Big Data as a Stakeholder of the Firm's Innovation Process

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Abstract **- Firms have effectively utilized big data to foster innovation and improve efficiency across various business processes. Among these processes, the innovation process stands out due to its significant impact on a firm's overall performance. Given its heavy reliance on data, the innovation process is greatly influenced by advancements in emerging technologies, particularly big data. This study aims to explore the influence of big data on a firm's innovation process and how it is integrated into each step to fulfill its requirements. To comprehensively understand this multidisciplinary subject, we employ a combined approach of bibliometric analysis and systematic analysis of existing scientific literature. By systematically analysing selected 59 studies, we have identified the primary areas where big data is utilized during the ideation phase, idea selection, product development, testing, and validation phases, as well as commercialization and continuous innovation.**

Keywords **– innovation process, big data, innovation management, technology management, bibliometric analysis.**

1. Introduction

While the amount of publications on big data (BD) as a means of innovation continues to grow [1], it is imperative to examine the changes that occur in the innovation process' nature and its steps as a consequence of the inclusion of big data in its development and application.

DOI: 10.18421/TEM122-50
https://doi.org/10.18421/TEM122-50

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Received: 05 November 2022.
Revised: 12 February 2023.
Accepted: 14 April 2023.
Published: 29 May 2023.

The urgency comes from that BD has become a component of the process and such a significant change is considered essential for knowledge management within enterprises [2]. The pressing need for research on the curves and transformation of the innovation process arises from its substantial influence on the overall innovations it generates [3]. As a primary systematic approach to innovation across teams, organizations, and industries, the innovation process has garnered increased attention, particularly regarding the technologies driving its digital transformation [4]. Numerous studies have presented findings regarding the extent and impact of big data (BD) utilization in enhancing firm performance [5] but still, insights on the BD usage in innovation management and more precisely in each of the innovation process' steps are missing. Besides, some comprehensive research has already revealed the role of BD in user, open and collaborative innovation as well as in co-innovation [6], service innovation [7], and new product development [8]. Still, most of the literature argues that the general collision of BD is on innovation performance [9], but how the innovation pattern changes has not yet been explored from the perspective of the innovation process. This study contributes to the BD's potential in the innovation process and its role as a significant stakeholder within it.

Within organizations, the innovation process typically holds a critical position as a vital business process that directly impacts the profitability of the firm [10]. Innovation is frequently regarded as the most significant result of business processes and is pivotal for driving the performance of the firm. [11]. Unlike most of the business processes which impact vertical firms' activities, the innovation process is often assumed to be a horizontal one, influencing the whole organization and being impacted by all firm's elements, structure, capabilities, resources, and culture [12]. This places the internal innovation process at the core, not only of a firm's innovation capabilities but also, more broadly, of the entire firm's capacity to operate successfully.

Big data incorporation enhancing for firm's innovation process is inevitable, especially after the results about the positive effects of BD on the creativity of employees by Danmmak, Dkhil, Cherifi, [13] and the overall impact on the company performance and decision-making [14].

However, the literature still does not provide a clear picture of the successful implementation of BD within the innovation process.

As an area of research with significant potential, demonstrated by the growing number of studies on the subject, including the use of BD in the business processes of firms to enhance their quality and outcomes, this study also seeks to identify avenues for future research. According to Sheng, Amankwah-Amoah, and Wang [15], BD in business processes on the one hand, and BD in innovation management on another, is an emerging research area that involves and suggests multi-disciplinary expertise and knowledge. Bibliometric analysis is amongst the preferable methods to analyze cross-discipline, newly emerging, or quickly changing research spheres with the potential of impacting diverse areas [16] in our case – a firm's innovation process and how big data technology is influencing it. We adopted a bibliometric method and a systematic literature review to address our research questions:

(1) What is the current understanding and evidence for the use of BD in the firm's innovation process?

(2) What are the insights in the literature that do call for a future research program on the use of BD as an ingredient or tool in the innovation process?

