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DIGITAL INNOVATION: FACTORS, INFLUENCERS AND TRENDS ARISING FROM DECADES OF RESEARCHING

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1. Introduction

DI has been affected all sectors of society, specifically economies. The digital revolution has increasingly steadily converted analog information into digital formats, making information more amenable to automated processing (Teece, 2018). Although DI is a popular point of discussion, the ideas of digital products, services, and mediums were well-understood in the 1990s and 2000s. However, there is currently not commonly accepted definition for the term DI. Moreover, the terms digitalization and the digitization are often used interchangeably (Teece, 2018; Hinnings, Gegenhuber & Greenwood, 2018).

DI is the use of digital technology in a wide range of innovations, understanding the term "digital" as the conversion from mainly analog information into the binary language understood by computers (Nambisan et al. 2017). The malleability (e.g., re-programmability), homogeneity (e.g., standardized software languages) and transferability (e.g., ease of transferring digital representations of any object) are at the heart of technologies meshing digital, and often physical materiality, thereby enabling, constraining, but also interwoven with, human action (Flyverbom et al., 2016; Lakhani, Lifshitz-Assaf, & Tushman, 2013; Yoo, Henfridsson, & Lyytinen, 2010). Even without a standard definition, we assume DI as the concerted orchestration of new products, processes, services and platforms, or even new business models in each context (Nambisan et al., 2017; Hargadon & Douglas, 2001).

Despite the ubiquity and visible impact of digital transformation and resultant new digital business models, the academic literature has paid little attention to them, only recently addressing the topics of digitization, digitalization, and digital transformation (Venkatraman, 2017). Digital change has received most attention within specific business disciplines. Verhoef et al. (2019) indicate that marketing researchers have focused on digital advertising and social media effects including attribution model developments (Lamberton & Stephen, 2016) and multi-channel and omni-channel developments (Verhoef, Kannan & Inman, 2015). The strategic management literature has focused on the conceptualization, operationalization, and renewal of (digital) business models (Foss & Saebi, 2017; Osterwalder & Pigneur, 2010). In the information systems, researchers have paid attention to technical developments regarding adoption and use of digital technologies and resultant business value (Nambisan et al., 2017; Sambamurthy, Bharadwaj & Grover, 2003).

We believe that a multidisciplinary discussion is required, given that DI is multidisciplinary involving changes in strategy, organization, information technology, supply chains and marketing. Nowadays' business world, managers are increasingly confronted with responding to the advent of new digital technologies that blur market boundaries and change agent roles (e.g., customers become co-producers, competitors become collaborators, and firms that vertically integrate or bypass existing parties). To provide theorical and managerial guidance, we must increase our understanding of how DI has been evolved and which factors affect the construct and how the influencers are structuring their findings that affect organizational strategies.

2. Methods and Data

Methodological procedures were performed in steps along with a previous citation analysis. First, the development of a list of references already cited found in the literature and of all the articles of the field of DI obtained from the Social Science Citation Index

(SSCI) collected manually during three multi-year periods: 1987-2002, 2003-2011 and 2012-2020, according to Rossetto et al., (2018), Shafique (2013) and Ramos-Rodríguez & Ruíz-Navarro (2004), covering a total of 32 years of academic publications in the DI field. Second, an analysis of the data citations, revealing the most cited publications, authors, and journals by DI scholars. Third, through the analysis of co-citation, the authors measured and weighed to detect their affinity according to the perception of their citations (Gmür 2003). The result was an ‘‘author x author’’ matrix, prepared from Bibexcel software, that served as the basis for later multivariate analyzes and for social network analysis. We follow the recommended procedures, using IBM-SPSS v.22, evaluating the KMO (above 0.5) of each item in the anti-image matrix, the general KMO (above 0.5), the exclusion of items with commonality below 0.5, for items with loads below 0.5 in one factor and items with cross loads (above 0.5 in more than one factor). We evaluated the internal reliability measure of each factor (Cronbach's alpha) whose value for exploratory analysis must be greater than 0.6. The extraction of the principal component method and Varimax rotation with Kaiser normalization described below was respected (Quevedo-Silva et al., 2016). Fourth, to represent the structure of the discipline, the results were mapped in a way that the groups of co-citations would represent different fields of DI (McCain, 1990).

2.1 Citation vs Co-citation

The sum of citations of an article, author or periodical from a representative sample can reveal the influence of a given article, author or periodical corresponds to a particular field of research (Culnan, 1987). The comparison of the three periods was based on a Citation Value (CV) calculated as the ratio of ‘‘number of individual citations’’ by ‘‘total citations received’’, in a specified period (Rossetto et al., 2018). Co-citation analysis is a dynamic approach, established by authors of papers other than those it links; understood as a relationship extrinsic to the documents involved (Vogel & Güttel, 2013). A similarity value introduced by Gmür (2003) is used, which offers especially well-balanced networks with quite different groups (Rossetto et al., 2018).

