EVOLUTION OF TRENDS IN INNOVATION STUDIES

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Purpose: The study has two primary goals: the first is to identify trends and their dynamics in innovation research, while the second is to show the original methods of systematic literature review based on text mining tools with the aim of detecting trends in research papers.

Design/methodology/approach: The authors offer an approach that enriches the toolset of classical systematic literature review methods. Analysis was focused on the full texts of papers published in selected subject areas. Categories were discovered automatically in data rather than being pre-defined. The quantitative approach to text-mining that has been successfully tried and tested in multiple studies was supplemented with original tools created by the research team. This approach allowed authors to identify categories and trends within innovation research. The approach applied is consistent with general rules for systematic literature reviews.

Findings: The outcome of this study was the identification of 16 trends, including 5 long-lasting (e.g. new product development and knowledge sharing and management) and 8 emerging trends (e.g. strategic foresight, sustainable application and leadership).

Research limitations/implications: Two limitations of this study were identified – one is related to the number of papers and cluster size. The study was restricted to the years 2000-2020 and 19 top tier journals dedicated to the field of management and innovation research based on the appearance in the rankings and search of journals dedicated to innovation. The issues of innovation have of course also been discussed in other journals, therefore authors decided to limit its number to the most frequently appearing in the citation rankings. Still, the sample size is significantly larger than in most other studies. The other limitation – the minimum cluster size in HDBSCAN – must be defined experimentally. The method requires only one parameter, which is less than is the case with other clustering methods.

Originality/value: Our work constitutes an original in-depth investigation into current advances in innovation research using text mining. Furthermore, our results indicate that the developed approach is universal and could be applied when selecting prospective research areas and spotting fields with increasing potential. Additionally, the text mining procedures adopted in this study could provide researchers with a tool for gaining a thorough grasp of knowledge of a specific field buried in a vast amount of scholarly literature. For practitioners it can offer suggestions on areas of possible business acceleration and transformation. The clustering technique produces an overview of a particular field in greater detail.

Keywords: innovations, systematic literature review, text-mining, trend analysis.

Category of the paper: research paper.

1. Introduction

Innovation has recently emerged as a key strategy for companies keen to maintain a competitive advantage and gain access to broader or new markets (Stock et al., 2002; Ferraris et al., 2017; George et al., 2021). It is also one of the major catalysts boosting the international competitiveness and productivity, output and employment performance of countries as well as a tool for measuring the health of an economy (Becheikh et al., 2006; George et al., 2021).

Innovation is a durable, time-consuming and resource-intensive process organized around ideas and future needs. The outcome of any innovation process is uncertain and challenging to predict. Therefore, to gauge its potential, we must understand its origins (Chesbrough, 2003; Fernandes et al., 2019). The cumulative nature of innovation emphasized by Lazonick (2002) in various of his papers is influenced by social conditions which change over time and can vary depending on the type of activity involved. To make progress and shape innovation, all these factors must be integrated with previous experiences and lessons learned.

It is important to emphasize the complex and diverse nature of business activities that are specific to analyzed countries, regions, and economic sectors. Hence, constructing a universal framework describing the development of the concept of innovation poses a challenge. Efforts have been made to classify eras or "critical technologies" that have played a crucial role in speeding up the development of further innovations constructed on the basis of or correlated with the critical technology (Bruland et al., 2009).

The economics of technological innovation in literature are described as a cumulative process and it is possible to observe the explicit course of development in specific fields (Mukoyama, 2003; Cantwell, 2000). One possible explanation of this phenomenon is that it is a kind of competition between companies to adopt new technologies or solutions and thus avoid locking into potentially less efficient technology and following the choices and strategies made by early adopters (Arthur, 1989). As a consequence, over the years the choices made by these early adopters have greatly influenced the paths taken by the companies which came after them. Although this phenomenon can be observed in relations between competitors, it is also very common among companies working in supportive or complementary infrastructure areas (Nieto, 2004).

Technology is specific, cumulative and differentiated in character, and as such the industrial composition of innovative activity in a specific location or amongst a national group of firms reflects past technological accumulations in that defined area. This suggests that international patterns of technological advantage, once established, remain relatively stable over time, at least in the short or medium term. Those sectors in which each group of firms is technologically strongest changes only gradually (Cantwell, 2000).

Another important concept for management research is disruptive innovation. Christensen, et al. suggest a number of topics that remain under-explored in current innovation research (2018). They propose focusing future research on: response strategies in reaction to disruptive innovation, performance trajectories and metrics of disruption (Christensen et al., 2018).

The data presented in the literature show that over the years changes have occurred in the way in which innovations are analyzed and variations in areas of interest are correlated with innovations. Reviews based on an analysis of patents issued in various countries reveal a shift from industrial innovation towards innovation in services, from the point of view of both companies and research interests (Fagerberg, 2002).

Monitoring the current trends in innovations can support progress and help in defining the direction of future development. The main research question is what the trends in the studies on innovations in the XXI century were. Based on a review of the literature from the years 2000-2020 and using an alternative method of data analysis, our objective was to identify shifts in interests and trends in the field of innovation so as to ensure a better understanding and improved research agenda in the upcoming years. Our second aim was to demonstrate the suitability of the original method based on text mining tools for detecting trends in research papers.

2. Literature review

2.1. Prior literature reviews on trends in innovation

Over the last 20 years various literature reviews have been conducted on the topic of innovations. Some of these were broad in scope (Becheikh et al., 2006; Crossan, Apaydin, 2010; Keupp et al., 2012; Khosravi et al., 2019), while some focused on more specific problems (Garcia et al., 2002; Hossain, Kauranen, 2016; van Oorschot et al., 2018; Gomes, et al., 2018; Cillo et al., 2019; Dziallasa, Blind, 2019). The detailed descriptions of these studies are presented in Table 1.

Table 1.
Summary of previous systematic literature reviews on the topic of innovations

Study	Sample size	Full text analysis	Method of analysis	Results	Detailed area of exploration
Garcia et al. (2002)	21 empirical studies	yes	systematic review of the literature and empirical studies	Method for classifying innovations.	Innovation typology and innovativeness terminology.
Becheikh et al. (2006)	108 articles (1993-2003)	yes	systematic review of empirical articles	Classification of studies by investigated region, discipline, type of innovation.	

Cont. table 1.

