https://doi.org/10.22306/atec.v10i1.190 *Received: 04 Dec. 2023; Revised: 28 Jan. 2024; Accepted: 15 Feb. 2024*

Bibliographic research on the linkages between intellectual capital and Industry 4.0

Natalia Slyvkanyc
Department of Banking and Investment, Faculty of Economics, Technical University of Košice, Nemcovej 32, 040 01 Košice, Slovak Republic, EU, natalia.slyvkanyc@tuke.sk
Jozef Glova
Department of Banking and Investment, Faculty of Economics, Technical University of Košice, Nemcovej 32, 040 01 Košice, Slovak Republic, EU, jozef.glova@tuke.sk (corresponding author)
Samed Kruger
University of Wuppertal, Schumpeter School of Business and Economics, Department of Finance and Corporate Governance, Gaußstraße 20, 42119 Wuppertal, Germany, EU, krueger@wiwi.uni-wuppertal.de

Keywords: intellectual capital, Industry 4.0, innovations, co-occurrence and co-authorship, bibliographic research.
Abstract: The modern world is changing rapidly. A new knowledge-based economy pushes companies and countries to pay attention not only to the products but also to the intellectual capital. This paper uses a bibliometric study to map the conceptual approach of the Relationship between intellectual capital and Industry 4.0 for 1980 – 2022. For this study, we used the Web of Science as a main database for data collection. During the period 1980 – 2022, we filtered 24 671 records for our final sample. Collected data were analysed with descriptive statistics, co-occurrence analysis, co-authorship and citation analyses. VOSviewer was used for further visualisation of results. As these linkages are not well understood yet, this paper has added value to developing these relationships from a bibliographic point of view.

1 Introduction

Industry 4.0 is gaining more and more attention and is often compared to a disruptive increase in products, such as the Industrial Revolution [1]. Like previous revolutions, Industry 4.0 is not initiated by a single technology but by the interaction of several technological advances whose impact will lead to production and management methods [2].

The world is changing rapidly, and businesses must adapt to keep up with the shifting landscape. As globalisation and interconnectedness grow, social responsibility and environmental concerns become increasingly important business considerations. At the same time, the focus on intellectual capital (IC) and intangible assets is opening up various questions and debates about how we measure value and success in the modern economy. To fully realise the potential of both IC and Industry 4.0, we must evolve our existing frameworks and adopt a more expansive view of value domains. That means integrating the economic and societal impacts of the fourth industrial revolution into our thinking and decision-making processes. Doing so can create a more sustainable and equitable future for individuals, organizations, and nations [2,3].

This paper is structured as follows. The first part of the paper is dedicated to the theoretical background, where we explain the terms “Intellectual capital” and “Industry 4.0” and how they are related. The second part describes the data collection process and the methodology used in our bibliographic research. Here, we have also described the research questions of this study. The third part is donated to empirical results where we describe co-word analyses, citation and co-authorship analyses to answer the research questions set in the beginning. The last part is the conclusion of the paper.

2 Theoretical background

Technological innovation is important in transforming consumers’ lives in today’s economy. New services and capabilities launched in various fields drive these changes. Among them are artificial intelligence, blockchain technology, further deployment and increased availability of digital channels. As a result, business operations, intellectual capital and efficiency have changed [4]. The phenomenon of knowledge capital has become a central theme due to the introduction of the new knowledge-based economy. This knowledge-based economy has generated interest in the intangible assets owned by organisations and economies [5].

Technological innovation, IC and economic growth are closely related and can be formulated as a general concept of cycle or wave. Each wave represents a diffuse phase in a series of technological innovations that create new economic sectors and opportunities for investment and growth. Since the start of the Industrial Revolution at the end of the 18th century, six waves have been identified [6]:

- 1st wave (1785 – 1845). It relied on innovations such as hydro power, textiles, and iron. The beginnings of the Industrial Revolution focused primarily on simple goods such as clothing and tools that could benefit many people. Existing maritime technology using sailboats supported and improved large colonial and trading empires, especially in England, France, the Netherlands and Spain. An important inland water transportation system was also established. Total production and transportation costs have been greatly reduced.

- 2nd wave (1845 – 1900). It was assumed that the massive use of coal as an energy source was only due to steam engines. That developed the rail transport system, opened up new markets and gave access to a wider range of resources at the international and national levels. Steamships had a similar impact on maritime transport and expanded commercial opportunities in world trade. Mass production of cotton also greatly expanded the possibilities of the textile industry, making clothing more affordable.
- 3rd wave (1900 – 1950). Electrification was an important economic change because it enabled the use of a wide range of machines and devices. It also allowed the development of urban transportation systems such as subways and trams. Another major improvement was the internal combustion engine, which created an entire automobile industry and expanded passenger and freight mobility.
- 4th wave (1950 – 1990). The post-World War II period was marked by major industrial changes involving new materials such as plastics (petrochemicals) and new electronics (television) sectors. The jet engine expanded the aerospace industry to the mass market and enabled global mobility.
- 5th wave (1990 – 2020). The development of information systems has greatly improved the trading environment with new communication methods and more efficient management of production and distribution systems (logistics). That has spawned new industries primarily related to personal computing devices, such as computer manufacturing, software programming, and, more recently, e-commerce platforms.
- 6th wave (2020 – ?). The key technologies likely to drive the sixth wave are already in place, primarily including robotics, automation, digitization and sustainability. Digitization implies a high level of information technology in management, operation, and goods and services. The sixth wave is called the fourth industrial revolution, called Industry 4.0.