The structure of the study follows this sequence: the first section provides a theoretical background on the two major domains from a managerial point of view: the firm's innovation process and BD in the firm innovation process. The second section presents the methods deployed for addressing the research questions, and then the third section introduces the results from the bibliometric analysis. In the last component of the article, the research questions and answers that emerged from our study are discussed. As a result, we provide scholars and practitioners with the full picture of the current state-of-art on BD use as part of the firm's innovation process and we identify some promising agendas for further research mostly in the context of the firm's innovation process.

2. Theoretical background

This study addresses the under-researched current use of BD as part of the firm's innovation process in a comprehensive and high-level plan so all potential stakeholders and future adopters of such a project are going to be able to take advantage of already used cases and researchers to identify some gaps for further research.

2.1. Firm's innovation process

The firm's innovation process (FIP) has been a vital point since the 1950s and has been still amongst the hottest sub-topics in management science.

The innovation process is a sequence of activities covering the development and commercialization of innovative outcomes from organizations to the audience/market or for internal needs.

Its progress and development have crossed different phases starting from more general and industry-based theories to more-internal-to firms models [17].

Lately, FIP has been more and more connected to more open and networking concepts such as Open Innovation [18], User Innovation [19], Lean Startup framework [20], chain-linked models [21], the Information assurance of innovation process [17], Innovation process based on continuous improvement [22], etc. with diverse kinds of extensions and customizations. Opening the innovation process not only towards different stakeholders but also to different concepts [23] incl. including emerging technologies such as artificial intelligence [24], technology acceptance models or BD [25] have clearly defined benefits in several case studies within the scientific literature. Nowadays, FIP is not the subject of constant research, although many new modern techniques and digital tools have recently been adopted and applied to create innovation processes and they are changing the innovation process itself [26]. A reason for this focus no matter the significance of FIP is its complexity and specificity in industry and leadership style [27]. Nevertheless, one of the crucial elements of FIP is still the same everywhere - gathering and transmitting information to several internal and external information areas, both within and outside of the organization, also called innovation systems [28]. BD provides a huge amount of data, incl. internal and external to the firm that may benefit the organizational innovation process [29]. BD use in the innovation process as a managerial approach influencing the process for developing not only technological innovations directly related to BD, but any kind of products or processes is still under-researched, which motivates this article.

2.2. Big data in innovation management and innovation process

Innovation management is widely recognized as a comprehensive and overarching scientific discipline that focuses on managing innovation within organizations. The innovation management and specifically firm's innovation process theories contain numerous sub-streams that are generally clustered into different themes and directions for research and practice. In this section, we will explore various sub streams of theories that have been previously discussed and researched in the context of big data (BD) within the firm's innovation process (FIP).

These include the utilization of BD, data analytics, decision-making supported by big data, leveraging big data for generating users' ideas, and employing big data to facilitate innovation commercialization, among others.

The digital transformation of firms and industrial sectors necessitates the incorporation of novel modes of human-machine collaboration, emphasizing the growing importance and utilization of big data (BD). This includes the adoption of cognitive systems to enhance decision-making processes and drive innovation [30]. According to Trabucchi and Buganza [31], academia continually offers diverse strategies and methods to assist firms in harnessing and comprehending the inherent benefits of their data. This enables them to enhance innovation, improve efficiency, and ultimately enhance profitability. A more efficient and out-of-the-box, use of existing and new information/data as well as their better assimilation are essential in organizing learning about FIP [2]. Furthermore, big data benefits not only the innovation process but also firm productivity in general [32].

3. Methods and Data

The research design of the study encompasses a bibliometric analysis and a systematic literature review in order to observe the topic from different angles and depths. We adopted different methods to address the three stated at the beginning of the study research questions, presented in table 1.

