Advanced technologies for open innovation strategies: Systematic literature review

Obradović Posinković Tena
Faculty of Economics and Business
University of Zagreb
J.F. Kennedy square 6, HR-10000 Zagreb, Croatia
tobradovic@net.efzg.hr

Dabić Marina
Faculty of Economics and Business
University of Zagreb
J.F. Kennedy square 6, HR-10000 Zagreb, Croatia
mdabic@net.efzg.hr

Abstract. *The progress in information technology has influenced the company's strategy and the development of advanced technologies. The open innovation paradigm encourages companies to collaborate with external partners and to share ideas and technologies. The study aims to explore the development of the literature on the connection between open innovation and advanced technologies. The literature review builds upon 95 articles indexed in the Web of Science database. The bibliometric analysis discovered five clusters that are showing the comprehensive intellectual structure on open innovation and advanced technologies. The article concludes with recommendations for future research streams.*

Keywords. open innovation, advanced technologies, literature review, science mapping

1 Introduction

Globalization, turbulent environment and constant technological development had influenced the company's business models and the way they collaborate with stakeholders. Open innovation (OI) paradigm was coined by H. Chesbrough in 2003 as: *"…valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well"* (Chesbrough, 2003, p. 43). In the era of advanced technologies companies are encouraged to exchange their knowledge and technology with external stakeholders. Advanced technologies are creating new business models, improving working conditions and making production more effective (Aquilani et al., 2020). By advanced technologies, we imply Internet of Things (IoT), augmented reality, big data analytics, cloud computing and so on, also they are called the core technologies for Industry 4.0 (Büchi et al., 2020).

The research aim is to contribute to current literature on OI and advanced technologies.

The main research questions are:

RQ1: What are the research trends in the literature of open innovation and advanced technologies?

RQ2: What are the potential future research avenues for open innovation and advanced technologies?

To answer the research questions, bibliometric analysis based on keywords co-occurrence will be used. The bibliometric analysis has been effective in classifying trends in similar scientific fields. For example, OI in manufacturing industry (Obradović et al., 2021), knowledge management in the fourth industrial revolution (Manesh et al., 2020), and digitalization and business models (Caputo et al, 2021).

2 Bibliometric methodology

The purpose of this systematic literature review is to express the current state of intellectual structure on open innovation and advanced technologies. Systematic literature review reveals theoretical background, identifies gaps in the research field and gives an opportunity for positioning future research streams (Okoli & Schabram, 2010). The research is conducted within the Web of Science: Thomas Reuters Social Sciences Citation Index (SSCI), and Science Citation Index Expanded (SSCI).

After reviewing the literature reviews (Ghobakhloo, 2020; Paschou et al., 2020) and studies on digital technologies (Lorenz et al., 2020; Büchi et al., 2020) the search query was formed. A list of ten pillars of Industry 4.0 enabling technologies (Büchi et al., 2020) and keywords from the literature review (Paschou et al., 2020) were combined. Büchi et al., (2020) listed the technologies: advanced manufacturing solutions, augmented reality, internet of things, big data analytics, cloud computing, cyber security, additive manufacturing, horizontal and vertical integration. The final list of keywords is shown in Supplementary Material, Table 3.

The search was completed on the 25th of May 2021, and it resulted in 104 articles. After reading the

articles, 9 of them were excluded from the analysis because they didn't correspond to the topic.

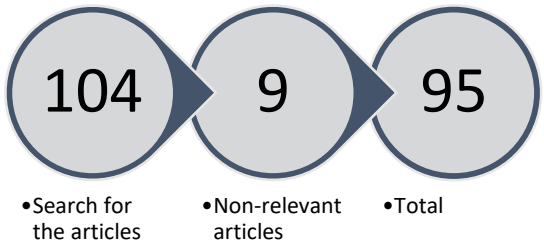

Figure 1. Data collection process

The bibliometric analysis was achieved through VOS viewer version 1.6.11. The analysis of co-occurrence was provided in order to better explore the authors' keywords.

This approach helps researchers to better visualize and understand the current state of the research field. The bibliometric analysis expresses the relationship among keywords. The connection between keywords is stronger when keyword occurs more in the combination with each other (Manesh et al., 2020).

3 Findings

3.1 Data

The period of published articles was between 2011 and 2021, with a peak in 2020.