Crossan, Apaydin (2010)	525 articles (1981-2008)	yes	systematic literature review	Identification of distinct meta-constructs: leadership, managerial levers and business processes.	
Keupp et al. (2012)	342 articles (1992-2010)	yes	systematic literature review (co-word analysis, cluster analysis and frequency analysis)	25 clusters identified with regard to the following: inter-firm collaborations; strategic management of innovations; deliberate non-innovation; implementing innovation and others.	
Hossain, Kauranen (2016)	51 articles (2006-2013)	no	abstract analysis (NVivo program)	Following themes identified: search strategies; collaboration; transforming from a closed to an open approach; innovation management; OI performance of SMEs; and challenges of SMEs in OI.	Open innovation in SMEs.
Van Oorschot et al. (2018)	1260 articles (2003-2016)	yes	systematic literature review (bibliographic coupling and co-citation analysis)	Research trends identified: determinants of IT adoption; adoption of technological standards; organizational rationales associated with adoption; modeling diffusion, and adoption of agricultural innovations.	Innovation adoption.
Gomes et al. (2018)	125 articles (1993-2016)	yes	systematic literature review (hybrid method including bibliometric and content analysis)	Identification of six research streams in the innovation ecosystem: industry platforms; innovation ecosystem strategy; innovation management; managing partners; the innovation ecosystem life-cycle; innovation ecosystem and new venture creation.	The innovation ecosystem.
Khosravi et al. (2019)	66 studies (1981-2017)	yes	systematic review combined with a meta-analysis of the literature	A model of management innovation, including organizational, managerial and environmental antecedents.	
Cillo et al. (2019)	69 articles (1995-2018)	yes	systematic literature review (content analysis)	Of three key perspectives, internal managerial perspective is the most frequently applied, whereas external relational and performance evaluation are not that often considered.	Sustainable innovations.
Dziallas, Blind (2019)	226 articles (1980-2015)	yes	systematic literature review	Identification of company specific and contextual dimensions indicators, as well as ex-ante and ex-post evaluation indicators.	Innovation indicators.
Our study	22139 articles (2000-2020)	yes	TF-IDF, cluster analysis	Identification of 16 trends including 5 long-lasting, 1 declining, 8 emerging and 1 ephemeris in character	

Source: Own results.

In 2006 Becheikh, et al. published a systematic review of the literature on technological innovations in the manufacturing sector from 1993 to 2003. The primary aim of this study was to deepen our understanding of the innovation process. As a result, the authors introduced a set of variables linked to the innovation process and the internal and contextual factors driving specific innovations. In their work, the authors highlighted the findings of trends connected with the regions they investigated (with Europe in the leading position), specific disciplines (with economics, management and business administration being the dominant disciplines), as well as the type of innovation investigated (with the focus on product & process and product).

A more extensive literature review, covering over 500 publications over a period of more than 25 years, was presented four years later by Crossan and Apaydin (2010). The authors synthesized the research perspectives and frameworks of organizational innovation, identifying on this basis three distinctive meta-constructs: leadership, managerial levers, and business processes. They suggested viewing innovation as a process and as an outcome. Their approach provides a multi-dimensional framework of organizational innovation.

Another general literature review comes from Keupp et al. (2012). After reviewing 342 articles dedicated to strategic management and innovation, the authors identified theoretical inconsistencies and knowledge gaps in the case of the following topics (Keupp et al. 2012, pp. 383): the performance implications of inter-firm collaboration; appropriation strategies; the strategic management of process innovations, administrative innovations, and service innovations; deliberate non-innovation; the causal relationship between internal organization and innovation; the implementation of innovation; the influence of ownership structure on innovation strategy; the development of resources for innovatory purposes; alternative measures for gauging the performance implications of innovation; environmental contingencies beyond country and industry settings; and the strategic management of innovation in low and medium-technology industries. Their analysis includes a classification of studies based on the types of innovation studied, the dependent and independent variables employed in the studies, the analytical methods used, and the industries analyzed.

The most recent analysis of general trends in innovation studies was published in 2019 by Khosravi et al. Their study was based on a systematic review combined with a meta-analysis of the literature and their objective was to assess existing empirical studies focused on management innovation. The authors analyzed 66 studies with the aim of identifying the trends and background of management innovation research. They proposed a model that included organizational (company size, knowledge management, organizational structure and strategy, human resources management (HRM), dynamic capabilities, culture, networks and resources), environmental (market dynamics, policy and law, people and communities) and managerial (leadership behaviors, stewardship, and characteristics and attitudes) antecedents. They listed a number of major theoretical concepts serving as a background in innovation studies, including: resource and capability based theory; organizational learning; institutional theory; innovation theory; human capital theory; the theory of knowledge inertia; full range leadership

model theory; knowledge management theory; dynamic capability; learning theory; contingency theory; organizational theory; behavioral theory; ability-opportunity motivation theory; knowledge-based theory of the firm; and innovation diffusion.

As far as studies focused on specific problems are concerned, one of the first issues that was a subject of detailed scrutiny was innovation typology and innovativeness terminology. Garcia et al. (2002) performed a literature review of empirical studies focusing on marketing, engineering, and new product development to ensure more clarity and continuity in the use of the terms employed to classify innovation. Such an approach helps avoid having to remodel the work carried out by researchers involving different labeling (wording) in descriptions. This in turn makes it possible to expand the area of research and avoid duplication of the same efforts. Otherwise, discrepancies in classification and operationalizing innovations in the new product literature may affect the progression of knowledge and can also influence how the research interests of academia and business are defined. The authors suggest that when identifying and describing innovation and its origins it is crucial that we consider various dimensions such as marketing and technological perspectives together with macro and micro-level perspectives. They also provided a method for classifying innovations as a common platform upon which practitioners and academics can define specific innovation types and the way in which the innovation process can be dedicated to a particular type of innovation.

In 2016, Hossain and Kauranen published a literature review that focused on the application of open innovations (OI) in SMEs. They identified six major themes: search strategies and networking; collaboration; transforming SMEs from a closed to an open approach; innovation and technology management; the OI performance of SMEs; the challenges faced by SMEs in OI and how to overcome the challenges. According to the authors' general findings, SMEs can improve their overall innovation performance by adopting OI.

The next issue to be addressed was the adoption of innovations,, which was analyzed by Van Oorschot et al. (2018). Their study, which includes a coherent overview of the theoretical cornerstones in the literature, was based on the bibliographic coupling method, which served as a tool for assessing current trends in research during the period 2003-2016. The authors grouped these trends into five clusters: drivers of, and impediments to, information technology adoption; acceptance and introduction of technological standards; organizational rationales associated with innovation adoption; modeling the diffusion process; and adoption of agricultural innovations. They identified four clusters based on co-citation analysis.

The very same year de Vasconcelos Gomes et al. (2018) published a work clarifying the concepts of innovation and ecosystems and identifying trends and research opportunities. In their work the authors highlighted the most influential papers in the field and discussed the concept of ecosystems whilst at the same time stressing the transition from a business ecosystem (mainly concerned with value capture) to an innovation ecosystem (primarily geared towards value creation). Finally, the authors discussed a number of trends shaping innovation ecosystems: industry platforms; innovation ecosystem strategies, strategic management, value

creation and business models; innovation management; partner management; the innovation ecosystem life-cycle; innovation ecosystems and new venture creation. The authors highlighted not only the most influential papers in the field and described six research streams in the innovation ecosystem, but they also proposed opportunities for further research aimed at supporting the transition from a business ecosystem to an innovation ecosystem.

Following a more general trend of sustainable development, Cillo et al. (2019) reviewed the existing literature on sustainable innovation. Using multiple perspectives of internal managerial, external relational, and performance evaluation, they identified the key issues most frequently considered in each (Cillo et al., 2019, p. 9):

- Internal managerial: strategic management, innovation management, ambidexterity, business model innovation, information systems, knowledge management;
- External relational: strategic alliances, stakeholder theory;
- Performance evaluation: a methodological approach.

Finally, the last of the presented studies, conducted by Dziallas & Blind (2019), covered the problem of innovation indicators throughout the innovation process. A literature review was key both to identifying indicators divided according to company-specific and contextual dimensions, as well as to assessing their potential for ex-ante and ex-post evaluation.