The Relationship between Industry 4.0 and organizational intellectual capital is poorly understood. Since the early 1990s, IC research has reached 40 years [7,8]. Meanwhile, the concept of Industry 4.0 only emerged and gained recognition in 2011. Since then, various aspects of the Relationship between Industry 4.0 and organizational change have been explored, and the interest in this type of research has recently increased [9,10]. Industry 4.0 drives organizational change in many economic, social, technological, political and legal aspects. Intellectual capital, a key resource and driving force behind value creation in organizations, is no exception. Its role in implementing Industry 4.0 is very important [2,11].

The phenomenon of intellectual capital has no standardised definition. Intellectual capital can be defined as the accumulation of individual knowledge, skills, experience and knowledge embodied in the human brain [8]. For W. J. Martin [12], intellectual capital is intellectual material formulated, captured, and used to create assets of higher value. Rudež and Mihalič [13] defined intellectual capital as a knowledge-based asset developed through flows between different categories. On one hand, intellectual capital can be defined as a portfolio of intangible resources and their flows. On the other hand, intellectual capital can be defined as obtaining future benefits without monetary or material form. Despite the absence of a single definition of intellectual capital, researchers recognize the existence of three main categories: the so-called triad of intellectual capital represented by human capital, structural capital and relation capital [13-18].

The Industry 4.0 phenomenon emerged in Germany in 2011 as a proposal for economic policy development based on the High-Tech Strategy [19], as well as the application of the Internet of Things (IoT) and Internet of Services (IoS) to industrial processes. Using digital technologies that unite the physical and virtual worlds, manufacturing companies are moving from mass production to custom production, which is happening rapidly [2].

Industry 4.0 applies to people as well as machines. In a knowledge-based economy, intellectual capital forms the basis for the successful development of businesses and countries. Industry 4.0 requires a paradigm shift towards organizational structures, human roles and activities. New types of employee competencies and skills are becoming important. There are issues related to employee interaction and organizational communication [20,21]. Changes in organizational structure lead to changes in overall structural capital. Innovation affects corporate strategy, work organization, workforce development, information and knowledge management, cultural aspects and other aspects of structural capital [22]. According to Fettig et al. [20], managing these transformations becomes paramount. Unfortunately, this is where traditional management methodologies reach their limits. Many different transformations are taking place in Industry 4.0 in the context of relation capital. Platformization increases complexity, while digitalization brings more dynamics and intensity to relationships. The boundaries between the organization and its environment become even more blurred while the possibilities to assess the total value of organizational relationship capital get even more complicated [23]. Remote working and process management opportunities and the contribution of social networks speed up internal and external communication, accelerate the establishment of new contacts, and facilitate the outsourcing external resources [24]. By automating communication and relationship management, new possibilities for developing personalized solutions emerge. In some situations, digital technologies such as blockchain increase transparency and efficiency by removing the human factor. At the same time, however, digital technology brings challenges such as dependence on technology uptime and cybersecurity concerns [25].

Industry 4.0 fundamentally changes an organization's intellectual capital by transforming its key components and characteristics, which poses management challenges. The challenges are preserving existing knowledge in organizations while maximizing the value created by new technologies. The impact of Industry 4.0 on different components of IC varies. However, the most difficult transformations regarding human capital responsible for developing the Relationship. and structural capital are perhaps observed. Industry 4.0 delivers process productivity and efficiency. However, this also increases management uncertainty and additional risks that must be managed [22].

3 Data collection

When conducting high-quality research, using the right database is crucial. We used Web of Science (WoS) by Clarivate for our study. WoS is a trusted and reliable database that university researchers widely use for its comprehensive coverage of scholarly literature across various disciplines. We used WoS filters to narrow our search results to ensure that our sample was representative and relevant to our research question. By applying filters such as publication date, subject area, and so on, we created a focused and diverse sample, including only impactful research in our field. Using WoS and its filters allowed us to conduct a rigorous and thorough literature analysis, ensuring our findings were based on the most reliable and relevant sources. Table 1 illustrates the framework of the data collection process.