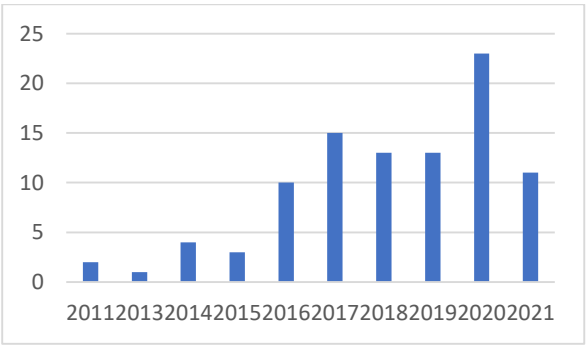

Figure 2. Number of articles published per year

Figure 2 shows the increasing interested in the area of open innovation and emerging technologies and confirms the need for conducting the literature review (Tranfield et al., 2003).

Table 1. shows the journals with at least three published articles in the field of open innovation and advanced technologies.

Sustainability is the leading journal with 12 articles. The top eight journals cover 43% of publications.

Table 1. Most frequent journals

Journal	Frequency
Sustainability	12
IEEE Access	5
Creativity and Innovation Management	5
R & D Management	5
Technological Forecasting and Social Change	4
Journal of Knowledge Management	4
Technovation	3
Business Process Management Journal	3

3.2 Authors keywords over time

The first article was published in 2011 which shows that this field is very new.

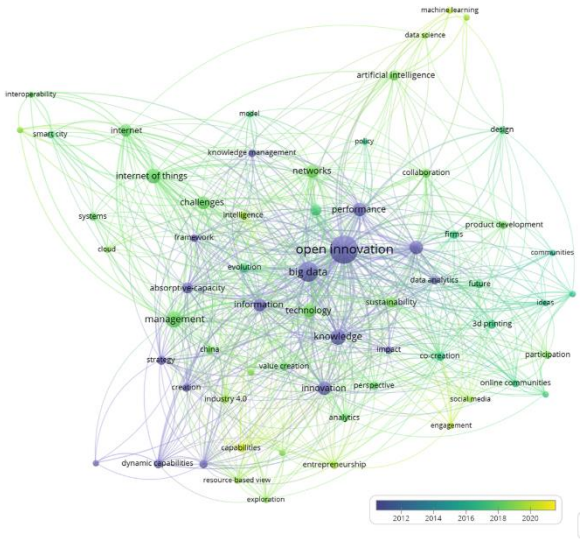

Figure 3. Authors keywords over time

Studies on machine learning that helps predict OI performance (Zheng et al., 2021), OI ecosystem for smart cities (Javed et al., 2020) and social media platforms in the OI context (Huang et al., 2019) are among the more recent studies and represents an opportunity for future research streams.

3.3 Intellectual structure of the field

The analysis shows five different clusters that express the visual map of the field overview (Figure 4.)

Red cluster - Research and Development

The red cluster consists of keywords open innovation, sustainability, co-creation, collaboration, participation, online communities and social media. Companies are collaborating with external stakeholders in order to develop new products. Research and Development

(R&D) is a method of producing new or improved technology that can provide additional value for the company. Del Vecchio et al. (2018) explored tourist involvement through social networks and highlighted the importance of data as a great knowledge asset. Farrington & Alizadeh (2017) studied the impact of digitalization on the wider use of open innovation that can result in an increased understanding of customer needs. Boeing & Wang (2021) explored the influence of the open innovation ecosystem in a digital context. They emphasized the importance of community collaboration during the COVID-19 in order to overcome challenges in public health.

Green cluster – Knowledge-based view (KBV)

The green cluster is characterized by the theory of knowledge-based view. Knowledge-based view highlights the importance of knowledge as a resource that represents the company's competitive advantage. The part of the knowledge-based view is absorptive capacity, which helps in exploring external knowledge. Absorptive capacity was coined in 1990 by Cohen and Levinthal as the*: "ability to recognize the value of new information, assimilate it, and apply it to commercial ends"* (Cohen and Levinthal, 1990, p. 128). The knowledge-based view is an extension of the resource-based view (RBV) that highpoints the organization-specific resources as a competitive advantage.

RBV facilitate the understanding of OI paradigm specifically, regarding dynamic capability (Kashan et al., 2018). Nylund et al. (2018) highlighted the importance of including external flows of knowledge when incorporating and developing advanced technologies. In the era of big data, it is more important than ever to collect, analyse and manage the data. Companies with proper knowledge management have the ability to increase firm's innovativeness (Santoro et al., 2017). KBV and RBV represent the most frequently used theories when researching OI and advanced technologies.