2.2. Prior approach to trend identification and the limitations of previous reviews

A systematic literature review (SLR), which was the most popular method employed in the studies presented above, allows researchers to better understand and describe a field of study. However, because it is a labor-intensive exercise, the number of papers included in an analysis is limited. To solve this problem, the authors use strict and narrow queries.As a consequence, the number of papers providing a more in-depth analysis is limited to a few hundred or less (e.g. Garcia et al., 2002; Becheikh et al., 2006; Hossain, Kauranen, 2016).

In most cases, such an approach is based on metadata: titles, keywords and abstracts (e.g. Hossain, Kauranen, 2016). Several software applications facilitate this process. Unfortunately, some authors report less than 8% of their research claims in abstracts (Blake, 2010). The relative importance of each word in a title or abstract is much higher than in the case of the full text. Abstracts and titles often contain catch-words that are used to increase readership and the likelihood of citation. Finally, many publishers define the structure of abstracts and introduce pre-defined keywords. This makes finding new ideas and topics in the metadata more difficult. Hence, studies relying on metadata cannot be treated as fully reliable.

Often, such studies are limited to specific databases, which narrows the scope of the review (e.g. Crossan, Apaydin, 2010; de Vasconcelos, Gomes et al., 2018). Reviews also usually excluded conference papers, books and unpublished full-text documents focusing only on selected articles (e.g. Khosravi et al., 2019).

Further, analysis is mostly narrative and qualitative (Tranfield et al., 2003) in form. More extensive studies require the adoption of a text-mining toolset and quantitative methods. Some previously presented literature reviews adopted a more complex approach: Van Oorschot, et al., (2018) used co-citation network analysis and cluster identification, while Keupp et al., (2012) relied on co-word analysis, cluster analysis and frequency analysis. This, however, gives rise to new limitations, which can be resolved by analyzing the full texts of papers. However, even in that case, some limitations apply. We found that most authors predefined themes, clusters or categories. This can prevent the discovery of new ones not known before the study and can also induce researcher bias. We are far from criticizing the results of previous SLR in this field. It is a valuable source of insight into the development of many scientific disciplines and an invaluable tool for comparative, network and semantic analysis. In our article, we wanted to point out an alternative approach which can supplement and enrich research efforts.

That is why the central aim of this article is not only to present a systematic literature review of studies on innovation, but also to show the suitability of a method based on text mining tools for detecting trends in research papers.

3. Method

In this study, the authors offer an approach that enriches the toolset of classical systematic literature review methods. We focused our analysis on the full texts of papers published in selected subject areas. Categories were discovered automatically in data rather than being pre-defined. The quantitative approach to text-mining that has been successfully tried and tested in multiple studies was supplemented with original tools created by our research team. This allowed authors to identify not only categories but also trends. The approach applied is consistent with general rules for systematic literature reviews (Ananiadou et al., 2009; Tranfield et al., 2003) and comprises several steps:

1. Selection of journals.
2. Collection of papers.
3. Search for the most critical terms.
4. Discovery of thematic groups (clusters).
5. Discovery of trends.
6. Verification, description and interpretation of trends.

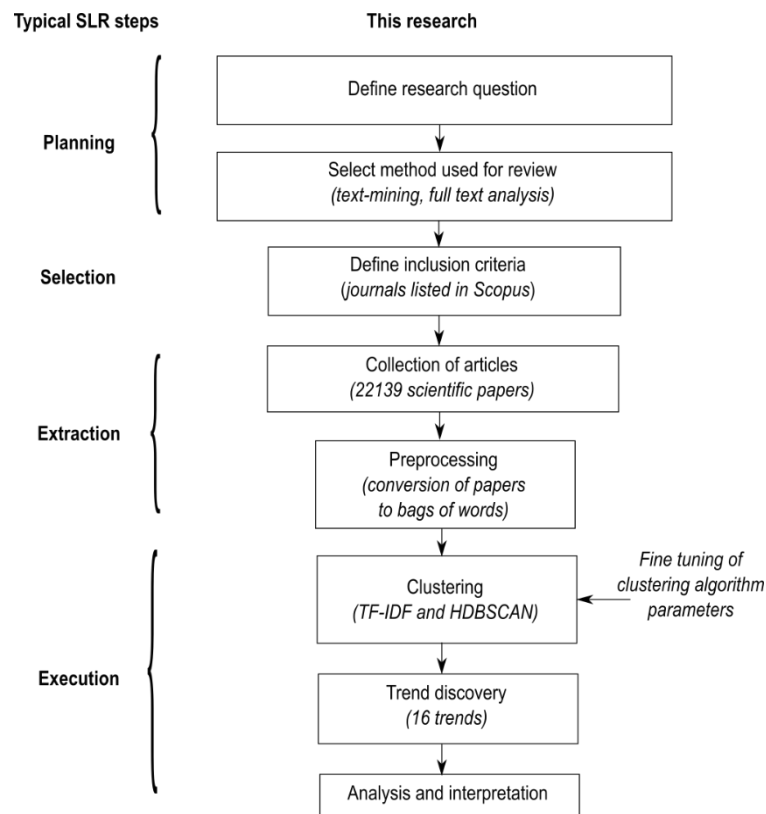The entire process is presented in Figure 1.

Typical SLR steps

This research

Planning

Define research question

Select method used for review
(text-mining, full text analysis)

Selection

Define inclusion criteria
(journals listed in Scopus)

Extraction

Collection of articles
(22139 scientific papers)

Preprocessing
*(conversion of papers
to bags of words)*

Execution

Clustering
(TF-IDF and HDBSCAN)

*Fine tuning of
clustering algorithm
parameters*

Trend discovery
(16 trends)

Analysis and interpretation

Figure 1. Diagram of the method and steps involved in a systematic literature review (SLR). Source: Own results.

3.1. Collection of papers

The proposed method avoids using predefined keywords and categories. Due to this fact, it was necessary to adopt a novel approach when selecting papers. Instead of keywords, we identified highly cited journals that cover the subject of innovation, technology and management. A similar approach has already been used, e.g. by Wawak, Woźniak (2020) and Wawak et al., (2020). The criteria for choosing journals and papers for analysis were as follows:

- journal is listed in the Scopus database in subject area "Management of Technology and Innovation" (total of 234 journals),
- journal is present in 90th percentile rank based on Scopus Citescore index based on citations between years 2017-2020 (23 journals),
- the full text of the published articles is available for over 10 years of publication (19 journals remained for further study)[1],
- the article was published in selected journal between 2000 and 2020,
- only research papers were included.

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[1] Following journals present in 90th percentile of CiteScore ranking were published for less than 10 years in 2000-2020 period and thus excluded from analysis: *International Journal of Precision Engineering and Manufacturing - Green Technology, Journal of Innovation and Knowledge, Entrepreneurship and Sustainability Issues, IEEE Communications Standards Magazine.*

To ensure thorough coverage of the field, we chose all published articles that met the criteria from the 19 journals presented in Table 2.