Table 1. Methods addressing the research questions in the study

	Methods
RQ 1	Bibliometric analysis for scoping the research done and pointing out the major research evidence of BD use
RQ 2	Systematic literature review and elicitation of the insights provided in the latest years that would be promising as a call for a future research

3.1. Sample and data collection

The data selection in this research relied on scientific literature retrieved from the Scopus database because it provides consistent and high quality research information as well as it can be used as a sole data source (Meho and Rogers, 2008), especially in the field of Technology and Innovation Management. The generated dataset allows us in performing citation and content analyses as well as mapping the current state of the art of the analyzed problem. A Boolean search has been performed with this formula:

TITLE-ABS-KEY ("innovation process" AND "big data") – Scopus

A total number of 59 publications from 51 sources resulted from the search with average citations per document amounting to 8.831. The research piece types are provided in Table 2.

Table 2. Publications' type addressing Big Data use in the firm's innovation process

DOCUMENT TYPES	Number of publications
article	26
book chapter	3
conference paper	21
conference review	4
note	1
review	4

A total number of 59 scientific publications were written by 163 scientists and only 12 of them are single-author (further arguing the multidisciplinary of the participating topics). The year of publications, without applying any restrictions on demand, starts in 2013 and is until 2021 (the search takes place in March 2021). The total citations of these 59 documents are 125. Fig. 1 presents the trend of yearly publications on the matters (the decrease in 2021 number of publications is due to exporting publications for 2021 in March).

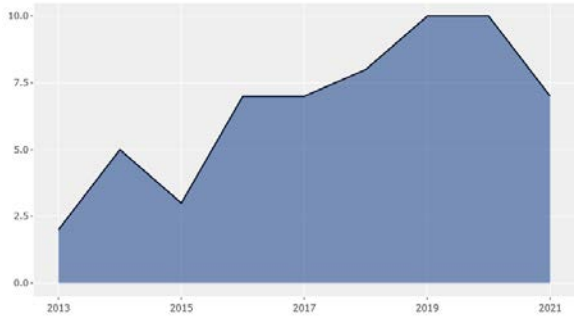

Figure 1. Scientific production in BD as part of the innovation process (following the inclusion criteria)

The diverse nature and objectives of the research within the scope motivate bibliometric analysis, as this method is usually applied in not fully covered scientific fields.

3.2. Bibliometric analysis

Bibliometric analysis was first established by Pritchard [33] and currently is amongst the most efficient scientific methods for understanding a research field's historical (incl. chronicled, documented, factual) evolution from a multi- and inter-disciplinary perspective [34], [35].

Bibliometric analysis facilitates and opens doors to a comprehensive perception of research areas and a mapping of its boundaries and issues, incl. catching knowledge gaps, and clusters of research already happened.

Simply, it delivers fast agenda and calls for further research [36]. The technology and Innovation Management scientific field recognizes this method and extensively uses it for multidisciplinary research [37] because of its efficiency in identifying emerging research [38] and comprehensively covering the research status of a particular research domain and forecasting future research agenda [39]. Consequently, this study targets outcomes revealing BD employed in the innovation process by applying bibliometric analysis following best practices of its current exploitation.

Our approach is similar to that of Khanra et al. [35], who used bibliometric analyses to identify the intellectual structure of, gaps within, and future research directions in big data analytics and enterprise research. As demonstrated by prior bibliometric studies, each of these techniques has inherent strengths as well as weaknesses that can be addressed by their concurrent application to a problem [40], [35], [36].

In this study, we adopted the following bibliometric analysis targeting answers of the formulated RQs:

- Wave analysis (countries, sources, keywords, journal labeling)
- Citation analysis
- Co-word analysis
- Keywords analysis
- Influential Authors
- Top-tier Journals
- A strategic thematic map
- Density and Centrality of Topics

R software, and specifically its package Biblioshiny, was used for bibliometric analysis.

3.3. Systematic literature review design – BD the innovation process

We performed a standard systematic literature review following Tranfield et al. [41]. The reasons for choosing this method were to contribute more deeply to the bibliometric analysis and to go through each of the scoped articles to reveal and analyze the current research done. We did the systematic literature review based on the data selection, which we already used for the bibliometric analysis ensuring the consistency of the research methods and the generated results, discussion, and conclusion from it. Each of the included scientific articles and papers was reviewed for their relevance to the explored topic and to the targeted research questions.