Concerning similarity value, Gmür (2003) demonstrated that counting absolute citations among authors is not suitable for the generation of clearly defined groups. Thus, this study uses the value of relative co-citation, the ‘‘CoCit’’ score as a measure of impact among authors in each period. The counting of absolute citations is set in relation to the individual citation count of each author. The CoCit score ranges from 0 to 1. Since the number of pairs of authors at the beginning of periods is significantly lower than in later periods, therefore a minimum entry threshold per period has been applied to ensure sufficient insights into the intellectual structure for each period. The relationship between the selected citations is visualized with authors as nodes and the lines between them representing the respective co-citation relationships (Rossetto et al., 2018).

2.2 Database

The data for the analysis were collected from the SSCI of the Web of Science (WoS) used in several similar studies (Rossetto et al., 2018; Shafique, 2013; Backhaus et al., 2011). All the publications pointed out in the main literature review articles on DI that are designated as seminal for DI were included in the sample. The result consists of 2.513 articles of 32 years of publications in this field (1987 to December 2020). The steps of search for publications were: (1) Following the path of Shafique (2013), this result was obtained by searching the keyword ‘‘digital innovation’’ in the advanced search field of the Core Collection of WoS, resulting in 11.159 articles. (2) In order to filter the results, excluding the publications that fall outside the scope of this work, only the articles that

were indexed belonging to the categories ‘‘Management’’, ‘‘Business’’, ‘‘Economics’’, ‘‘Business, Finance’’, ‘‘Operations Research & Management Science’’ from WoS TM (WoS Categories). (3) 2.513 DI-related articles were obtained representing 22,5% of the whole data after clearing and normalizing their respective bibliographic references, resulted in a knowledge base used as source to produce knowledge in DI throughout business management field in the period of analysis (Table 1).

Table 1. Data base *Source:* Research data

	1st period 1987-2002	2nd period 2003-2011	3rd period 2012-2020	Total 1987-2020
Total # of published articles [a]	62	269	2182	2513
Cited references (total) [b]	4260	8730	18098	31088
Average citations per year [c]	196.4	586.2	3712.2	4494.9
Average citations per item [d]	69.8	32.5	8.3	12.4
h-index [e]	23	46	61	81
# of different source [f]	42	171	773	897

a. The total number of articles published in the SSCI database with the word ‘‘digital innovation’’ in the title, abstract, keywords or additional keywords (keywords plus)
b. Base of digital innovation articles sample
c. Sum of the total number of unique references cited in each of the articles of the base of innovation articles.
d. Value referring to the sum of citations that all articles of the period received by the number of years of the period.
e. The h-index is defined as the value ‘‘h’’ that a scientist receives for his ‘‘Nh’’ (number of articles) that has at least ‘‘h’’ citations each. That is, an author or journal that has an h-index = 20 means that it has at least 20 publications with at least 20 citations each. Thus, h-index is a joint that evaluates the number of publications (number of articles) and the quality of the publications (impact or number of citations received) (Hirsch 2005)
f. The number of distinct sources resulting from the analysis of data base.

3. Citation analysis results

Citation analysis answers the question of how knowledge dynamics in DI are generated and transferred over time (e.g., Shafique 2013; Backhaus et al. 2011). We present the evaluation of the knowledge transfer process involved (1) citing behaviors, (2) the origins of the cited references, (3) the most cited references, and (4) the characteristics of the key references.

In Table 2 the average number of publications per year grew from the average of 4.13 publications in the period of 1987–2002 to the average of 242.44 publications per year in the period of 2012–2020. The growth in the volume of publications and being consistent and significant reflects the popularization of DI and the specific knowledge base growth, mainly due to its relevance that has been gaining associated with the achievement of differentiation, value creation and sustainable competitive advantage (Barney, 1991; Chesbrough, 2003; Porter & Heppelmann, 2014; Svahn, Mathiassen & Lindgren, 2017). A considerably factor is the growth of digital ecosystems creation to spread out searching, acquisition and diffusion of knowledge in DI and we see the average number of publications increased significantly in the last period (2012-2020).

The average number of references per article have reduced significantly, going from 68.71 to 32.45 (- 47,23%) from the 1st to the 2nd period and in the 3rd, period reducing to 8.29 (- 25,5%), showing that the growth in the average number of annual publications from the 2nd to the 3rd period (+ 138%) has impacted on the reduction in the number of references used by the most recent articles. This reduction was highlighted by Rossetto et al. (2018) as a trend towards the acceptance of publications with less pages (15–25 pages) that have been occurring in the last decade. We believe that other factors have been influence this reduction such as lacking investments in research making

researchers lives more difficult to make new discoveries. Major of them are working in circle with the existent knowledge. It is observed no aging of the cited references, which keeping in average from 2.84 to 2.02 from the 1st to the 3rd period, implying stagnation in the discipline's evolution. However, it is common to have some classic and seminal articles that persist in the knowledge base of a discipline, being able to influence knowledge to nowadays, which is common in scientific disciplines (Backhaus et al. 2011). The self-citation rate provides another indicator to explore the dynamics of the research. Sometimes, the lack of alternative references leads researchers from more recent fields to self-citation practice more often than researchers who have been established for the longest time (Garfield 1979; Porter 1977). Thus, the growth rate of the self-citation rate from 0.16% in the 1st period to 16.1% (+ 99.38%) in the 3rd period indicates that DI field needs more attention as a scientific discipline and there is still room for potential new contributions and findings.