Table 2.
Journals included in the study

Journal title	Scopus Cite Score	Impact Factor 2020	Number of papers included
International Journal of Management Reviews	15,4	8,63	416
Academy of Management Journal	14,0	7,57	1520
Academy of Management Annals	13,0	11,87	245
International Journal of Project Management	13,0	6,62	1706
Journal of International Business Studies	12,1	9,16	1087
Technovation	11,5	5,73	1292
Journal of Business Venturing	11,3	7,59	838
Organizational Research Methods	11,2	5,71	579
Research Policy	10,4	5,35	2493
Journal of Product Innovation Management	9,8	5,00	962
International Journal of Physical Distribution and Logistics Management	9,8	4,74	839
Journal of Management Studies	9,4	4,89	1225
International Journal of Operations and Production Management	9,1	4,62	1294
Technological Forecasting and Social Change	8,7	5,85	3256
Journal of Knowledge Management	8,5	4,75	1347
Operations Management Research	8,4	2,00	150
Human Relations	7,1	3,63	1387
Electronic Commerce Research and Applications	6,9	3,82	830
Journal of Human Resources	6,8	3,70	673
Total			22139

Source: Own results.

We collected the PDF versions of the papers using the Ebsco, ScienceDirect and Emerald databases. No duplicates were found at this stage due to previous screening. Files that contained editorials, calls for papers, errata or book reviews were removed. Finally, 22139 papers were the subject of further analysis. The size of the sample should be sufficient, as we included a wide range of articles published in highly cited and recognized journals.

Given the concerns raised when restricting an analysis to titles, keywords and abstracts only, in this study we scrutinized the full-texts of papers without titles, keywords, abstracts and references.

Supplementary data, e.g. bibliographical records and number of citations was retrieved from the Crossref database. Each paper was converted into a text file and then into a bag of words, which was required for automatic analysis using computer algorithms. The algorithms have been created using Python libraries including grobid, nltk, scikit-learn, hdbscan, and scipy (Jones et al., 2001; Lopez, 2009; McInnes et al., 2017; Pedregosa et al., 2011).

The approach proposed in this paper has already been applied in similar studies published in several papers (Guzik et al., 2020; Wawak et al., 2020; Wawak, Woźniak, 2020).

3.2. Search for the most important terms

The most important terms are not always those which are the most frequently used. The most frequent words in English are "the" and "of". In this study, the keyword "innovation" appears in almost every article. As a consequence, it has no impact on decisions made by researchers or algorithms. Keywords that occur only in one paper may be crucial for that one publication but say nothing about the corpus as a whole. The most important terms are those which occur in several papers as a group. An analysis of thousands of such terms allows researchers to identify groups of similar papers, identify clusters, and then trends (Cong et al., 2016; Salton, Yang, 1973). Fortunately, this laborious task can be automated thanks to the term frequency – inverse document frequency method (TF-IDF). It considers the frequency of a term but simultaneously counts the number of documents in which this term was found. The following formula describes the main calculation performed with the TF-IDF method:

$$w_{i,j} = tf_{i,j} \cdot \log\left(\frac{N}{df_i}\right) \tag{1}$$

where:

$w_{i,j}$ – result for term i in document j,

$tf_{i,j}$ – number of occurrences of i in j,

df_i – number of documents containing i,

N – number of documents in the corpus (set of documents).

The TF-IDF method has several limitations, which we took into account. It is not a mathematical model, requires extensive computation, cannot identify synonyms and ignores the multiple meanings of certain words (Zhang et al., 2011). In the case of research papers, these problems have a minimal impact due to the more precise language used by researchers. Other approaches to this problem are available, e.g. Latent Semantic Indexing (LSI) or Latent Dirichlet Allocation (LDA). However, they were not suitable in the present situation as the format of the results was incompatible with the other methods used.

3.3. Discovery of thematic groups (clusters)

Algorithms require the conversion of papers into numbers. The text of each paper was converted into multidimensional vectors. The number of dimensions was equal to the number of keywords used in the analysis (on average over 50000 in this study). These vectors can be compared to each other by means of, among other methods, cosine similarity, and, as a consequence, make it possible to identify thematic groups. This can be achieved using partitioning or hierarchical clustering methods. The fundamental difference between these methods is that with partitioning all papers have to be included in one group, while hierarchical clustering allows some papers to be left unassigned. This second approach leads to better results

in trend analysis because journals often contain papers that are sometimes loosely connected with others. Such papers should not be used in trend discovery, as they could result in false trends being identified. There are multiple hierarchical clustering methods available, e.g. meanshift, DBSCAN, Optics and HDBSCAN (Jain, 2010; McInnes et al., 2017). The latter is the latest technique and resolves some of the shortcomings of other methods. HDBSCAN (Hierarchical Density-Based Spatial Clustering of Applications with Noise) takes each paper (vector) and checks at what distance it can find similar ones. Then it compares the results and detects the densest areas, which it deems to be clusters. The density and number of elements in a cluster can differ. It is the duty of researchers to define the minimum size of a cluster. This requires a series of experiments. In this study, we found that the best results were achieved when the minimum cluster size is set to 20^2.

The whole sample was divided into groups of papers published in five-year periods that overlapped with each other, starting with 2000-2004 and ending with 2016-2020. Each paper was assigned to every group in which it fitted. Cluster analysis was performed on each group separately, and the results provided the basis for discovering trends. The percentage of papers published by different journals each year is presented in Figure 2.
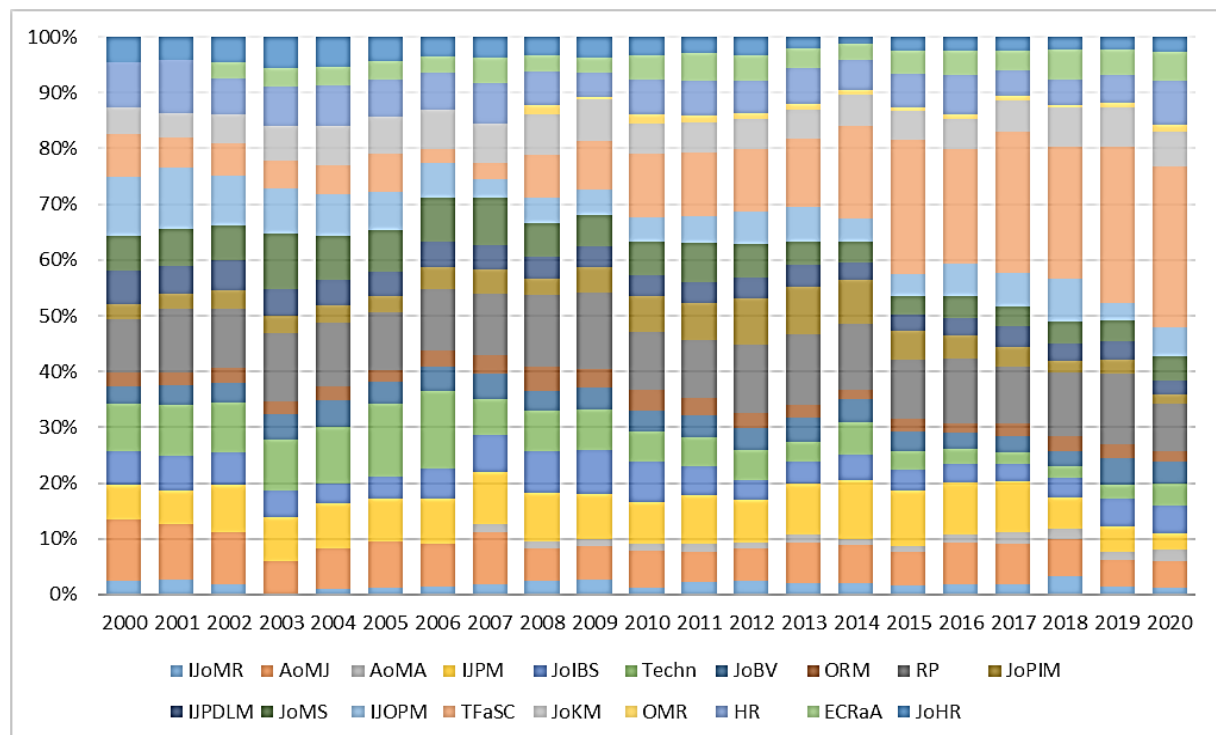

Figure 2. Percentage of papers published by selected journals in the years 2000-2020.
Source: Own results.