Table 1 Framework of the data collection process

	Results of filtering
SELECTED KEYWORDS	Intellectual (All Fields) AND Capital (All Fields) OR Intellectual Capital (All Fields) OR Manufacturing (All Fields) OR Industry 4.0 (All Fields) OR Industry 5.0 (All Fields) OR Intangibles (All Fields) OR Intelligent manufacturing (All Fields) OR Innovation (All Fields) OR Innovative techniques (All Fields) OR Smart factory (All Fields) OR Manufacturing systems (All Fields).
WoS Database	Total Documents: **3 464 654**
1st Inclusion Criteria:	Web of Science Categories: "Management", "Multidisciplinary Sciences", "Economics", "Business", "Business Finance", "Social Sciences Interdisciplinary", "Research Management Science", "Social Science Mathematical Methods", "Mathematics interdisciplinary Applications" AND exclude all others. Total Documents: **262 940**
2nd Inclusion Criteria:	Years: 1980 - 2022 Total Documents: **258 833**
3rd Inclusion Criteria:	Language: "English" Total Documents: **249 425**
4th Inclusion Criteria:	Document types: "Article", "Open access". Total Documents: **117 588**
5th Inclusion Criteria:	Citation topics: "Management", "Economics", "Economic Theory". Total documents: **24 671**
FINAL SAMPLE	**24 671 RECORDS**

The keywords above in a bibliographic analysis identify relevant literature on intellectual capital, manufacturing, industry 4.0 and 5.0, intangibles, intelligent manufacturing, innovation, innovative techniques, smart factories, and manufacturing systems. By including these keywords, we can explore various aspects of the manufacturing industry and how it is evolving by integrating new technologies and concepts. Additionally, using these keywords helps identify research gaps and potential areas for further study.

We need to consider that intellectual capital development started in the late 1980s. The concept of Industry 4.0 did not emerge until much later, around 2011, with the publication of a report by the German government on the future of manufacturing. This report outlined the potential for integrating advanced technologies in the manufacturing industry, such as the Internet of Things, artificial intelligence, and robotics. As a result, we divide our sample into two periods: 1980 – 2010 and 2011 – 2022. This approach can help ensure the study produces robust and reliable findings grounded in a comprehensive understanding of the available data.

Table 2 Selected samples

	Total number of articles
1980 – 2022	24 671
1980 – 2010	3 253
2011 – 2022	21 418

Figure 1 demonstrates the countries with the highest publication records, with more intense blue colours representing higher publication rates, middle blue representing moderate publication rates, and less intense blue representing lower publication rates. Unfortunately, we have no information regarding the light grey areas. Authors from the United Kingdom have the highest number of articles related to intellectual capital and manufacturing areas. So, the United Kingdom has published 6,534 papers from 24,671. The second is the USA, with 4,807 published articles. The next is China, with 2,099 articles. Countries like Germany, the Netherlands, Spain, France, Australia, Sweden and Italy have published around 1 thousand papers. Our study includes a total of 152 countries for further analysis.