Table 2 Citation behavior *Source:* Research data

Citation Behaviour	1st period 1987-2002	2nd period 2003-2011	3rd period 2012-2020
Average number of publications per year *a*	4,13	33,63	242,44
Average number of references per article *b*	68,71	32,45	8,29
Average age of references (absolute) *c*	20,84	12,05	2,02
Average age of references (relative) *d*	2,84	3,05	2,02
Self-citation ratee *e*	0,16%	0,32%	16,1%
Average number of authors per article *f*	1,69	2,25	2,61

a. Values referring to the average number of publications per year, within each of the indicated periods, considering the final collected database (composed of 2.513 articles). The calculation is given by dividing the total number of articles published in the period by the number of years of each period.
b. Values resulting from the division of the result of the sum of all the references of each article by the total number of articles of each indicated period.
c. Average age of the references considering the absolute value from the year 2020.
d. Average age of references considering the relative value from the end year of each indicated period, being 2002 for the references of the first period, 2011 for the references of the second period, and 2020 for the references of the third period.
e. Percentage of self-citation of analyzed articles.
f. Average number of authors per article within the analyzed period

Table 3 provides the list of the 20 publications in the database that were most cited in each of the three periods, and it is observed the relevance of authors such as Tripsas and Gavetti (2000) who were influential during the first period of analysis among the 20 most cited. He also appears in second period individually (Tripsas, 2009) and in co-authorship in the third period. The number of sole authors among the works (Wheeler, 2002; Rosenbloom, 2000; Prencipe, 2000; Lee, 2001) reinforces the idea of representativeness of the individual researcher in the first period and that has been keeping. The author Yoo, in the second period compose two most cited also appears in the third period as the second highest cited author. The main highlight is Nabimsan, who in the third period has three works, two in co-authorships (Lusch & Nambisan, 2015; Nambisan et al., 2017), besides one work individually (Nambisan, 2017). Overall, where the volume of publications is much higher, the highlight is Sambamurthy, Bharadwaj and Grover (2003) who, having only one work among the 60 most cited, has the highest citation. Such a difference in the volume of citations demonstrates the great relevance of these studies, being able to generate a significant theoretical framework for DI, specifically introducing concepts such as ''open innovation and business model innovation'' (Chesbrough, 2003; Chesbrough, 2010; Teece 2010) and the ''dynamic capabilities to manage DI" (Teece, 2007) and recently the theory of ecosystems (Jacobides, Cennamo & Gawer, 2018). The characteristics of key-references including

the identification of the most cited publications of each period reveals the most prominent authors and the key issues that most drive DI at different times.

Table 4 the main publications coming from the co-citation analysis are listed. The 89,856 references analyzed from the 2,513 articles in the database resulted in this list below, indicating that the articles presented are the most cited articles together. To exemplify, we take the authors Tripsas and Gavetti (2000) who during the first period of analysis were cited 1084 times among the articles of the database published in the period and among these articles they appear in the references of 10 publications simultaneously in the second period, this being the amount of co-citation.

Thus, among the publications that emerged as classics that served as a base of support for the generation of scientific knowledge in the DI, we can highlight some prolific authors becoming a reference over time (Eisenhardt, 1989; Teece, Pisano & Shuen, 1997) being able to maintain a single work among the top 20 references in the three analyzed periods that generated relevant contributions to organizational management serving as support for several studies that would later explore DI. Another author in the first period and back in the third period is Barney (1991) who established a milestone in the studies about firm resources and sustained competitive advantage. Other examples are Chesbrough (2003) with "Open innovation: The new imperative for creating and profiting from technology" and Henderson & Clark (1990) with "Architectural innovation". In highlighted by the theoretical framework established in his work on the evolutionary theory of economic changes we pointed out Nelson & Winter (1982) in the first two periods.

About the works that appear in the two first periods studied, we highlight Davis (1989) in "Perceived usefulness, perceived ease of use, and user acceptance of information technology " about with usage behavior against ease of use. A regression analyses suggested that perceived ease of use may be a causal antecedent to perceived usefulness, as opposed to a parallel, direct determinant of systems usage.

In the third period a greater number of works can be highlighted, however one of them, highly cited and co-cited, was presented by Yoo, Henfridsson and Lyytinen (2010) who argue that pervasive digitization gives birth to a new type of product architecture: the layered modular architecture which extends the modular architecture of physical products. They posit that this new architecture instigates profound changes in the ways that firms organize for innovation in the future and develop (1) a conceptual framework to describe the emerging organizing logic of DI and (2) an information systems research agenda for digital strategy and the creation and management of corporate information technology infrastructures. Tripsas and Gavetti (2000) are another example of highly cited and co-cited work also bringing evidence that established firms often have difficulty adapting to radical technological change.

In general, despite the fluctuations between the different time periods studied, the result is very instructive and allows insights. This analysis of the key-references provided evidence of a spread out in the focus of the subject, evident in the view of the theory of organizations, architecture for tech platforms and dynamic capabilities serving as support for the generation of DI studies, such as the strategic process of technological and organizational change, development of new products, communication and diffusion of technology to the most current themes present in the last period studied, such as service innovation, absorbing capacities, digital-entrepreneurship in the development of studies based on DI resources.