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[2] We created primary analysis for cluster sizes 15, 20, 25 and 30. The criterion for selecting the size of the cluster was a heuristic consisting in the optimal selection of the level of detail and the number of identified trends (sets of keywords). Too small size of the cluster meant that the number of identified categories of keywords reached 100 or more items, which would increase the volume of the article (many more trends to describe). Too large cluster size resulted in the identification of a few <10 trends too general in nature and obvious. Access to source files for this analysis is made public on the Github platform along with software we created for this purpose (https://github.com/wozniakk-uek/Trends_in_innovation).

Because of the limited length of the paper, it is not possible to present the HDBSCAN algorithm in detail. Full documentation with examples and a comparison with other clustering methods can be found on a dedicated website (http://hdbscan.readthedocs.io).

Software used during preparation of this article is available on GitHub repository (https://github.com/wozniakk-uek/Trends_in_innovation).

3.4. Identification of trends

The identification of a cluster provided the basis for classifying papers included in the study. Clusters have to be identified in multiple subsequent periods to enable trend discovery. Previously, when endeavoring to identify trends authors tried to analyze subsequent and independent periods. This required an analysis of each cluster and could induce researcher bias. In this study, we made use of overlapping periods. Because the analyzed periods intersect with one another, it is possible to track year after year in which clusters each paper was included. Thanks to this fact, we could observe the evolution of clusters, and trends could be distinguished. As a result, four types of trend could be identified:

- long-lasting trends that existed and developed during the studied period,
- declining trends which ended during the studied period,
- emerging trends which began during the studied period,
- ephemeris trends that began and ended during the studied period.

As this approach only applies to groups of papers bigger than the minimum cluster size, it is important to stress that papers not included in clusters cannot be regarded as less important or uninteresting. For example, the average number of citations of both papers included in clusters and papers lying outside clusters is similar (analyzed yearly based on data received from Crossref.org). The only reason why our algorithm did not include a paper in any thematic group was the selected minimum size of a cluster. Papers which are located out of clusters possibly touch upon essential topics that have been studied by very few researchers. Among them, future trends can probably be found that have not been discovered in the current research.

3.5. Interpretation of trends

In the final step trends are verified, interpreted and described. However, the algorithm cannot perform this step yet. Typical situations which depend on the decisions taken by researchers include: a merger of two similar trends and a split in one trend because of multiple paths adopted by different studies. We designed the algorithm so as to detect even slight differences between trends. This requires more analysis by human observers, but at the same time reduces the risk of omissions. Therefore, merging two very similar trends based on an analysis of leading keywords and texts of sample papers is sometimes justified. In this approach, the researcher must also name each trend. The interpretation phase should help highlight changes within trends and try to predict their future evolution.

4. Results

This analysis, based on automatic algorithms and further verification performed by researchers, led to the discovery of 16 trends presented in Table 3. The trends in the table are arranged according to the year of their first occurrence and length.

Table 3.
Trends in innovation research in the years 2000-2020

Year/ ID	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Internationalization																				
2	New product development																				
3	Patenting																				
4	Knowledge sharing and management																				
5	Project and project risk management																				
6	Work-life balance and career development																				
7			Incubators & spin offs																		
8									Lean management												
9				Innovation policy																	
10					Leadership & team management																
11						Strategic foresight															
12									Business cooperation												
13										Corporate Social Responsibility (CSR)											
14													Crowdfunding								
15													Big data								
16														Sustainable applications							

Source: Own results.

We identified 16 trends, of which 5 were long-lasting, 1 declining, 8 emerging and 2 ephemeris in character. The exact year in which a trend was discovered does not indicate when the idea behind it was created, but it shows when the subject became increasingly popular among researchers.

The research problems behind the identified trend are:

1. Internationalization, understood as the potential and specific skills of companies with regard to expanding into foreign markets and export, as well as foreign direct investment (Ibeh et al., 2005).
2. New product development, which mainly concerns its influence on the general condition of companies focused on developing new assets (Lakemond et al., 2006).
3. Patenting, which addresses the role and motives of patent protection for work performed by researchers involved in academia and business sectors (Veer et al., 2011).
4. Knowledge sharing and management, which deals with the ability to use intellectual capability and create new solutions for humans and organizations (Kakabadse et al., 2003).

5. Project and project risk management deal with issues such as time, resource and cost in relation to the definition, planning and monitoring of complex projects (Petit, 2012).

6. Work-life balance and career development covering various aspects of family welfare and career planning related to market opportunities, managerial competences and income (Caceres-Delpiano, 2006, Gomez-Mejia 2011).

7. Incubators & spin offs; where researchers defined as a role of university linkage and knowledge transfer (Rothaermela et al., 2005, Fontes, 2005) and relationship between university and industry (Perkmann et al., 2007).

8. Lean management is defined as a method of organizing and managing a company's work to improve product quality and profitability of production processes (Hasle et al., 2012; Bhamu et al., 2014).

9. Innovation policy – reflecting how policy-makers and governments have realized the importance of innovation for economic conditions (Dodgson, 2011).

10. Leadership & team management where researchers focused on transformational leadership seen as important aspect of project-based organizations and risk management (Keegan et al., 2004; van Knippenberg et al., 2013).

11. Strategic foresight where we observe structured and systematic approach to analyze available information to roadmapping and anticipation of future events and changes (Lee et al., 2005, Bezold, 2010).

12. Business cooperation, including relations with various partners: other companies, partners from academia and non-profit organizations, as well as the problems of outsourcing, offshoring, and public-private partnership Schwartz et al., 2010; Colombo, 2012.

13. Corporate social responsibility (CSR), which correlates mainly with ISO and corporate communication (Hemingway et al., 2004).

14. Crowdfunding, mainly geared towards an analysis of sources of funding for innovations (Stanko, Henard, 2017).

15. Big data, a set of relatively new tools and techniques used for creating knowledge and supporting decision making (Hartmann et al., 2016).

16. Sustainable applications, which is focused on implementing innovative technologies in manufacturing and business (Markarda et al., 2012).

5. Discussion

An extensive literature review based on an analysis of the full-texts of over 22.000 papers published over the last 20 years led us to identify 16 different trends in studies on innovations, the nature and dynamics of which are highly diversified.

