention in the literature, a fact already observed in the reviews of Crossan and Apaydin (2010), Keupp et al. (2012) and Kim and Chung (2017). The three studies identified are all empirical, examining innovation development and protection in the industry sector.

As protection strategies are among the facets least covered in the literature, the study of M. Kim (2013) provides a crucial input to understanding how firms may implement different types of isolating strategies, with different sets of resources and capabilities, in order to sustain their competitive advantage. Multiple paths may lead to establishing isolating mechanisms but causal factors from the two sources of the isolating

mechanisms identified (intrinsic characteristics of knowledge and geographic scope of knowledge acquisition) might be functionally equivalent.

Strategy implementation also interlinks with innovation development. Frameworks for assessing the management of technological innovation enable firms to continually improve through examining the processes which drive the development of technological innovations. In the case study by Chiesa et al. (1996), their auditing methodology goes beyond performance measurement by underlining problems and needs, and providing information susceptible for deployment in the design and development of action plans for improving performance. Based on the technology road-mapping (TRM) tool, the study by Choomon and Leeprechanon (2011) concludes that the power-line communication (PLC) sector of Thailand plays an important role in the technological innovation domain but influences only one specific market due to its business complexity.

There is a need for further studies to better understand the implementation of strategies, such as for improving the tools for developing technological innovations not only in industry but also in the service sector, especially as regards the terminology and the focus (Chiesa et al., 1996).

Environment

The environment topic features only in one article (Veliyath & Sambharya, 2011), which confirms the conclusions of Keupp et al. (2012), that focuses on the factors determining R&D investments by multinational corporations. Developed countries have continued to attract the largest amounts of international R&D investments made by MNCs since the most important factors in attracting R&D investments are the country's capacity for the creation of technology, technology infrastructures and the development of human skills.

Further studies must analyse environment-related issues, especially as more developing countries become part of the international R&D networks of MNCs, and as the relative comparative advantages of countries shift because of the dynamic forces of globalisation (Veliyath & Sambharya, 2011).

Conclusions

Our study displays certain limitations. On the one hand, the SLR relies only on *ISI Web of Knowledge SSCI* articles, even while this database ranks as one of the most comprehensive peer-reviewed publications databases. On the other hand, the filtering process applied may have omitted relevant literature, even while the rigorous SLR procedure mitigates the likelihood that any excluded articles may include information that would significantly alter our conclusions.

The SLR on the strategic management of technological innovation confirms the diversity of concepts and typologies related to technological innovation that reflects the highly fragmented literature that hinders its study, especially from the strategic management perspective. This study strives to set out the main themes related to the strategic management of technological innovation, proceeding with its temporal analysis and establishing links between the different areas studied.

The increase in the number of articles published in recent years demonstrates both the growing interest in issues related to the strategic management of technological innovation as well as the inclusion of new research topics. Despite the deployment of multiple concepts and the need for their clarification, conceptual articles remain poorly represented in the literature. In turn, the empirical studies focus essentially on the industrial sectors of developed countries and, furthermore, while the main methods applied in the 1987–1996 period were qualitative, in the following periods (1997–2006 and 2007–2016) the quantitative methods took precedent.

Analysing the literature on the strategic management of technological innovation published over the last three decades, we witness an evolution in the thematic preferences of researchers. There was a transition from studying only a limited number of themes to approaching a wider range of research topics, confirming a trend towards fragmentation. The study of performance, applied to sources and the development of innovation, is the area that receives greatest attention from the scientific community, especially in the last ten years. The external sources of innovation, whether achieved through acquisition or collaborative processes, are the most studied, while integrating functions/assets/resources constitutes the preferred topic for researchers studying the development of innovation. In the 2007–2016 period, the articles published also featured internal analysis of types of innovation, such as product or process innovations.

On the other hand, there are only a few studies dealing with industry analysis, strategy implementation and environment. Two areas attracting lower levels of interest in the field of technological innovation are diffusion/adoption (Aarstad, 2014; Cavallo et al., 2014) and commercialisation (Loya & Rawani, 2016) and furthermore always associated with strategy formulation. Only the work of Vega-Jurado et al. (2009) simultaneously examined types and sources of innovation, determining their effects on performance and thereby becoming one of the articles with the highest number of citations.

Considering the lack of a specific review on the strategic management of technological innovation, our study has contributed to a better understanding of the literature, finding similarities and specific characteristics compared with other reviews focusing on innovation from the strategic management perspective.

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No potential conflict of interest was reported by the authors.

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