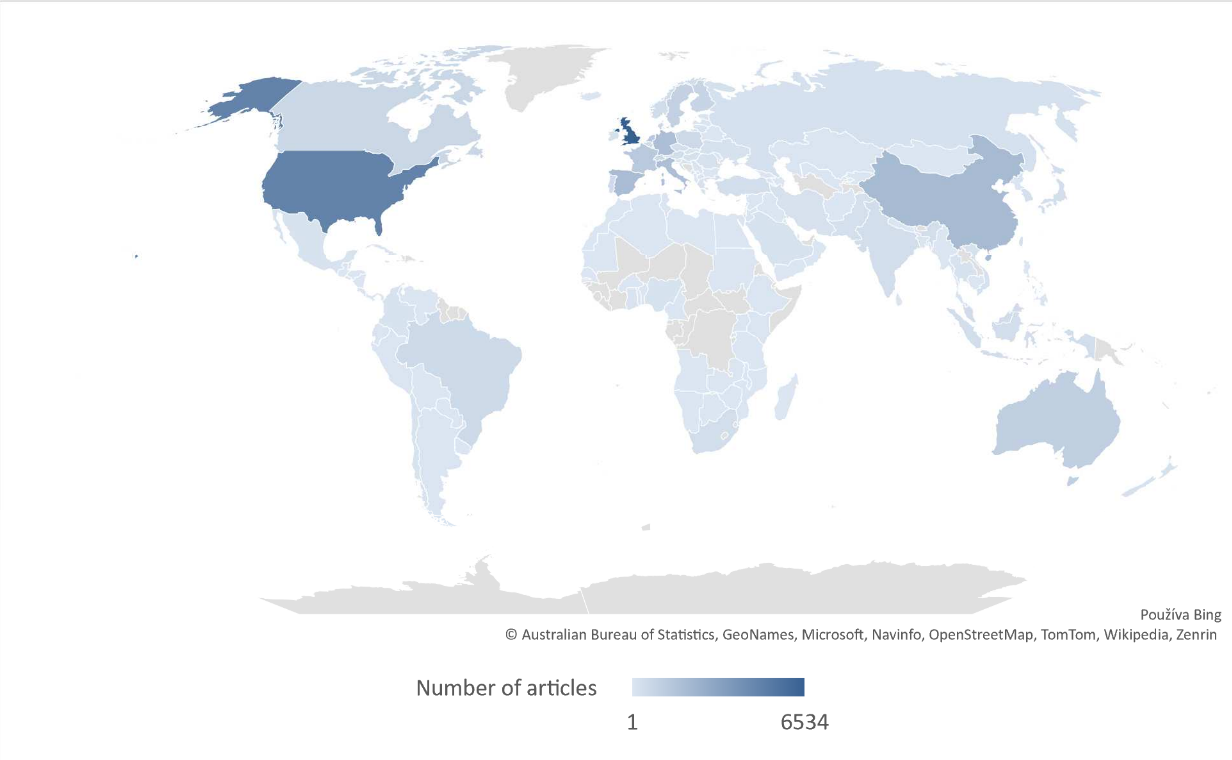

Figure 1 Wold map of the number of articles

4 Methodology

Bibliographic research is an important aspect of research in various scientific fields. That includes the systematic study of published material such as books, articles, and other relevant sources of information on a particular topic. A bibliographic study aims to identify and analyse the existing literature on a particular topic and provide a comprehensive overview of research conducted in this field [26]. One of the major benefits of bibliographic research is that it can help researchers identify gaps in the literature and potential areas for future research. It can also provide a deeper understanding of the history of a particular field of study and the evolution of concepts, theories and methodologies. Bibliographic studies can also help researchers determine the validity and reliability of existing research by identifying the source and authors of the research and assessing the quality of their work [27]. Citations play an important role in bibliographic research because they track the impact and influence of research over time. It enables researchers to identify key authors and publications in a particular field and to track the spread and adoption of new ideas and concepts. Citation data can also be used to analyse the structure and dynamics of research networks and collaborations and to assess the impact of individual researchers and institutions [26], [28].

This study aims to provide answers to the research question that was set:

RQ1: What are the main themes framing the Relationship between intellectual capital and Industry 4.0?

RQ2: Does the trend of topics is similar during the researched period?

RQ3: Which journals are the most cited?

RQ4: Which authors are the most cited?

RQ5: Which countries lead the research of intellectual capital and Industry 4.0 (the most cited)?

VOSviewer was used as the main software for realising the mentioned analysis. Visualization of Science Landscapes (VOSviewer) is free downloadable software for building and visualizing reference networks in journals, researchers, or individual publications. It can be based on citations, bibliographic links, or co-authors. The software provides text-mining capabilities that can be used to visualize consensus networks of important information in scientific literature. The software associates keywords using the association function (default). Association strength is used to normalize the strength of links between elements [29].

5 Empirical analysis

5.1 Keywords analysis

Co-occurrence analysis includes keywords with the same subject. That indicates the presence, frequency and proximity of similar keywords in articles. It is crucial to set up the threshold of the minimum number of occurrences of keywords [30,31]. As research is divided into three parts, for each of them, we set a threshold separately: a threshold of 50 was set for the period 1980 – 2022; a threshold of 20 was set for the period 1980 – 2010; a threshold of 50 was set for the period 2011 – 2022. The top 50 frequent keywords for each sample are shown in Table 3.

Table 3 The top 50 more occurred keywords of three researched samples

Keywords (1980 – 2022)	Occurrence	Keywords (1980 – 2010)	Occurrence	Keywords (2011 – 2022)	Occurrence
Innovation	6 852	Innovation	790	Innovation	6 062
Performance	3 955	Performance	326	Performance	3 629
Impact	2 523	Model	257	Impact	2 388
Model	1 942	Growth	247	Management	1 806
Management	1 933	Productivity	204	Model	1 685
Growth	1 754	Firms	177	Knowledge	1 530
Knowledge	1 687	Research and development	170	Growth	1 507
Research and development	1 648	Technology	165	Research and development	1 478
Firms	1 374	Industry	159	Technology	1 202
Technology	1 367	Knowledge	157	Firms	1 197
Productivity	1 237	Competition	154	Entrepreneurship	1 107
Entrepreneurship	1 185	Impact	135	Productivity	1 033
Determinants	1 055	Investment	128	Firm performance	966
Strategy	1 035	Management	127	Determinants	951
Firm performance	1 010	Entry	120	Strategy	933
Competition	878	Trade	116	Capabilities	779
Capabilities	867	Dynamics	111	Competition	724
Investment	850	Market	109	Investment	722
Industry	814	Determinants	104	Information	682
Information	774	Strategy	102	Industry	655
Market	750	Evolution	95	Networks	653
Networks	736	Information	92	Perspective	643
Perspective	705	Capabilities	88	Market	641
Behaviour	695	Networks	93	Absorptive capacity	630
Absorptive capacity	694	Diffusion	83	Behaviour	630
Dynamics	680	Spillovers	81	Dynamic capabilities	609
Trade	641	Entrepreneurship	78	Business	600
Dynamic capabilities	639	Competitive advantage	73	SMEs	578
Business	623	Policy	67	Dynamics	569
SMEs	595	Organizations	66	Trade	525
Competitive advantage	548	Behaviour	65	Antecedents	510
Evolution	543	Absorptive capacity	64	Framework	500
Organizations	540	Product development	64	Strategies	492
Antecedents	535	Patents	64	Systems	477
Strategies	535	Integration	62	Governance	476