Blue cluster – Internet of Things (IoT)

IoT connects people, machines and products through sensors and intelligent devices. It helps companies to produce new products faster but also to reduce their costs. On the other hand, IoT can help users in everyday life. IoT is changing the way knowledge is managed within organizations, and highlights the necessity for a new open approach (Santoro et al., 2017). Liu et al. (2019) explored the radical innovations that are using the IoT in their product and service innovations. The authors also explored the use of the Internet of Things in smart tourism (Gretzel et al., 2015), smart homes (Kim & Shin, 2021), and smart cities (Alkhammash et al., 2019). Santoro et al. (2017) concluded how knowledge management systems encourage creation of the open ecosystem.

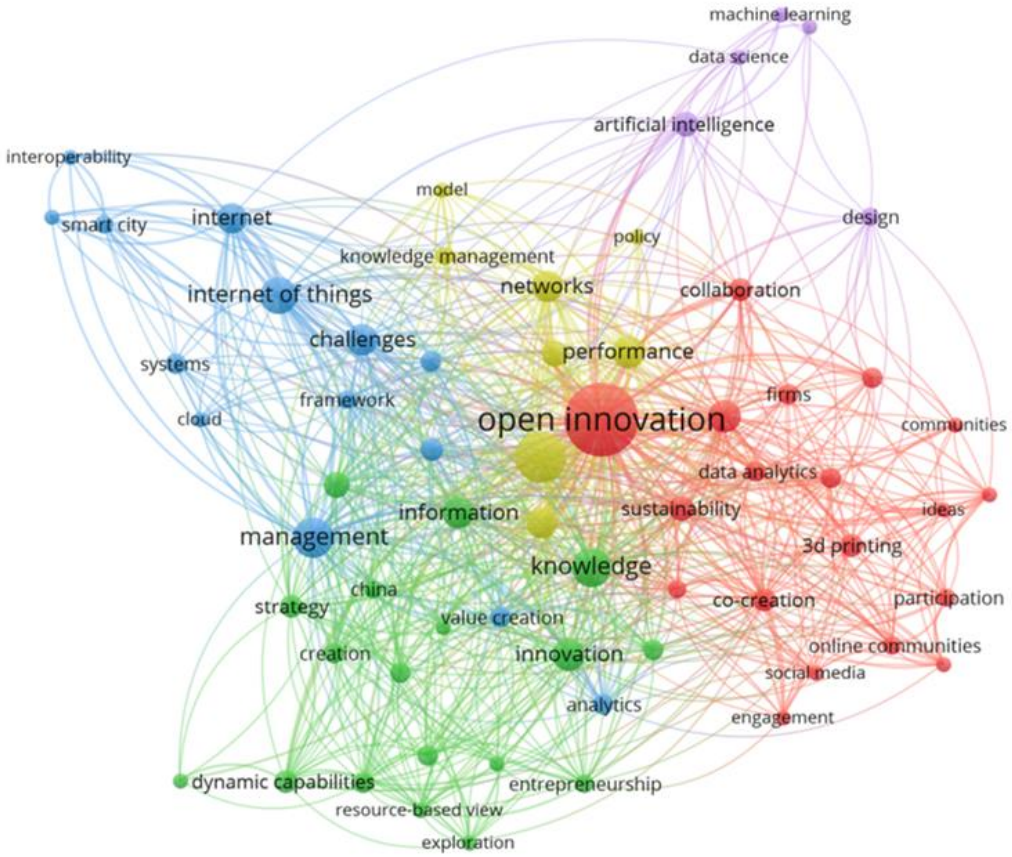

Figure 4. Intellectual structure of the field

Yellow cluster – Data management

Keywords belonging to the yellow cluster are big data, performance and knowledge management. Big data is the most frequent keyword in this cluster, and the importance of organizing and maintaining the data in the meaning of data management was highlighted. Firms can collect a high volume of data, but it is the manager's job to make them useful. Big data for open innovation strategies can be collected from different sources, for example, customers, competitors, employees or machines, products and processes. Big data helps firms in the decision-making process, product design, risk management and customer relationship (Urbinati et al., 2018).