We did the systematic review by going through all the titles and abstracts and when necessary through the whole articles/papers (in 50% of the cases) in order to verify their connection and importance to our research.

We apply the following exclusion criteria to the data set selection explained above:

- We removed the conference review pieces
- We extract from the “golden source” non-relevant articles and papers which are not referred to the use of BD in the innovation process (these were mostly cases when BD had been used as a method for achieving the research purposes rather than involvement in the innovation process per se [42] or as a means for reaching BD innovation [43].

We decided not to exclude conference papers from the scope as most of the respected systematic literature review articles did, because of the newness of the topic and the assumption after reading some of the conference papers that they provide valuable insights for future work and are based on important experiments which all should be included in our full picture on the theme.

As a second step, we labeled each article/paper for its major findings and the industries to which each of this scientific research was applied. In the results part we focus on the most relevant articles concerning the topic and the performed analysis and in the discussion part, we address directly our research questions.

4. Results

In this section, we present the findings of bibliometric analysis as well as a systematic literature review to provide a comprehensive picture of the theme of using BD in a firm's innovation process. The discussion and resolution of the research questions will take place in the section that follows this one.

Bibliometric analysis was performed by the use of the statistical open source software R, its package Bibliometrix in particular, and Biblioshiny as a user interface. For the purposes of using the tool efficiently, the full set of data from scientific publications in scope was uploaded to the software (all available meta-data from Scopus advanced search). As we are researching a topic that has not currently had a clear and finalized scope and still is evolving, no limitations have been set as exclusion criteria. We also followed the PRISMA statement's best practices for reporting systematic reviews and meta-analyses [44]. First, the analysis aimed at comprising the main keywords used by researchers when they studied BD in the innovation processes.

These words are presented in Figure 2 and are based on the author keywords of the papers in scope.

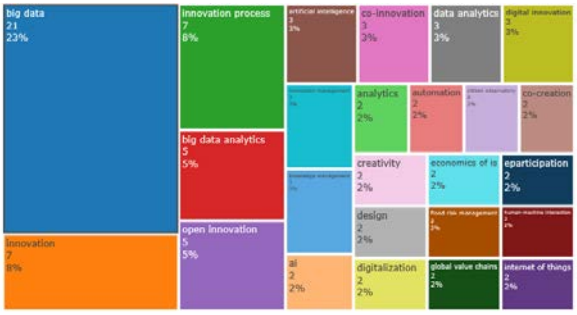

Figure 2. Tree of author keywords in science publications for Big Data within the firm's innovation process

The insights provided in Fig. 2 are valuable for mapping the current research to the future expectations of developing the knowledge of the innovation process. Now, the current literature reveals awareness mostly about the big data and innovation involved, secondary topics are BD analytics, open innovation, and innovation process. Less research interest for the moment has been focused on topics such as artificial intelligence in the innovation process, digitalization, creativity, analytics, co-innovation, co-creation, the internet of things, global value chain, automation, and digital innovation. Nevertheless, a few researchers have already studied these topics, which might be used as cornerstones for further investigations.

Figure 3 sheds light on the basics of the researched topic by showing the wave streams of keywords (author keywords and journal keywords given by journals) and their relation to the country of origin of the respective study.

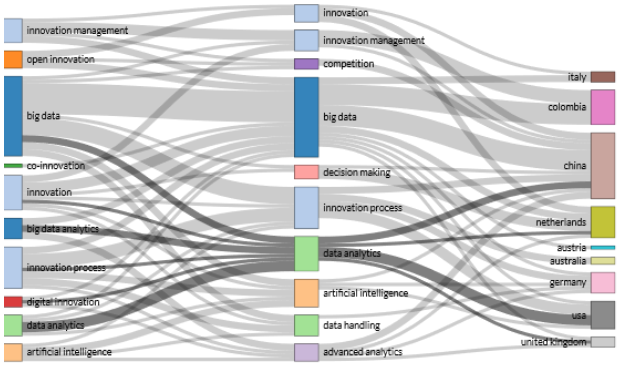

Figure 3. Three analysis based on keywords, keywords plus; and country (top 10 indicators)

Figure 3 provides awareness of the main journal keywords associated with studies related to BD usage in the innovation process and these are innovation, innovation management, competition, big data, decision-making, innovation process, data analytics, artificial intelligence, data handling (management), and advanced analytics. The centrally positioned keywords are those given by the authors.