New product development is a relatively coherent, long-lasting trend identified in the analyzed literature. Over the years considerable attention has been paid to the management area to foster innovation and its efficiency (Lewis et al., 2002). Researchers explored the nature, changes and factors affecting specific project and knowledge management behavior and styles (Kim, Kim, 2009; Magni et al., 2013), as well as of corporate culture (De Brentani, Kleinschmidt, 2004). The publications connected with this trend discuss the methods and consequences of planning as well as how to control the performance of NPD. Researchers worked on business design and risk at each step of NPD, and these factors are also broadly described in various works produced by the academia and business experience sectors (Salomo et al., 2007). If we observe the development of this trend we can see more interest in new technologies designed to improve product design (Perks et al., 2005; Mauerhoefer et al., 2017), globalization and international cooperation (Dubiel et al., 2016) followed by open innovation, social media (Du et al., 2016) and a need for dialogue with customers (Lynch et al., 2015) as constructive tools for NPD-related innovation (ex. complex adaptive systems in the article by McCarthy et al., 2006).

The next long-lasting trend is *patenting*, in which authors consider the quality of the patents introduced on the market with a view to discussing the commercial market value of protected innovations and analyzing potential differences (Harhoff et al., 2003; Sapsalis et al., 2006). Originally the focus was on the innovative capabilities and research commercialization of universities (Owen-Smith, Powell, 2003; Hsieh, 2013). The analyzed publications often referred to the patenting index, which is a tool for describing and comparing the level of economic development of countries in which patents are filed in various areas of technology (Park, 2008). Over the years there has been an increase in the number of patents filed for business, academia and joint research. Innovation can be stimulated and managed by changes in patenting policy, grant funding regulations, and policy supporting businesses in their efforts to speed up development so as to maintain a competitive advantage over others, which as a consequence causes an increase in the interest of companies in basic research from academia (Encaoua et al., 2006; Belderbos et al., 2014; Shu et al., 2015). The discussion on patenting shifted towards the ways in which the commercial value of patented ideas can be boosted by supporting technology transfer, academia-business collaboration, and spin-off creation as well as by helping venture capital enter the field of innovation (Gredel et al., 2012; Suzuki, 2011). Another dimension of this trend relates to the practices of different countries and regions and focuses on how these geographical differences change over the years in ways that influence the economic development and competitiveness of specific markets (Cohen et al., 2002; Goto et al., 2007; Mariani et al., 2007; Acosta et al., 2012; Li, 2012).

Knowledge sharing and management is another trend identified in the whole 20-year period of analysis. The articles in this trend describe the impact of knowledge management on the performance of an organization and its innovativeness and the extent of influence that is exercised by the support policies of the management system (Darroch, 2005; Du Plessis, 2007).

The articles also identify different approaches to developing knowledge management competences in projects and programs (Koskinen et al., 2003). Majority of articles in this section relate to practice-based or reflective learning, while qualitative research approaches focus on analysis and discussion and conceptual studies. Another area in the field of knowledge management taken up by the identified articles is the issue of knowledge transfer. Organizations may significantly improve their knowledge and innovative capabilities by leveraging the skills of others through the proper communication and transfer of knowledge both within and across firms (Easterby-Smith et al., 2008; Liyanage et al., 2009). Knowledge transfer is also considered in an international context, through the transfer of knowledge across firms in foreign cultures and knowledge developed by firms in foreign countries to other countries (Fang et al., 2010). This topic is often discussed with analysis of subsidiary effectiveness and absorptive capacity as means through which we can view knowledge transfer (Chang, 2012). Some authors also point to challenges and barriers related to sharing knowledge, in particular the difficulties in gaining access to knowledge (Gächter et al., 2010).

Another long-lasting trend identified during our study is *project and project risk management*. A common theme throughout the literature surveyed is the need for a process and set of tools that can help project managers to identify where their attention should be focused on and provide necessary guidelines. A number of researchers investigate the influence of project portfolio management on innovation and entrepreneurship. Authors are looking for methods for managing project portfolios in dynamic environments such as new product development, where the rate of technological innovation is high (Petit, 2012; Sundström et al., 2009; Abbassi et al., 2014). Some authors see project management offices as an organizational innovation helping to achieve higher efficiency (Hobbs et al., 2008). It is often understood as an innovation driver, providing the right tools, and making research and development (R&D) projects more efficient (Gemünden et al., 2018). Project risk management has been a common subject in articles identified in this trend. Risk described as the negative outcome of an uncertainty is sometimes interpreted as a probability, but in real life, it is an expected return of some event or state. The opposite of risk is opportunity, which describes the positive outcomes of uncertainty. Some authors assume that the risk management process is not enough, and managers should instead try to manage opportunities to improve the project outcome (Olsson, 2007).

Work-life balance and career development is the last long-lasting trend identified in the analyzed literature. We can observe the focus of researchers on the interactions between work and family communities (Voydanoff, 2001; Grant et al., 2008). The topic is correlated with family-owned companies (Romano et al., 2001, Matzler et al., 2014) and in consequence with family welfare (Caceres-Delpiano, 2006; Gomez-Mejia, 2011). Studies investigate correlation between work and private life (Carlson et al., 2009) and how it influences career planning and development (Arthur, 2008; Bennett et al., 2016). We can also see interest in a role of mentoring in that process and managerial aspects influencing decision making process of career paths

(Lee et al., 2010; Roach et al., 2010). Additionally income inequality and health welfare were investigated and discussed (Gerdtham et al., 2004; Leana et al., 2015; Berrone, 2018).

Two ephemeral trends identified during our study were *incubators & spin offs* and *lean management*. Incubators and spin offs trend emerged in 2001 and declined in 2012. After 2001 researchers became increasingly interested in incubator firms and spin-offs creation (Rothaermela et al., 2005; Wright et al., 2006) discussing the role of university linkage and knowledge transfer (Rothaermela et al., 2005, Fontes, 2005). Additionally, the role of technology transfer organizations was investigated (Debackere et al., 2005, Walter et al., 2006). Researchers discussed the importance of patenting (Sampat, 2006; Baldini, 2008), various types of alliance and cooperation to increase knowledge transfer and innovation creation (de Man et al., 2005). Next we can observe interest in open innovation, academic entrepreneurship activities (Grimaldi et al., 2011) and relationship between university and industry (Perkmann et al., 2007). The nature of this trend reflects business processes: at the beginning of a century many innovative initiatives were started which induced academic research in that field. With business growth the focus of scientists was on more advanced problems of business operations. That resulted in the fading of this trend.

Lean management was classified as another ephemeral trend in the analyzed time period. The first publications on this topic occurred in the 80's and 90's, however what originated as a method of organizing and managing company's work to improve products quality and profitability of production processes was analyzed in the context of innovations much later (Hasle et al., 2012; Bhamu et al., 2014). It was inspired by the Toyota Production System aiming at resource optimization and elimination of redundant steps or operations (Cochran, 2010; Moyano-Fuentes et al., 2012). In analyzed literature we can observe that first researchers emphasized lean in supply chain management and industry implementations (Halldorsson et al., 2008; Hofmann, 2010). Then the interest was moved to services according to the lean philosophy and sustainability of processes e.g. in healthcare (McCann et al., 2015), finances or sales (Leyer et al., 2014, Piercy et al., 2015). Then the field of lean management was fulfilled with six sigma methods to provide organizations tools improving business capability and quality of processes (Lambert Marzagão et al., 2016). Additionally interest was put on lean leadership discussing profiles and capabilities of managers in companies implementing lean philosophy (Ruiz-Benitez et al., 2019).