Big data has been used in different areas of research. For example, Wang et al. (2020) explored the role of big data in health care. With the digitalization and change of communication standards in medicine, the development of cloud analysis is growing. Festa et al. (2018) explored the use of big data in the pharmaceutical sector, similarly, there are researches on opportunities of big data in chemistry (Tetko et al. 2016), and biopharmaceutical (Allarakhia, 2014). Cappa et al. (2020) explored the influence of big data on firm performance, and concluded how big data can help firms with a better understanding of opportunities, but at the same time, a high volume of data can have a negative effect on firms when too much information is suffocating the system. Managers have an important role in understanding, using and executing data, and Zeng & Glaiser (2017) explored that transformation process. Also, they highlighted how value creation occurs through the process of data management. Fortunato et al. (2017) studied the use of big data for open innovation activities in the Television domain, while Tan & Zhan (2016) and Zhan et al. (2018) studied the use of big data in the new product development process. By conducting different data, firms can better understand customer's needs. Data providers are most often customers (Zhang & Xiao, 2020) or more specific tourists (Del Vecchio et al., 2018).

Purple cluster – Artificial intelligence (AI)

The purple cluster consists of keywords artificial intelligence, machine learning, data science and design. Machine learning is part of data analysis and is based on artificial intelligence. Machine learning helps in screening huge amounts of information and automates analytical model building (Christensen et al., 2018). Artificial intelligence implies simulation of natural intelligence in machines.

Himanen et al. (2019) explored data-driven science and highlighted the importance of data as a new resource, and emphasized the role of data-science in material science. Wang et al. (2020) studied the role of artificial intelligence in clinical use and stressed the future requirements for AI model architecture sharing.

4 Future research avenues

Based on the bibliometric analysis of 95 articles it is concluded how authors mostly explored the big data and Internet of Things in the context of open innovation. That is why we encourage researchers and practitioners to explore the opportunities of other advanced technologies such as augmented reality, 3D printing, horizontal and vertical integration and cyber security for open innovation. Table 2 shows the clusters and their keywords with recommendations for future research questions.

Table 2. Future research avenues

Cluster	Keywords	Future research questions
Red *R&D*	Open innovation, sustainability, co-creation, collaboration, participation, online communities, social media	• How can 3D printing technologies be useful for open innovation activities? • How can vertical and horizontal integration encourage open innovation activities? • By opening up the innovation process, how can 3D printing reduce production waste?
Green *KBV*	Knowledge, information, innovation, resource-based view, dynamic capabilities, strategy	• What is the role of dynamic capabilities in big data analytics? • What is the role of absorptive capacity in big data analytics?
Blue *IoT*	IoT, internet, management, challenges, smart city	• How can the implementation of IoT open up new potential for collaboration in the healthcare sector?
Yellow *Big data*	Big data, performance, network	• How can big data analytics capability help firms to improve their relationships with customers?
Purple *AI*	AI, machine learning, data science	• How can AI encourage companies to create new open business models? • How can augmented reality impact the knowledge exchange in medical training?

We encourage the study of benefits not only for companies but also for users. Collaboration between firms and consumers can encourage new products and services, but also make production more sustainable. New digital technologies can improve life in order to make medicine more effective, production more sustainable and bringing more value for the customers. Aquilani et al. (2020) studied the new perspective, called Society 5.0 that will surpass the Industry 4.0 concept and put people in the center. They highlighted the importance of open innovation in this transition process.

5 Conclusion

The study aimed to explore the comprehensive intellectual structure of open innovation and advanced technologies. The bibliometric analysis based on keywords co-occurrence was used for exploring the current research trends in the literature and for discovering future avenues. The results show that big data and Internet of Things in the context of open innovation were the most frequently studied topics. That is why, we encourage practitioners and researchers to study the relationship between other advanced technologies (for example 3D printing, augmented reality and artificial intelligence) and open innovation.