Figure 4 below brings forth the main contributors to the researched topic by indicating the main authors and journals and proceedings publishing articles/papers on the matters. The Figure 3 also yields the major focus of authors and sources by associating them to the main keywords used.

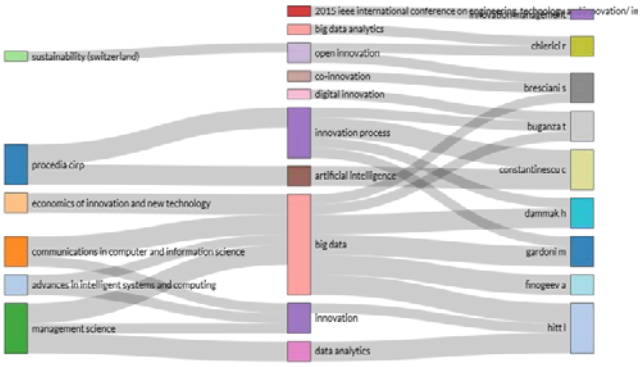

Figure 4. Three analyses based on sources; keywords and authors (top 10 indicators)

Table 3 commits to outline information for the most relevant sources published research on BD use in the innovation process (fitting to the Boolean search in the Scopus database).

Table 1. Most relevant sources publishing research on both Big Data and Innovation Processes

Source (journal or conference proceeding)	Number of publications	SJR (Q)
PROCEDIA CIRP	3	0,73
ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING	2	0,18 | Q3
COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE	2	0,19 |Q3
CREATIVITY AND INNOVATION MANAGEMENT	2	0,97 |Q1
ECONOMICS OF INNOVATION AND NEW TECHNOLOGY	2	0,92 |Q1
MANAGEMENT SCIENCE	2	5,44 |Q1
SUSTAINABILITY (SWITZERLAND)	2	0,58 |Q2

Figure 5 shows up the keywords of the sources used in the bibliometric analysis. The purpose of performing a co-occurrence network diagram is to give a reason to cover later in the discussion section of the article on fact for having so many distant and unattached keywords. This observation gives a taste of under-exploration of the theme since most of the research done is still on too scattered topics.

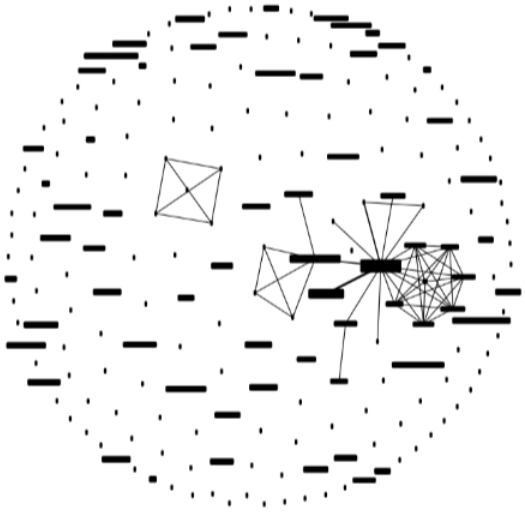

Figure 5. Co-occurrence Network of author keywords, Kamada & Kawai network layout, normalization with the association;

In order to analyze the evolvement of the topic of BD in FIP, no matter of the novelty of the topic we also applied a thematic mapping [45], [46] that distinguished four different typologies of themes as shown in Figure 5. Motor themes (higher right angle) are those that are relatively well developed in the literature, they are characterized by high centrality and density. Basic themes (low and right on the scatter) reveal topics with high centrality and low density. They are significant for future research so to map the thematic field, which is yet under-researched in the literature. Niche themes (high and left) are extremely specialized themes, but marginal as part of the overall field. Emerging themes (low and left) include both emerging and declining themes, are characterized by low density (under-researched) and centrality (marginal), and primarily represent emergent or disappearing themes. We did the thematic mapping for publications until 2018 and after in order to reveal the most prominent and up-to-date topics for further research agenda.