Table 3 Ranking of the Top 20 papers most cited[a] currently Source*:* Research data

	1st period 1987-2002			2nd period 2003-2011			3rd period 2012-2020		
Rank	Paper's author (year)	Cit	CV (%)	Paper's author (year)	Cit	CV (%)	Paper's author (year)	Cit	CV (%)
1	Tripsas & Gavetti, 2000	1084	25.4	Sambamurthy, Bharadwaj & Grover, 2003	1149	13.2	Lusch & Nambisan, 2015	449	2.5
2	Hargadon & Douglas, 2001	575	13.5	Gilbert, 2005	724	8.3	Yoo et al., 2012	410	2.3
3	Adner & Levinthal, 2001	380	8.9	Yoo, Henfridsson & Lyytinen, 2010	490	5.6	Barrett et al., 2015	244	1.3
4	Thomke & Fujimoto, 2000	226	5.3	Christensen, Olesen & Kjaer, 2005	303	3.5	Rayna & Striukova, 2016	222	1.2
5	Lyytinen & Yoo, 2002	221	5.2	Yoo, 2010	248	2.8	Nambisan et al., 2017	217	1.2
6	Wheeler, 2002	202	4.7	Tripsas, 2009	245	2.8	Susarla, Oh & Tan, 2012	216	1.2
7	Rosenbloom, 2000	182	4.3	Zhu et al., 2006	239	2.7	Baumers et al., 2016	208	1.1
8	Sambamurthy & Zmud, 2000	153	3.6	Boland, Lyytinen & Yoo, 2007	224	2.6	Gavetti, 2012	203	1.1
9	Straub & Watson, 2001	150	3.5	Benner, 2010	176	2.0	Nambisan, 2017	200	1.1
10	Gupta, Jain & Sawhney, 1999	110	2.6	Pavlou & El Sawy, 2010	176	2.0	Dwyer, 2015	190	1.0
11	Prencipe, 2000	95	2.2	Yi, Fiedler & Park, 2006	172	2.0	Boudreau, 2012	188	1.0
12	Lai & Guynes, 1997	94	2.2	Lyytinen & Rose, 2003	171	1.9	Li, 2018	172	1.0
13	Dekimpe, Parker & Sarvary, 2000	81	1.9	Loch, Straub & Kamel, 2003	168	1.9	Cardona, Kretschmer & Strobel, 2013	169	0.9
14	Lee, 2001	74	1.7	Mu & Lee, 2005	168	1.8	Henfridsson & Bygstad, 2013	158	0.9
15	Brown & Duguid, 2002	72	1.7	Hotho & Champion, 2011	154	1.6	Fichman, Dos Santos & Zheng, 2014	156	0.9
16	Chircu & Kauffman, 2000	67	1.6	Lucas & Goh, 2009	143	1.6	Benner & Tripsas, 2012	145	0.8
17	Wong, 2002	60	1.4	Kohler, Matzler & Fueller, 2009	137	1.6	Ritala, Golnam & Wegmann, 2014	141	0.8
18	Leonard, 1987	55	1.3	McAfee & Brynjolfsson, 2008	137	1.6	Autio et al., 2018	133	0.7
19	Islam, Fiebig & Meade, 2002	43	1.0	Howe & Strauss, 2007	134	1.5	Vendrell-Herrero et al., 2017	126	0.7
20	Nieto, Lopez & Cruz, 1998	41	1.0	Carayannis & von Zedtwitz, 2005	129	1.5	Oh, Teo & Sambamurthy, 2012	124	0.7
	Total Citation/period	4260		Total Citation/period	8730		Total Citation/period	18098	

List of the most cited papers, among the 2.512 works that compose the collected database for this work. For each study the number of citations is presented in the column (Cit.) and the CV representing the calculated value as the ratio of ''number of citations'' by ''total citations received in the period''

a. The citation number corresponding to the number of citations received by each paper at the moment of the gathering data. The last line shows the total number of citations received by all publications of the period that are within the database indicated in Table 1.

Table 4. Ranking of the top 20 key-references by period. Source: Research data

	1st period 1987-2002		2nd period 2003-2011		3rd period 2012-2020	
Rank	Paper's author (year)	CoCit	Paper's author (year)	CoCit	Paper's author (year)	Cocit
1	Nelson & Winter, 1982	8	Tushman & Anderson, 1986	16	Yoo, Henfridsson & Lyytinen, 2010*	178
2	Henderson & Clark, 1990	7	Rogers, 1995	16	Eisenhardt, 1989	172
3	Christensen, 1997	6	Henderson & Clark, 1990	15	Yoo et al., 2012*	155
4	Rogers, 1995	6	March, 1991	14	Nambisan et al., 2017*	116
5	Tushman & Anderson, 1986	6	Teece, 1986	13	Teece, 2010	106
6	Porter, 1980	5	Utterback, 1994	12	Bharadwaj et al., 2013	106
7	Leonard-Barton, 1992	5	Rogers, 2003	12	Cohen & Levinthal, 1990	99
8	Brown, 1981	4	Cohen & Levinthal, 1990	11	Tilson, Lyytinen & Sørensen, 2010	93
9	Dosi, 1982	4	Anderson & Tushman, 1990	11	Chesbrough, 2003	90
10	Teece, Pisano & Shuen, 1997	4	Leonard-Barton, 1992	11	Teece, Pisano & Shuen, 1997	88
11	Bass, 1969	4	Katz & Shapiro, 1985	11	Tiwana, Konsynski & Bush, 2010	82
12	Eisenhardt, 1989	3	Tripsas & Gavetti, 2000*	10	Barney, 1991	79
13	Curley & Gremillion, 1983	3	Shapiro, Varian & Becker, 1999	10	Nambisan, 2017*	79
14	William, 1978	3	Porter, 2001	10	Teece, 2007	77
15	Davis, 1989	3	Eisenhardt, 1989	10	Parker, Van Alstyne & Choudary, 2016	75
16	Porter, 1985	3	Nelson & Winter, 1982	10	Vargo & Lusch, 2004	70
17	Teece, 1986	3	Christensen & Bower, 1996	9	Osterwalder & Pigneur, 2010	70
18	Barney, 1991	3	Teece, Pisano & Shuen, 1997	9	Zott, Amit & Massa, 2011	69
19	Clark & Fujimoto, 1991	3	Chesbrough, 2003	9	Lusch & Nambisan, 2015	68
20	Evans & Wurster, 1997	3	Davis, 1989	9	Amit & Zott, 2001	67