References

Alkhammash E.H., Jussila, J., Lytras M.D., Visvizi A. (2019). Annotation of Smart Cities Twitter Micro-Contents for Enhanced Citizen's Engagement. IEEE Access, 7, 116267-116276. DOI: 10.1109/ACCESS.2019.2935186

Allarakhia, M. (2014). The successes and challenges of open-source biopharmaceutical innovation. Expert Opinion on Drug Discovery, 9(5), 459–465. DOI: 10.1517/17460441.2014.905539

Aquilani B, Piccarozzi M, Abbate T, Codini A. (2020). The Role of Open Innovation and Value Co-creation in the Challenging Transition from Industry 4.0 to Society 5.0: Toward a Theoretical Framework. Sustainability. 12(21):8943. https://doi.org/10.3390/su12218943

Boeing P. & Wang Y. (2021). Decoding China's COVID-19 'virus exceptionalism': Community-based digital contact Tracing in Wuhan. R&D Management. https://doi.org/10.1111/radm.12464

Büchi, G., Cugno M. & Castagnoli R. (2020). Smart factory performance and Industry 4.0. Technological Forecasting & Social Change. Volume 150, 2020, 119790, https://doi.org/10.1016/j.techfore.2019.119790.

Cappa, F., Oriani, R., Peruffo, E., & McCarthy, I. (2020). Big Data for Creating and Capturing Value in the Digitalized Environment: Unpacking the Effects of Volume, Variety and Veracity on Firm Performance. Journal of Product Innovation Management. doi:10.1111/jpim.12545

Caputo, A., Pizzi, S., Pellegrini, M. M., & Dabić, M. (2021). Digitalization and business models: Where are we going? A science map of the field. Journal of business research, 123, 489-501. DOI: 10.1016/j.jbusres.2020.09.053

Chesbrough, H.W. (2003). Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business School Press, Boston, MA.

Christensen, K., Scholderer J., Hersleth S.A., Næs T., Kvaal, K., Mollestad T., Veflen, N. & Risvik E. (2018). How good are ideas identified by an automatic idea detection system? Creativity and Innovation Management, 27, (1), 23-31. https://doi.org/10.1111/caim.12260

Cohen W.M. & Levinthal D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35, 1, 128-152.

Del Vecchio, P., Mele, G., Ndou, V., & Secundo, G. (2018). Open Innovation and Social Big Data for Sustainability: Evidence from the Tourism Industry. Sustainability, 10(9), 3215. doi:10.3390/su10093215

Farrington T. & Alizadeh A. (2017) On the Impact of Digitalization on R&D. Research-Technology Management, 60 (5), 24-30. DOI: 10.1080/08956308.2017.1348130

Festa, G., Safraou, I., Cuomo, M.T. and Solima, L. (2018). Big data for big pharma: Harmonizing business process management to enhance ambidexterity, Business Process Management Journal, 24 (5), 1110-1123. https://doi.org/10.1108/BPMJ-10-2017-0272

Fortunato, A., Gorgoglione, M., Messeni Petruzzelli, A., & Panniello, U. (2017). Leveraging Big Data for Sustaining Open Innovation: The Case of Social TV. Information Systems Management, 34(3), 238–249. doi:10.1080/10580530.2017.1330000

Ghobakhloo, M. (2020). Industry 4.0, Digitization, and Opportunities for Sustainability. Journal of Cleaner Production, 252. https://doi.org/10.1016/j.jclepro.2019.119869

Gretzel, U., Sigala, M., Xiang, Z., & Koo, C. (2015). Smart tourism: foundations and developments. Electronic Markets, 25(3), 179–188. https://doi.org/10.1007/s12525-015-0196-8

Himanen, L., Geurts, A., Foster, AS. & Rinke, P. (2019). Data-Driven Materials Science: Status, Challenges, and Perspectives. Advanced Science, 6 (21). https://doi.org/10.1002/advs.201900808.

Huang L, Zhao Y, Mei L, Wu P, Zhao Z, Mao Y. (2019). Structural Holes in the Multi-Sided Market: A Market Allocation Structure Analysis of China's Car-Hailing Platform in the Context of Open Innovation. Sustainability, 11(20), 5813. https://doi.org/10.3390/su11205813.

Javed A., Kubler S., Malhi A., Nurminen A., Robert J., Främling K. (2020). bIoTope: Building an IoT Open Innovation Ecosystem for Smart Cities. IEEE Access. DOI 10.1109/ACCESS.2020.3041326.