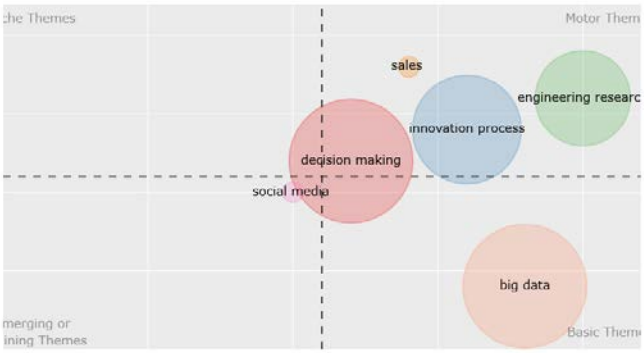

Figure 6. Thematic map based on Journal Keywords until 2018

From Fig. 6 we can clearly observe that the big data topic is still underdeveloped in the field of the innovation process and innovation management (being highly centrally on the topic and with a low-density index). The decision-making and innovation process is well researched even though it may be because of the data set, which focuses purposefully on the innovation process. However, social media is also a topic of interest. The most critical surveillance is that Niche and Emerging themes are missing which indirectly gave us the opportunity to suggest that the whole topic is immensely under-researched, especially in terms of guidance for further research agenda. After all, there are some changes in the thematic mapping in the last two years, and Figure 7 which gives insights into the swaps that have taken place.

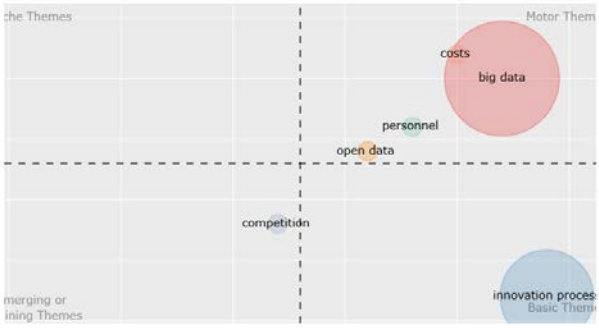

Figure 7. Thematic map based on Journal Keywords after 2018

In the very latest research after 2018, (keywords mapped by journals since we used Journal Keywords instead of Author Keywords for this analysis) innovation process was less researched but purposefully. A few new keywords appear such as competition, cost, open data, and personnel. Big data is proving its prominent and influential role in the innovation process and increases its density within the latest research. We performed also a similar analysis with Author Keywords, which revealed research in the direction of using artificial intelligence and big data analytics, which surely are part of the course of evolving the innovation process utilizing emerging technologies.

5. Discussion: current state of the art and agenda for further research

We identified in the literature a total number of 59 pieces of scientific evidence exploring both topics' entanglement and after systematically reviewing them (following our inclusion criteria), we performed a systematic literature review on 43 articles and conference papers (following our exclusion criteria).

16 science contributions have been excluded because of discrepancy in the focus (they were either not focused on the firm's innovation process, or BD was used only as a means for achieving the research goals and not directly explored as a technology shifting and curving the innovation process). Their contributions are reviewed in this section in order to present the full picture and open the room for discussions on the topic with the most relevant and close to the center of the problematic sub-topics.

Big data for idea generation

The Center for Creativity and Innovation Studies' Creative Concerto Platform [47] has used BD in the idea generation process to help organizations leverage the power of crowdsourcing ideas. It is also a tech approach in deploying open innovation strategy for organizations by motivating broad brainstorming with external actors. Analytical modules that narrow the ideas into concepts support BD. BD and data analytics have been also used in the context of generated content from social media and this content is used in the innovation process and the decision-making in organizations [47]. By analyzing historical data patterns on ideas development, waste can be reduced and funds can be diverted to ideas that are more likely than others to succeed [48].