Framework	534	Perspective	62	Competitive advantage	475
Systems	532	Employment	56	Risk	475
Risk	528	Systems	55	Evolution	448
Policy	515	Costs	55	Policy	448
Governance	503	Uncertainty	55	Quality	424
Quality	463	Demand	54	Integration	397
Integration	459	Size	53	Sustainability	387
Product development	430	Economics	53	Collaboration	384
Collaboration	417	Risk	53	Exploration	379
Exploration	407	Resource-based view	52	Market orientation	367
Cooperation	407	Economic growth	51	Design	367
Uncertainty	407	Returns	49	Product development	366
Market orientation	401	Panel data	45	Open innovation	364
Efficiency	400	Firm performance	44	Trust	363
Resource-based view	394	Efficiency	42	Adoption	361

The period of 1980 – 2022 is the final sample from our filtering which was step-by-step described in the previous part. The sample includes 24 671 articles and 46 025 keywords. Almost 620 keywords met the threshold of 50. These keywords are divided into 4 clusters, illustrated in Figure 2.

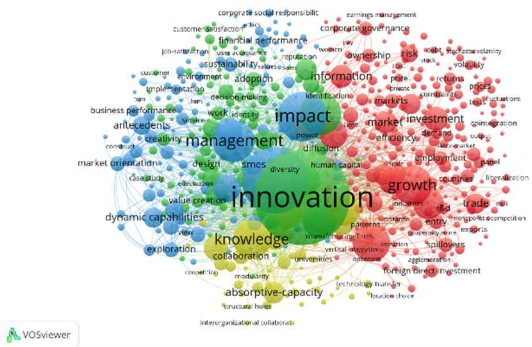

Figure 2 Analysis of keywords during 2011 – 2022

Period of 1980 – 2010. This sample includes 3,253 articles, which include 7,573 keywords. As we mentioned, a threshold was set at 20. One hundred seventy-six keywords that met the threshold were divided into 5 clusters with 6 481 links, illustrated in Figure 3.

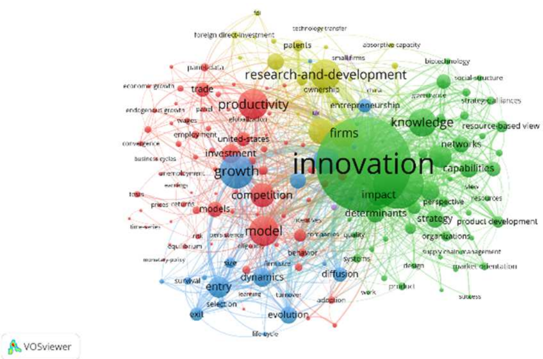

Figure 3 Analysis of keywords during 1980 – 2010

Period of 2011-2022. This sample includes 21,418 articles with total keywords of 43,253. As we mentioned, the threshold for this sample was set at 50. Five hundred sixty-five keywords that met the threshold were divided into 5 clusters with 64528 links, illustrated in Figure 4.

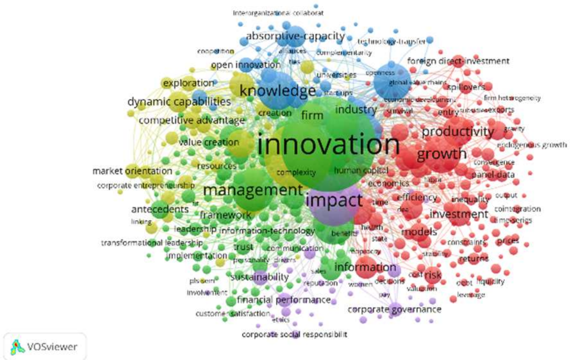

Figure 4 Analysis of keywords during 2011 – 2022

5.2 *Citation analysis*

With the help of co-citation analysis, we analysed the most cited journals, authors, and countries. For this analysis, we used the third sample for 2011 – 2022. The reason is that we want to represent the current trend of citations or in other words, we would like to illustrate the results for the period when both researching concepts are already developed in research fields.

For this citation analysis, we set the minimum number of source documents to 5 and the minimum number of source citations to 100. The sample contained 1 109 sources, of which 379 reached the threshold. Added impact factor, quartile and publisher according to Journal Citation Record (WoS product). We used the most recent data available for 2021.

Table 4 The top 10 most cited journals sorted by the number of citations

	Number of citations	Number of documents	Impact factor (2021)	Quartile (2021)
Research Policy	21 734	400	9,473	Q1
Journal of Business Research	14 389	398	10,969	Q1
American Economic Review	10 986	115	11,490	Q1
Small Business Economics	8 849	287	7,096	Q2
Strategic Management Journal	8 250	130	7,815	Q1
Quarterly Journal of Economics	7 524	47	19,013	Q1
Management Science	5 225	112	6,172	Q2
Organization Science	5 141	101	5,152	Q2
International Journal of Operations & Production Management	5 003	160	9,360	Q1
Journal of Financial Economics	4 971	55	8,238	Q1

To analyse the most cited authors, we used the co-authorship analysis. The minimum number of source documents was set to 5, and the minimum number of source citations to 200. Four hundred forty-eight authors met the threshold out of 39164. These authors were divided into 25 clusters with 205 links (see Figure 5).