The only declining trend was *internationalization*, various aspects of which have been described in the literature. First, the problems of multinational companies (Kumar, 2001; Rugman et al., 2004) and export (Nassimbeni, 2001) were addressed. Second, skilled management is an important factor enabling companies to expand their network of markets (Ibeh et al., 2005). More efficient and cheaper ways of exporting innovation are required, enhanced by greater competitiveness in case of small and medium-sized companies (Fischer et al., 2003). Another dimension of this trend is innovation driven by various regional, cross-country and cultural aspects (Roper et al., 2002; Özçelik, Taymaz, 2004). Throughout the

whole analyzed period, high interest was also on foreign direct investments (Meyer, Nguyen, 2005; Filatotchev et al., 2007; Buckley et al., 2009). Trends of declining importance and ephemeral appearance involved issues of less interest to current research work on innovation, possibly because there was a good understanding of these aspects and extensive research had largely exhausted the topic. The disappearance of specific trends is a natural phenomenon observed in science and research. It is usually signaled by a decrease in the volume of publications and research work, as was observed in our own studies.

Our most interesting observations concern trends that emerged during the studied period and are still active. These trends include CSR, business cooperation, crowdfunding, innovation policy, leadership & team management, strategic foresight, sustainable applications, and big data.

In 2004 the first identified emerging trend appeared: *innovation policy*. The importance of innovation for the economy as a whole, an issue that was also considered in previously defined trends, is addressed in the theme of innovation policy emerging since around 2004. This trend highlights the need for more sophisticated solutions for coping with legal and macro-challenges to innovation at the global and regional levels (Laranja et al., 2008; Chaminade et al., 2008). Both Europe and the European Union can serve as examples of the increased awareness of the importance of this specific trend for cross-country cooperation based on joint rules and guidelines (Blind, 2012; Borrás et al., 2019). As a consequence, innovation policy (from 2005 open innovation policy in particular) has emerged as a separate aspect of innovation concerned not only with the technical or scientific perspectives of knowledge development, but also the political parameters to be regulated at the governmental and regional levels (Aghion et al., 2009; Bodas et al., 2008). Companies and institutions also need to adjust to the regulations and requirements affecting their focus on innovation and its sources (Fernandes et al., 2013), absorptive capacity (Wang, Han, 2011), and sustainable development (Nill, Kemp, 2009).

For *leadership & team management* we can observe long lasting interest of researchers. From around 2005 researchers focused on transformational leadership, seen as an important aspect of project-based organizations and risk management (Keegan et al., 2004; van Knippenberg et al., 2013). Due to the course of research in the space we can observe some references to another trend which is knowledge sharing and management, in the form of the discussion on learning (Edmondson, 2009), tacit knowledge management (Mooradian, 2005) and focus on knowledge distribution and sharing (Lawson et al., 2009; He et al., 2014). Furthermore, researchers analyzed leadership and team management supporting development of innovation (Yang et al., 2008; Le et al., 2019) in cross-functional and international project teams (Aime et al., 2013; Bertolotti et al., 2015). Additionally, leadership competency profiles (Muller et al., 2010), styles and methods (Yang et al., 2011) were broadly discussed to analyze their influence on team creativity and company performance (Bolden, 2010).

Another trend for which we can observe an increase of interest is named *strategic foresight*. It emerged around 2006 and was defined as a structured and systematic approach to analyze available information to road mapping and anticipation of future events and changes (Lee et al., 2005; Bezold, 2010). Researchers were discussing this topic by approaching strategic management (Linstone, 2011), and financial performance, strategic alliances of the organizations as well as planning of organizational sustainable development (Ravasi et al., 2006). To some extent this trend is related to the implementation in supply chain and risk management (Kirchoff et al., 2016), strategic flexibility (Miles, 2010; Huang et al., 2014), and to another trend identified in our study which is new product development (Kahn et al., 2006). What is more, we can find emphasized importance of strategic foresight for innovation development and implementation (Andersen et al., 2014) followed by strategic knowledge management and organization performance (Ruff, 2015; Bamel et al., 2018).

Business cooperation, another rising trend in innovation studies deals with participation of many different parties in business activities. While innovation has recently become one of the key drivers of a company's life cycle, since 2009 the interest has been growing in the idea of fostering collaboration to help speed up and support the development of competitive assets (Lasagni, 2012). As a consequence, in the analyzed papers business cooperation appears as a key, emerging aspect of the discussion on innovation (Schwartz et al., 2010; Colombo, 2012). The articles revealed a multi-dimensional discussion on models of collaboration that can meet the expectations of partners, for example public–private partnerships (Cruz, Marques, 2013). Also, there is a considerable need for highly skilled managers to coordinate joint work on innovation and to support this not always straightforward relationship, where mutual trust and help are needed (Chiaroni et al., 2011; de Araújo Burcharth, 2016). Researchers also discussed the role of science parks, incubators, hubs and an open innovation spirit in promoting the idea of business cooperation (Hansson, 2005; Ratinho, 2010; Bøllingtoft, 2012), and were attracted to the topics of outsourcing, alliances or consortiums as potential models of cooperation (Colombo, 2006; Wagner, Goossen, 2018). Finally, the role of reshoring (Foerstl et al., 2016), outsourcing (Scherrer-Rathje et al., 2014), and offshoring (Lin et al., 2017) was under the scrutiny.

Another interesting rising trend we spotted during our analysis was related to *corporate social responsibility (CSR)*. Before that most times authors highlighted the fact that CSR should be treated from the perspective of the commercial dimension of responsible marketing rather than as an ideological approach to business operations (Hemingway et al., 2004). Over the years, however, we have observed the increasing role played by ISO regulations, ISO 9001 and ISO 26000 (Manders et al., 2016). Especially the introduction of the latter in 2010, the guidance on social responsibility, boost the interest in innovations and strategies and in the context of CSR (Moratis, 2016). Another aspect of this trend is correlated with the increased popularity of public policies combining the formation and fulfillment of the needs of various stakeholders and interdependencies (Wang et al., 2016). This, in turn, has led to research on the

attitudinal employee and consumer typology shaped by different cultures and countries and as well as by the economic conditions of a society (Öberseder et al., 2011; Frynas, Stephens, 2014). There has also been a discussion on the need for CRS communication channels and tools (Seele et al., 2015) depending on social norms (Steven et al., 2017).

Next emerging trend we observe in the literature is the sources of *crowdfunding* for the development of innovation. Finances play a crucial role in innovation development, allowing research organizations to conduct their work, use the latest technologies and, in the end, commercialize innovation (Reynolds, 2011). Some companies often finance their work on innovation with revenue from other areas of their operations, e.g. from sales of generic products. Over the last years we have observed a trend towards accessing external funds for development purposes by means of various instruments provided by investors, governments or financial intermediaries (Hanley et al., 2006; Watkins, 2007). It emerged as a trend around 2013, as apart from interest in the role of banks and the cost of loans, particularly at the seed and early stages of business development (Rostamkalaei, 2016), we have observed the rise of crowdfunding as an alternative strategy adopted by small companies or startups to finance their ideas and innovations by means of social media and social platforms (Stanko, Henard, 2017; Kgoroeadira et al., 2019). Understandingly, the focus in the studies was on crowdfunding performance (Allison et al., 2017), involving the right crowd (Belleflamme et al., 2013; Ryu, Kim, 2016; Roma et al., 2017), and other determinants of the success of crowdfunding (Calic, Mosakowski, 2016). Moreover, some researchers discussed sustainable competition and human rights as important factors of balanced innovation development when selecting a source of financing (Li et al., 2014).