Kashan, A.J., Mohannak, K., Perano, M., and Casali, G. (2018). A discovery of multiple levels of open innovation in understanding the economic sustainability. A case study in the manufacturing industry. Sustainability, 10, 12, 4652. https://doi.org/10.3390/su10124652

Kim, E. & Shin, K. (2021). Evolution of Open Innovation by Value-based Network Perspective: The Case of Korean Smart Home IndustryScience, Technology & Society 26 (2), 223–241. DOI: 10.1177/09717218211005603

Liu, W., Tan, R., Cao, G., Zhang, Z., Huang, S., & Liu, L. (2019). A proposed radicality evaluation method for design ideas at conceptual design stage. Computers & Industrial Engineering. doi:10.1016/j.cie.2019.04.027

Lorenz, R., Benninghaus, C., Friedli, T. & Netland, T.H. (2020.). Digitization of manufacturing: the role of external search, International Journal of Operations & Production Management, Vol. 40 No. 7/8, pp. 1129-1152. https://doi.org/10.1108/IJOPM-06-2019-0498

Manesh, M. F., Pellegrini, M. M., Marzi, G., & Dabic, M. (2020). Knowledge management in the fourth industrial revolution: Mapping the literature and scoping future avenues. IEEE Transactions on Engineering Management, 68(1), 289-300. doi: 10.1109/TEM.2019.2963489.

Nylund, P. A., Ferras-Hernandez, X., & Brem, A. (2018). Automating profitably together: Is there an impact of open innovation and automation on firm turnover? Review of Managerial Science. doi:10.1007/s11846-018-0294-z

Obradović T., Vlačić B. & Dabić M. (2021.). Open innovation in the manufacturing industry: A review and research agenda. Technovation, 102, https://doi.org/10.1016/j.technovation.2021.102221

Paschou, T., Rapaccini, M., Adrodegari, F., & Saccani, N. (2020). Digital servitization in manufacturing: A systematic literature review and research agenda. Industrial Marketing Management. doi:10.1016/j.indmarman.2020.02.012

Santoro, G., Vrontis, D., Thrassou, A., & Dezi, L. (2017). The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity. Technological Forecasting and Social Change. doi:10.1016/j.techfore.2017.02.034

Tan, K. H., & Zhan, Y. (2016). Improving new product development using big data: a case study of an electronics company. R&D Management, 47(4), 570–582. DOI: 10.1111/radm.12242

Tetko, I. V., Engkvist, O., Koch, U., Reymond, J.-L., & Chen, H. (2016). BIGCHEM: Challenges and Opportunities for Big Data Analysis in Chemistry. Molecular Informatics, 35(11-12), 615–621. https://doi.org/10.1002/minf.201600073

Tranfield, D., Denyer, D., and Smart, P. (2003), Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, 14(3), 207-222. doi:10.1111/1467-8551.00375

Urbinati, A., Bogers, M., Chiesa, V., & Frattini, F. (2018). Creating and capturing value from Big Data: A multiple-case study analysis of provider companies. Technovation. doi:10.1016/j.technovation.2018.07.004

Wang, S. Y., Pershing, S., & Lee, A. Y. (2020). Big data requirements for artificial intelligence. Current Opinion in Ophthalmology, 31(5), 318–323. doi:10.1097/icu.0000000000000676

Zeng, J., & Glaister, K. W. (2017). Value creation from big data: Looking inside the black box. Strategic Organization, 16(2), 105–140. doi:10.1177/1476127017697510

Zhan, Y., Tan, K.H., Li, Y. et al. (2018). Unlocking the power of big data in new product development. Ann Oper Res 270, 577–595. https://doi.org/10.1007/s10479-016-2379-x

Zhang H. & Xiao Y., (2019). Customer involvement in big data analytics and its impact on B2B Innovation. Industrial Marketing Management, https://doi.org/10.1016/j.indmarman.2019.02.020.

Zheng, J., Qiao, H., Zhu, X. and Wang, S. (2021), "Knowledge-driven business model innovation through the introduction of equity investment: evidence from China's primary market", Journal of Knowledge Management, Vol. 25 No. 1, pp. 251-268. https://doi.org/10.1108/JKM-02-2020-0158

Appendix

Table 3. Search Query

	Search Query	
#1	TS = ("cyber* security*" OR “advanced manufacturing*” OR “IoT” OR "internet of things*" OR “cloud*” OR “Big data*” OR "simulation of connected machines*" OR “horizontal system integration*” OR “vertical system integration*” OR “additive manufacturing*” OR “augmented reality*” OR “autonomous robots*” OR "artificial intelligence*" OR "3D printing*")	326,500
#2	TS = ("open innovation*")	2,622
Combine Search Query 1 and 2		104