Paper's list (authors/year) that were most used as key-reference by the 2513 papers in the DI field in each period. Key-reference is measured by the frequency with which two papers are cited together by other papers (Co-cited), representing the most important and influent papers used by each period.
* Papers that also appear as the most cited (table 4) in each period.

4. Co-citation network 1987–2002

The first-cycle co-citation network (Figure 1) is characterized by authors with relatively few relationships of co-citation (size) and ego networks with only a few links, so the isolated authors only co-cited with each other, and the co-citation chains (e.g., co-citation strings with no significant crosslinks) are likely to occur many times in this period, implying a smaller concentration or interrelated search field (Gmür 2003). Because of isolated authors the links are irrelevant according to the requirements for the formation of clusters and are eliminated.

In the co-citation maps of the three periods, the relative size of the nodes indicates the central role of each author, increasing consistent with the number of other authors who are co-cited with the author in question. A large node indicates that the author's works play an important role for the topical orientation of the cluster. Thus, the node often serves as a beginning for the detection of thematic points in focus by the cluster and that can be better analyzed together with the basic references of the other cluster's authors. The lines between authors represent the co-citation relationships, based on the CoCit score. The thicker lines indicate higher CoCit scores, which means a closer relationship between the cited co-authors (Rossetto et al, 2018).

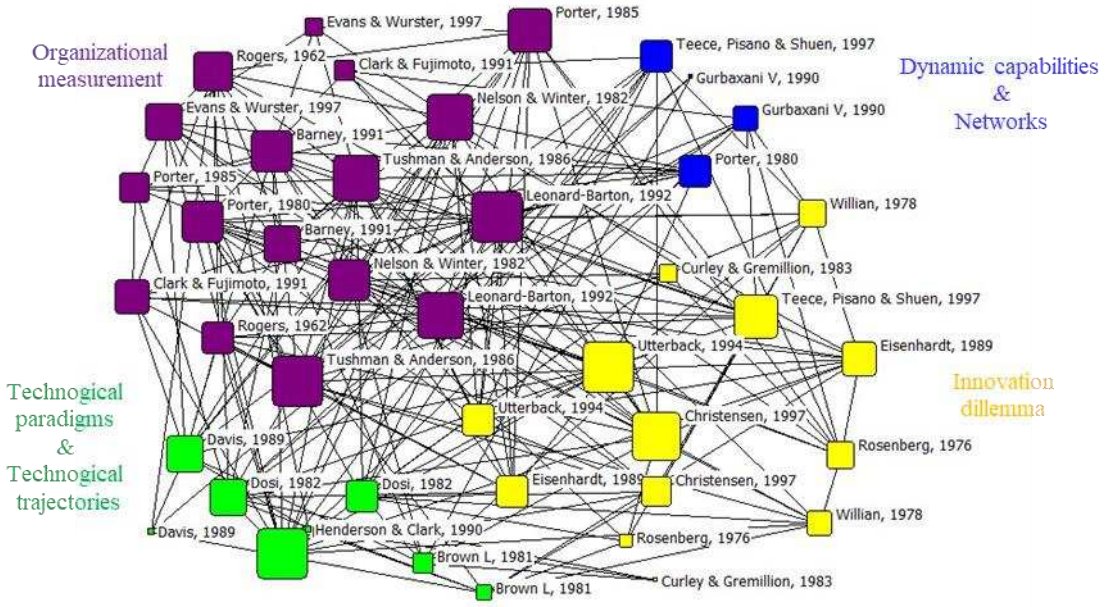

Figure 1. Authors' co-citation networks 1987–2002

The first network of co-citations comprises 26 most co-cited authors of the period, which is the one with the fewest authors among all the periods. It consists of four clusters fully connected. Group 1 and 2 are larger in size than the others, with 8 and 6 authors. It has a low density and topics like: Organizational measurement (i.e., productivity, performance, and capabilities) and technological dilemmas that embrace innovators (i.e., strategic decisions, perspectives on technologies and dynamic of innovation). The size of the cluster and the finding that all central authors also appear among the twenty most cited publications in this period (Table 4) reflects the great importance of this sub-theme for researchers in DI from 1987 to 2002. Group 3 is somewhat smaller than group 1 and 2, having 4 authors of the 21 displayed on the network. Its focus is technological paradigms and technological trajectories. Its main representatives are Dosi (1982), Davis (1989) and Henderson & Clark (1990). In group 4, the only three authors (Teece, Pisano & Shuen;

1997; Gurbaxani, 1990 and Porter, 1980) have as central theme the dynamic capabilities and networks diffusion to enhance competitive advantages.