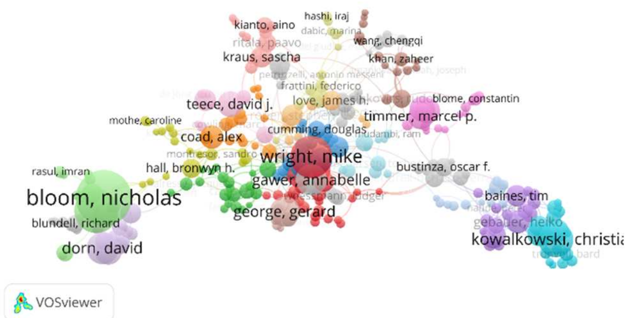

Figure 5 Co-authorship analysis by authors

Table 5 illustrates the top 10 most cited authors sorted by the number of citations.

Table 5 The top 10 of the most cited authors

	Number of citations	Number of documents
Nicholas Bloom	5 968	21
John Van Reenen	4 103	35
Mike Wright	3 755	42
Christian Kowalkowski	2 778	29
David Dorn	2 433	9
Annabelle Gawer	2 326	8
Gerard George	2 203	24
Hashem M. Perasan	1 816	7
Qiang Ji	1 815	18
Gordon H. Hanson	1 797	5

We have already mentioned (and illustrated) some countries with the most published articles (see Figure 1). In this part, we paid attention to the number of citations. For this analysing, we have used co-authorship analysis. The minimum number of source documents was set to 5, and the minimum number of source citations to 100. Eighty-eight countries met this special threshold setting out of 151. Figure 6 illustrates this co-authorship analysis. These 88 countries were divided into 7 clusters with 1,619 links.

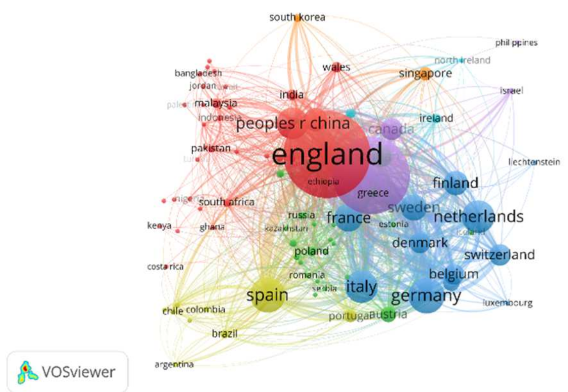

Figure 6 Co-authorship analysis by countries

The citation analysis gives similar results to a simple descriptive statistics analysis (Figure 1). Results are demonstrated in Table 6.

Table 6 The top 10 most cited countries

	Number of citations	Number of documents
England	151 371	5 503
USA	125 492	3 377
Germany	36 044	1 559
Spain	33 936	1 749
Netherlands	30 947	1 046
Italy	30 885	1 562
China	28 935	1 860
France	24 087	1 109
Sweden	21 253	854
Finland	18 785	734

6 Conclusion

This study provides an overview of published papers about intellectual capital and Industry 4.0 from 1980 – 2022. The final sample of documents dealt with 24 671 articles. We used descriptive statistics, co-occurrence analysis, and citation and co-authorship analyses to answer the research questions. We noted that the number of articles is increasing yearly and that researchers are increasingly interested in the field under study.

The first research question concerns the main themes framing the Relationship between intellectual capital and Industry 4.0. The second research question is closely related to the first one and deals with the trend of topics during the research period. The time window of research was divided into three samples to understand the trend of topics and their main keywords. The keywords during the three periods are similar but have crucial differences. For instance, the keyword "Innovation" takes a main part of each of them, but it relates to different areas in those samples. From 1980 – 2010, innovations are understood as a part of a resource-based economy and product development; during 2011 – 2022, innovations are related to management, models, leadership, and others. So, we can summarize that the trend and frequency of the main keywords are similar, but clusters and related topics vary in different periods. Also, the Relationship between intellectual capital and Industry 4.0 is not well studied yet, but it gives a good opportunity to provide new research and explore this relatively new area.

The third and fourth research questions include the most cited journals and authors. To identify the most cited journals we use citation analysis. We can constantly see the fact that more cited journals are also high-quality. They belong to the better quartile groups and have a distinguished impact factor. The most cited journals are, for example, "Research Policy" from ELSEVIER, "Journal of Business Research" from ELSEVIER, "Strategic Management Journal" from Willey, and others (for more information, see Figure 5, Table 3 and Table 4). Co-authorship analysis was used to identify the most cited authors. Based on our results, the most cited authors are Nicholas Bloom, John Van Reenen, Mike Wright, Christian Kowalkowski, David Dorn, Annabelle Gawer, Gerard George, Hashem M. Perasan, Qiang Ji, and Gordon H. Hanson (for more information, see Figure 6).

The fifth and last research question deals with the countries which are leaders in the field of researching intellectual capital and industry 4.0 (based on the information about counts of citations). Here, the co-authorship analysis was used. We mentioned leaders by the number of articles in describing Graph 3. A similar situation is with the citation. According to the number of publications and citations, England, the USA, China, the Netherlands, Germany, Italy, France and Sweden are among the leaders.