Big data as a trend emerged in the year 2014 in our analysis as a result of significant increase in the computing capabilities of modern information systems used in organizations. The analysis of large amounts of data on customer behavior and economic processes allows for making development decisions and setting directions for research and development (R&D) work (Hartmann et al., 2016; He et al., 2017; Johnson et al., 2017). The subject matter often discussed by the authors was also the relationship between knowledge management and the use of big data in organizations. Potential of big data lies in valuable knowledge creation which helps and in gaining competitive advantage (Sumbal et al., 2017). Among the important topics undertaken in the field of big data, there was also the issue of compliance of big-data systems with the growing regulatory requirements related to the protection of user privacy or obtaining their consent for commercial use (van den Broek, van Veenstra, 2018).

The last trend identified in our study was multifaceted and involved much discussion to define an appropriate name for it. After internal discussion and analysis of relevant publications the name *sustainable applications* was selected as sufficiently general to reflect areas of articles included in this trend. Innovation and technology studies have received increasing attention over the past years (Markarda et al., 2012). In the analyzed literature we can observe the emergence of sustainable economic, technological and social systems (Coenena et al., 2012).

One of the leading areas are renewable sources of energy (Hsu et al., 2013; Peng et al., 2014) with agriculture as important part of sustainable energy transition (Sutherland et al., 2015) as well as mobile industry and banking (Dahlberg et al., 2015) or implementation of innovations in disasters recovery (Ballesteros et al., 2017). Interesting aspects observed are innovations developed by users especially in emerging markets, and their impact on market shape (van der Boor, 2014). Researchers also analyzed socio-technical and political aspects of applications of new technologies and the need for new construct of policy development requirements (Li et al., 2015) and standardization needs (Wiegmann et al., 2017).

Certain logical interconnections can be observed between trends. For example, in the case of business cooperation, the focus was initially on building strong bonds and relationships between partners. This trend evolved towards technology transfer, which is a subject of much debate nowadays (knowledge sharing and management trend). Then, as has been observed in various areas of business operations, the rapid development of technology and innovations require systematic changes in legal regulations and policies, as is reflected in the appearance of another trend: innovation policy. Finally, innovative businesses search for innovative sources of financing. According to our analysis, companies originally relied on banks and other financial institutions, whereas now the stress is on foreign investments and venture capital (in business cooperation).

It is also worth emphasizing the fact that the trends we identified conform to the results of previous studies but are more extensive. The relations are presented in Table 4.

Table 4.
Correspondence of the authors' own results with those of other studies

Trend	Corresponding studies
Internationalization	-
Corporate Social Responsibility	Keupp et al. (2012); Cillo et al. (2019)
Patenting	-
New product development	Garcia et al. (2012); Cillo et al. (2019)
Business cooperation	Keupp et al. (2012); Hossain, Kauranen (2016); De Vasconcelos Gomes et al. (2018); Cillo et al. (2019)
Incubators & spin offs	Crossan, Apaydin (2010); Keupp et al. (2012); De Vasconcelos Gomes et al. (2018); Cillo et al. (2019); Dziallas, Blind (2019)
Crowdfunding	Dziallas, Blind (2019)
Innovation policy	Hossain, Kauranen 2016; Khosravi (2019)
Sustainable applications	Becheikh et al. (2006); Keupp et al. (2012); Garcia et al. (2012); Van Oorschot et al. (2018)
Work-life balance and career development	-
Project and project risk management	Crossan, Apaydin (2010); Gomes et al. (2018); Khosravi et al. (2019)
Knowledge sharing and management	Keupp et al. (2012)
Leadership & team management	Crossan, Apaydin (2010); Khosravi et al. (2019)
Strategic foresight	Keupp et al. (2012)
Big data	-
Lean management	-

Source: own work.

The above table highlights the interdependence between the trends identified in our study and those noted in the literature reviews conducted by other authors. At the same time, it reflects the comprehensive nature of our approach, as none of the previously mentioned literature reviews covered such a broad range of topics. Moreover, a number of detailed issues such as *internationalization, patenting, work-life balance & career development*, *big data*, and *lean management* were given insufficient attention in the previous analysis.

We also appeared to have made a suitable selection of journals for our analysis as they turned out to be the same as those selected by other researchers as leading journals publishing research on innovation (e.g. *Research Policy* – Crossan, Apaydin, 2010; Dziallas, Blind, 2019; *Academy of Management Journal* – Crossan, Apaydin, 2010; Dziallas, Blind, 2019; *Journal of Product Innovation Management* – Crossan, Apaydin, 2010; Dziallas, Blind, 2019, *International Journal of Management Reviews*, Keupp et al., 2012).

6. Conclusions

One of the primary objectives of the present article was to identify present trends in innovation research conducted over the last 20 years. Based on a systematic literature review covering over 22 000 papers we identified 16 trends - 5 long-lasting, 1 declining, 8 emerging and 2 ephemerides in character. The following trends were identified: internationalization, new product development, patenting, knowledge sharing and management, project and project risk management, work-life balance and career development, incubators & spin offs, lean management, innovation policy, leadership & team management, strategic foresight, business cooperation, Corporate Social Responsibility (CSR), crowdfunding, Big data, and sustainable applications.

The two dominant, long-lasting trends that are most frequently discussed in innovation literature are project and project risk management and knowledge sharing and management. The following emerging trends appear to be the most promising from the perspective of future studies: i*ncubators & spin offs, innovation policy, business cooperation, sustainable applications*, with the latter recently gaining the most attention from academics.

The second aim of this study was to verify the usefulness of the proposed methodological approach based on the term frequency – inverted document frequency method (TF-IDF) performed as a full-text analysis. In fact, such an approach enabled us not only to discover trends that had been singled out in previous studies, but also to identify a number of less popular, yet still significant trends.

Our work constitutes an original in-depth investigation into current advances in innovation research using text mining. Furthermore, our results indicate that the developed approach is universal and could be applied when selecting prospective research areas and spotting fields

with increasing potential. Additionally, the text mining procedures adopted in this study could provide researchers with a tool for gaining a thorough grasp of knowledge of a specific field buried in a vast amount of scholarly literature. For practitioners it can offer suggestions on areas of possible business acceleration and transformation. The clustering technique produces an overview of a particular field in greater detail.

We identified two limitations of this study related to the number of papers and cluster size. The study was restricted to the years 2000-2020 and 19 top tier journals dedicated to the field of management and innovation research. The issues of innovation have of course also been discussed in other journals, but if we had applied a broad keyword-based search it would have introduced more serious limitations. Still, the sample size is significantly larger than in most other studies. The other limitation – the minimum cluster size in HDBSCAN – must be defined experimentally. The method requires only one parameter, which is less than is the case with other clustering methods.

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