Big data for selecting innovative ideas

Business intelligence tools have been identified as means for assessing and selecting ideas and business opportunities [49]. Analytical tools have also been recognized as instruments for selecting the right features of further developing innovations [50].

Big data for new product development

BD along with machine learning and data analytics have all impacted positively product design, especially in the fuzzy front end of the innovation process [51]. Primary factors that enable innovation development in data-rich environments are considered to be pattern spotting, real-time decisions, and synergistic exploration that impact product development through all the sup-phases [52].

Big data for testing and validation

Validation of the innovation development progress, in contrast to a traditional project management progress, is a niche for BD application. BD may be extremely useful in assessing and validating the innovative product/service impact over the process of its development and continually improving its impact is consistent and still beneficial for the developer [48]. BD and some close concepts such as machine learning are highly applicable for testing purposes using term-based clustering [26].

Big data for commercialization and continuous innovation

In the post-development phase of the innovation process, market commercialization could also be impacted by BD. Evidence was given by Niebel, Rasel & Viete [53] who elaborated that BD may support the market success of product innovations. BD was used also for fast-tracking relevant market information from customers [54], their behavior, and changing habits as part of the continuous innovation process.

6. Conclusion

This study attempts to provide a synthesized and comprehensive picture of BD utilization in FIP. It is not surprising that most of the studies in the scope of this research are from the last three years: 2018-2020. The ability of firms to employ BD and technological advancements in general as well as to integrate these into their managerial processes and innovation development is amongst the emerging research directions of the Technology and Innovation Management science field. The study provides many insights on the possible integration of BD in the firm's innovation process for achieving diverse purposes such as creativity management of employees, market and customer feedback analytics, open and user innovation through systematic interaction, and BD, measuring and assessing innovation efforts.

A summary of the findings in response to the research questions led us to the conclusion that the possibility of integrating Big Data into the firm's innovation process is still a highly underdeveloped managerial theme. The literature has yet to address many elements, steps, and functions of the innovation process. All reviewed research is mapped to the corresponding phase of the firm's innovation process. The big data process-based approach [55] for innovation management is still far from being adopted by enterprises. The study revealed some knowledge gaps and calls for further research topics such as customer data utilization in the innovation process; market data for commercialization of innovations; involvement of non-R&D employees in the innovation process through big data means, selection of ideas with open data, opportunities for collaboration with external stakeholders for innovation development and management, measuring and assessing innovations as part of the development process. This study could serve as a springboard for future research on the integration of Big Data into the firm's innovation process. It contributes also to the nature of adaptive learning around new technology in organizations [56] from the prism of Big Data technology [57].

RQ 1: The current state of the art and evidence for the use of BG in FIP reveals underdeveloped research streams with little evidence of BD use in all phases of the innovation process. However, the following processes and functions have been addressed in the literature: creativity management; open innovation and co-innovation practices; assessment and measurement through big data analytics; and using customer data in the commercialization and post-commercialization phases.

RQ 2: Many insights in the literature call for a future research program on the use of big data as an ingredient or tool in the innovation process specifically in the fields of decision-making in the innovation process, user innovation, involving non-R&D employees in the innovation process, development of innovations with incorporated BD metrics and constant market feedback.

The main theoretical knowledge areas on which the scoped studies were based were co-innovation, service innovation, innovation process, product innovation, and process innovation.

Limitations in the study keep away all functions within the innovation process for which BD might be also used such as decision-making, group decision management, digital transformation, etc. since the pillar of the research is the innovation process and its steps. The study limits some potential scope creep toward BD concepts such as data analytics, machine learning, and data-rich environment, but still focused the results and the discussion on pure BD use within the phases of a Cooper stage-gate innovation process with which it contributes mostly to the further development of exploration of BD application for organizing innovation in enterprises.

Acknowledgments

This work was financially supported by the UNWE Research Programme.

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