This study also has limitations. This type of research only captures previously published works in the Web of Science database and may not include emerging or innovative ideas that have yet to be published. The Web of Science database is comprehensive but does not cover all existing intellectual capital articles. Therefore, our results are accurate for Web of Science articles but may differ for other databases. We should also note that readers should be careful when summarizing our results. This method does not analyse entire articles because reference analysis analyses published studies' titles, keywords, and abstracts. However, the bibliographic analysis also has positive aspects. It provides readers with a comprehensive overview of areas of interest.

Acknowledgement
The Slovak Scientific Grant Agency supported this research as part of the research project VEGA 1/0638/22, "Intellectual capital and productivity of European regions".

References

[1] CABRITA, M.D.R., BONTIS, N.: Intellectual capital and business performance in the Portuguese banking industry, *International Journal of Technology Management*, Vol. 43, No. 1-3, pp. 212-237, 2008. https://doi.org/10.1504/IJTM.2008.019416
[2] CABRITA, M.R., CRUZ-MACHADO, V., DUARTE, S.: *Enhancing the Benefits of Industry 4.0 from Intellectual Capital: A Theoretical Approach*, In: Xu, J., Cooke, F., Gen, M., Ahmed, S. (eds) Proceedings of the Twelfth International Conference on Management Science and Engineering Management, ICMSEM 2018, Lecture Notes on Multidisciplinary Industrial Engineering, Springer, Cham., pp. 1581-1591, 2019. https://doi.org/10.1007/978-3-319-93351-1_124
[3] EDVINSSON, L.: IC 21: reflections from 21 years of IC practice and theory, *Journal of Intellectual Capital*, Vol. 14, No. 1, pp. 163-172, 2013. https://doi.org/10.1108/14691931311289075
[4] WANG, W., WU, S., NOURANI, M., KWEH, Q., CHEN, J.: Corporate Social Responsibility, Intangibles, and Dynamic Performance of the U.S. Airlines, *Revista de Contabilidad-Spanish Accounting Review*, Vol. 24, No. 1, pp. 104-115, 2021. https://doi.org/10.6018/rcsar.357891
[5] OBEIDAT, B.Y., ABDALLAH, A.B., AQQAD, N.O., AKHOERSHIEDAH, A.H.O.M., MAQABLEH, M.: The Effect of Intellectual Capital on Organizational Performance: The Mediating Role of Knowledge Sharing, *Communications and Network*, Vol. 9, No. 1, pp. 1-27, 2017. https://doi.org/10.4236/cn.2017.91001
[6] RODRIGUE, J.-P.: *The Geography of Transport Systems*, 5th ed., London, Routledge, 2020. https://doi.org/10.4324/9780429346323
[7] EDVINSSON, L.: Developing intellectual capital at Skandia, *Long Range Planning*, Vol. 30, No. 3, pp. 366-373, 1997. https://doi.org/10.1016/S0024-6301(97)90248-X

[8] STEWART, T.A.: *Intellectual Capital*, in Intellectual Capital, 1st ed., Doubleday Business, 1997.

[9] ESMER, Y., ŞAYLAN, O.: The Link of Industry 4.0 and Organizational Transformation, *Bilge International Journal of Social Research*, Vol. 3, No. 1, pp. 1-8, 2019.

[10] SONY, M., NAIK, S.: Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review, *Benchmarking: An International Journal*, Vol. 27, No. 7, pp. 2213-2232, 2019. https://doi.org/10.1108/BIJ-09-2018-0284

[11] XU, J., COOKE, F.L., GEN, M., AHMED, S.E.: *Proceedings of the Twelfth International Conference on Management Science and Engineering Management*, Lecture Notes on Multidisciplinary Industrial Engineering, Cham: Springer International Publishing, 2019. https://doi.org/10.1007/978-3-319-93351-1

[12] MARTIN, W.J.: Approaches to the measurement of the impact of knowledge management programmes, *Journal of Information Science*, Vol. 26, No. 1, pp. 21-27, 2000. https://doi.org/10.1177/016555150002600102

[13] RUDEŽ, H.N., MIHALIČ, T.: Intellectual capital in the hotel industry: A case study from Slovenia, *International Journal of Hospitality Management*, Vol. 26, No. 1, pp. 188-199, 2007. https://doi.org/10.1016/j.ijhm.2005.11.002

[14] BEATTIE, V., THOMSON, S.J.: Lifting the lid on the use of content analysis to investigate intellectual capital disclosures, *Accounting Forum*, Vol. 31, No. 2, pp. 129-163, 2007. https://doi.org/10.1016/j.accfor.2007.02.001

[15] CHU, P.Y., LIN, Y.L., HSIUNG, H.H., LIU, T.Y.: Intellectual capital: An empirical study of ITRI, *Technological Forecasting and Social Change*, Vol. 73, No. 7, pp. 886-902, 2006. https://doi.org/10.1016/j.techfore.2005.11.001