4.1 Co-citation network 2003-2011

In the second period, compared with the previous network, there are more authors and clusters (Figure 2), in line with the general growth of research activities in DI in the first decade of 2000's. With a larger and differentiated network, the network of co-citations corresponds to 33 authors, distributed in 5 clusters. The four groups formed from the previous network change considerably and now the clusters have different directions. Despite the transition of some authors between the groups (Porter, 1980; Teece, Pisano & Shuen, 1997; Barney, 1991, Christensen, 1997), the changes reflect the research efforts in the publications made during the period, showing that the bases that would constitute the foundations were still incipient.

One huge factor emerged with some dynamics of innovation which will sustain aspects of DI. This cluster is a combination of the four-cluster found in the first period where strategic decision of product innovation (Eisenhardt, 1989), capabilities (Tripsas & Gavetti, 2000; Eisenhardt & Martin, 2000), absorptive capacity (Cohen & Levinthal, 1990) and Organizational exploration and exploitation (March, 1991) start to boost in the literature.

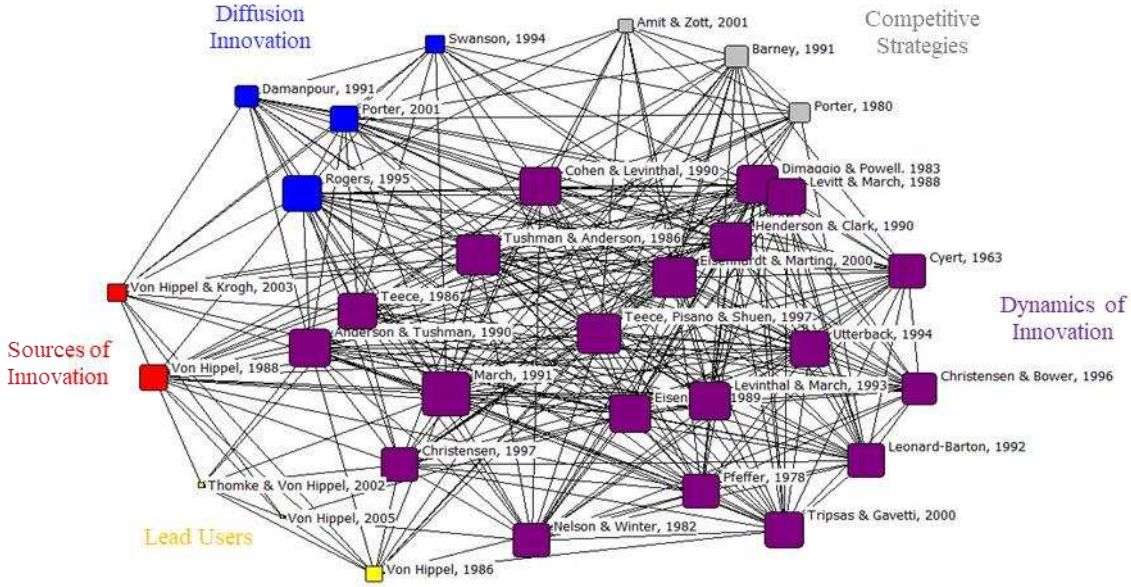

Figure 2. Authors' co-citation networks 2003–2011

Although, sources of innovation were highlight by Von Hippel (2005) to understand open-source software development, democratizing innovation. Information systems have become the main approach to create value (Amit & Zott, 2001) and avoid organizational inertia (Damanpour, 1991). A dynamic model of strategic change (Porter, 2001) emerged among organizations due to a new dynamism in the market with the raise of new technologies (Von Hippel & Von Krogh, 2003; Anderson & Tushman,1990). Notwithstanding, some themes or fields of investigation were initiated by certain authors, and the authors´ change among the clusters potentially suggest that newer research findings and themes have been developed by younger researchers, who have replaced the previous dominant authors.

4.2 Co-citation network 2012–2020

The co-citation network shown in Figure 3 is significantly larger, with 81 authors, many of whom did not appear on the maps of previous periods. The topical structure of the period in focus changed considerably, because of many new researchers who emerged in the scientific research scenario. It is assumed that many of them needed to deal with new paths of DI in process of formation at the time which increasing the number of clusters from 5 to 7 and the thematic complexity.

The cluster 'Diffusion innovation' and 'Digital transformation' reunited two authors who directed their research to investigate open collaboration that accelerates innovation using online communities (Berman, 2012) and to explain the main elements in the diffusion of innovations model, and to apply them to the case of the diffusion of new telecommunications technologies (Rogers, 1995).

In 'Open Innovation' cluster, the authors discuss themes related to process of externally innovation through sourcing integrated and ultimately commercialized, i.e., a central part of the innovation process concerns the way firms go about organizing search for new commercial potential ideas. Many innovative firms have changed the way they search for new ideas, adopting open search strategies including a wide range of external actors and sources to achieve and sustain innovation (Laursen & Salter, 2006; West & Bogers, 2014).

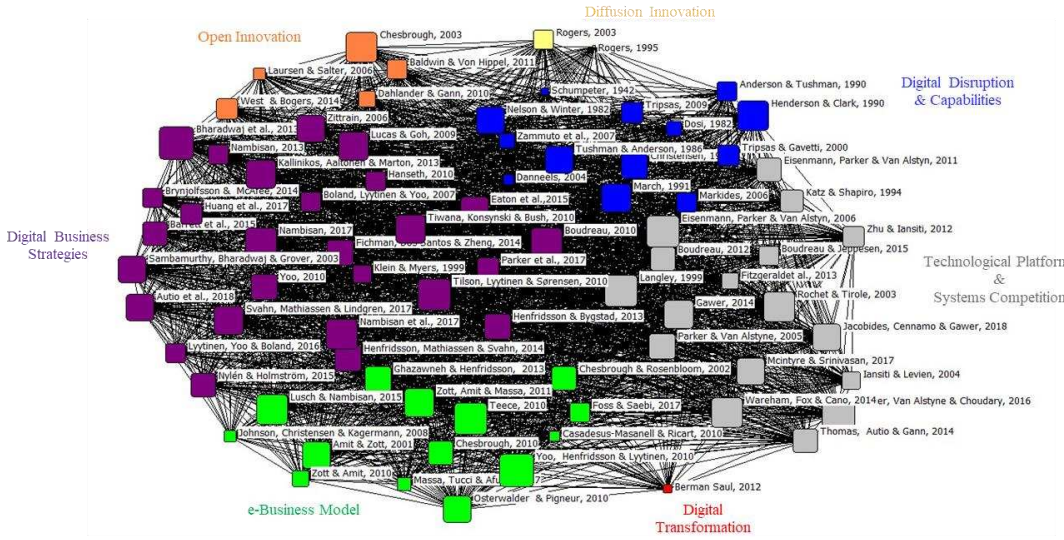

Figure 3. Authors' co-citation networks 2012–2020

'Digital Business Strategies' cluster is dedicated to research the business infrastructure becoming digital with increased interconnections among products, processes, and services. Many firms spanning different industries and sectors and digital technologies are fundamentally transforming business strategies, business processes, firm capabilities, products and services, and key interfirm relationships in extended business networks. Some embraced in this cluster are (1) scope of digital business strategy, (2) scale of digital business strategy, (3) speed of digital business strategy, (4) the sources of business value creation and capture in digital business strategy, (5) user experience (6) digital evolution scanning and (7) skills and improvisation (Bharadwaj et al., 2013; Fitzgerald et al., 2013; Fichman, Dos Santos & Zheng, 2014; Nylén & Holmström, 2015).

The clusters 'Technological platforms & Systems competition' reveal thoroughly the structure of the knowledge that was developed and the topics of greater relevance for the researchers in how developers might cause a shift in organizational form. Authors provided theories in how firms optimize their own intellectual property regimes and

relational networks through platforms to maximize organizational growth. Some models allowed the different platform types to be placed into context with others and outline how the concept of architectural leverage can be used to understand platforms and systems evolution (Thomas, Autio & Gann, 2014; Eisenmann, Parker, & Van Alstyne, 2011; Parker & Van Alstyne, 2005).

'Digital Disruption and Capabilities' cluster bring works that explores foundations of theories of disruption and the revolutionary change the way of doing business. They highlight technological breakthrough, or discontinuity initiating an era of intense technical variation and selection. This era of new technologies is explored and followed by a period of incremental technical progress, which may be broken by a subsequent technological discontinuity and that affects existing competences demanding new capabilities account for the majority of observed technical progress (Markides, 2006; Tripsas & Gavetti, 2000; Christensen, 1997; Anderson & Tushman, 1990).

And 'e-business model' cluster explores the barriers to business model innovation, including conflicts with existing assets and business models. Some examples of business model innovation were provided to underline its importance, in hopes of inspiring managers and academics to take DI challenges on (Chesbrough, 2010; Massa, Tucci & Afuah, 2017; Zott, Amit & Massa, 2011).

The key results for this last network include the increase in the number of links between the research sub-areas and the emergence of many authors. Only a set of researchers have been able to appear on the maps over time, indicating the relevance and consistency of the research fields where they work (Chesbrough, 2003; Nelson & Winter, 1982; Anderson & Tushman, 1990). The discontinuity of the themes and clusters indicate a variation in the topical orientation and composition of clusters, which may indicate a highly dynamism of the research which shows consistency with the results of the citation analysis. Finally, this method of analysis revealing the growing influence of the network approach for the analysis of citations and co-citations, indicating the importance of social network analysis for a better understanding of science and the advance of knowledge, as in the case of DI.