[16] MANZARI, M., KAZEMI, M., NAZEMI, S., POOYA, A.: Intellectual capital: Concepts, components and indicators: A literature review, *Management Science Letters*, Vol. 2, No. 7, pp. 2255-2270, 2012. https://doi.org/10.5267/j.msl.2012.07.018

[17] MARTÍNEZ-TORRES, M.R.: A procedure to design a structural and measurement model of Intellectual Capital: An exploratory study, *Information & Management*, Vol. 43, No. 5, pp. 617-626, 2006. https://doi.org/10.1016/j.im.2006.03.002

[18] PEDRO, E., LEITÃO, J., ALVES, H.: Back to the future of intellectual capital research: a systematic literature review, *Management Decision*, Vol. 56, No. 11, pp. 2502-2583, 2018. https://doi.org/10.1108/MD-08-2017-0807

[19] MOSCONI, F.: *The New European Industrial Policy*, Global Competitiveness and the Manufacturing Renaissance, 1st ed., London, Routledge, Great Britain, 2015. https://doi.org/10.4324/9781315761756

[20] FETTIG, K., GACIC, T., KOSKAL, A., KUHN, A., STUBER, F.: *Impact of Industry 4.0 on Organizational Structures*, In: 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), Stuttgart, IEEE, June 2018, pp. 1-8, 2018. https://doi.org/10.1109/ICE.2018.8436284

[21] VEREYCKEN, Y., RAMIOUL, M., DESIERE, S., BAL, M.: Human resource practices accompanying industry 4.0 in European manufacturing industry, *Journal of Manufacturing Technology Management*, Vol. 32, No. 5, pp. 1016-1036, 2021. https://doi.org/10.1108/JMTM-08-2020-0331

[22] UŽIENĖ, L.: *Transformations of Intellectual Capital in the Age of Industry 4.0*, In: European Conference on Knowledge Management, Kidmore End, United Kingdom: Academic Conferences International Limited, Sep. 2021, pp. 786-793, 2021. https://doi.org/10.34190/EKM.21.102

[23] CHIERICI, R., TORTORA, D., DEL GIUDICE, M., QUACQUARELLI, B.: Strengthening digital collaboration to enhance social innovation capital: an analysis of Italian small innovative enterprises, *Journal of Intellectual Capital*, Vol. 22, No. 3, pp. 610-632, 2020. https://doi.org/10.1108/JIC-02-2020-0058

[24] VEILE, J.W., SCHMIDT, M.-C., MÜLLER, J.M., VOIGT, K.-I.: Relationship follows technology! How Industry 4.0 reshapes future buyer-supplier relationships, *Journal of Manufacturing Technology Management*, Vol. 32, No. 6, pp. 1245-1266, 2020. https://doi.org/10.1108/JMTM-09-2019-0318

[25] KNUDSEN, M.S., KAIVO-OJA, J., LAURAEUS, T.: *Enabling Technologies of Industry 4.0 and Their Global Forerunners: An Empirical Study of the Web of Science Database*, In: Knowledge Management in Organizations, L. Uden, I.-H. Ting, and J. M. Corchado, Eds., in Communications in Computer and Information Science. Cham: Springer International Publishing, 2019, pp. 3-13, 2019. https://doi.org/10.1007/978-3-030-21451-7_1

[26] DONTHU, N., KUMAR, S., MUKHERJEE, D., PANDEY, N., LIM, W.M.: How to conduct a bibliometric analysis: An overview and guidelines, *Journal of Business Research*, Vol. 133, pp. 285-296, 2021. https://doi.org/10.1016/j.jbusres.2021.04.070

[27] CASTILLO-VERGARA, M., ALVAREZ-MARIN, A., PLACENCIO-HIDALGO, D.: A bibliometric analysis of creativity in the field of business economics, *Journal of Business Research*, Vol. 85, pp. 1-9, 2018. https://doi.org/10.1016/j.jbusres.2017.12.011

[28] LIM, K.W., BUNTINE, W.: Bibliographic analysis on research publications using authors, categorical labels

and the citation network, *Mach Learn*, Vol. 103, No. 2, pp. 185-213, 2016. https://doi.org/10.1007/s10994-016-5554-z

[29] DEGROOTE, S.: *Subject and Course Guides: Bibliometric Analysis and Visualization: Bibliometrics with VOSViewer*, [Online], Available: https://researchguides.uic.edu/c.php?g=1233392&p=9025986 [27 Jan 2023], 2023.

[30] XU, D., YIN, X., ZHOU, S., JIANG, Y., XI, X., SUN, H., WANG, J.: A review on the remediation of microplastics using constructed wetlands: Bibliometric, co-occurrence, current trends, and future directions, *Chemosphere*, Vol. 303, Part 1, p. 134990, September 2022. https://doi.org/10.1016/j.chemosphere.2022.134990

[31] LIU, L., MEI, S.: Visualizing the GVC research: a co-occurrence network based bibliometric analysis, *Scientometrics*, Vol. 109, No. 2, pp. 953-977, 2016. https://doi.org/10.1007/s11192-016-2100-5

Review process
Single-blind peer review process.