4. Conclusion

Some studies have already been carried out to investigate the state and evolution of innovation, but none focused on DI in management field, associating the use of social network analysis methodology, and did so with such a wide range or volume of data as performed by the present study. Moreover, with this study, we have contributed to complement some previous studies (e.g., Cancino et al. 2017; Merigó et al. 2016; Shafique 2013; Rossetto et al., 2018) providing a wide range of analysis with a good volume of data. To reinforce the studies and to evaluate the intellectual structure of this field from a different perspective, this article used bibliometric methods and techniques for the first time in this field of research, associating bibliometrics with social network analysis, carrying out a longitudinal study with a thirty-two-year span of publications.

Regarding the first research question, the results of the citation analysis reveal a framework in DI characterized by a continuous and accelerated growth in the number of publications and authors mentioned, especially in the third period analyzed, revealing the great openness and potential of new publications. However, citations tend to decrease as the differentiation of themes that make up DI advances, appearing in new research fields, becoming universally accepted (Rossetto et al., 2018; Ramos-Rodríguez & Ruíz-Navarro 2004). The increasing maturity of the references occurs precisely because of the dynamism since the most cited articles in the last period. The same with the average age,

that the references have in the three-period indicating the tendency of the recent research in resorting to the classic publications with average age equal or superior to 2 years after published. The analysis of citations carried out and presented by the maps of each period was summarized in Figure 4, which indicates the evolution of DI after tracing and comparing different factors detected. The size of the labels represents the size of the clusters in the co-citation networks.

Thus, two main conclusions emerge: first, the increasing interaction of DI subfields over time suggests a convergence of subfields within the core of DI, resulting in the creation of a common knowledge base. Isolated approaches, therefore, have been increasingly replaced by jointly developed research projects. Joint efforts to develop research towards in the core factors could allow the joint application of different schools answering future research questions. Second, DI is completely new under theoretical perspectives, however we assume an important role for future research which is organize subfields that could facilitate the evolution of DI; therefore, we propose to follow a structure of delineating subfields for DI such as, (1) digital strategy, (2) e-business models, (3) Tech platforms and systems; (4) digital transformation towards new tech generations.

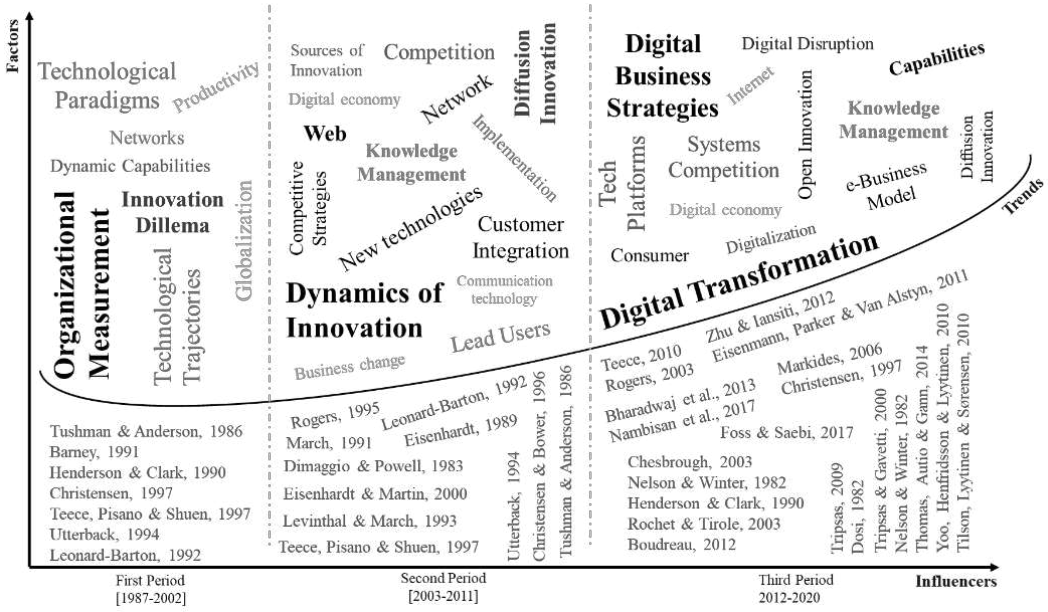

Figure 4. Summary of DI evolution

5. Limitations and Directions for future studies

Concerning the dataset, the main disadvantage is the multi-authorship, since the databases only contain the data of the first author of the articles referenced by each publication available in the database. Even if all the authors were available, the volume of data to be treated and analyzed considering all the authors in question would require computational resources that would render such resources unviable. Despite the analysis, filtering, corrections, and normalizations performed in the databases, there is always the possibility of failures, mainly due to errors in spelling, incoherence, homonyms, that is, different authors with the same name (Smith, 1981). The data collection was carried out covering all articles within the indicated parameters until January 12, 2021, which indicates that the most recent articles published certainly did not have enough time to be cited and appear in the networks of citations and co-citations.

New methods of DI research, and how these methods may contribute to the field could be exploited, helping to highlight new avenues for future studies. We stand out the

relevance to develop studies to able to help understand how new methodologies such as big data, artificial intelligence, machine learning, statistical modeling, Bayesian networks, experiments, among others, are changing these emerging themes in DI research. We also believe to provide findings able to help future research, managers, and practitioners to understand the theoretical basis of DI research in the business context and how its pillars are sustained. Futures studies could exploit those clusters presented in Figure 4, deepening the comprehension of the themes, authors, and their relationships.

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